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RELIABILITY AND VALIDITY OF THE CROSS-SECTIONAL AREA OF THE QUADRICEPS MUSCLES BY PANORAMIC ULTRASONOGRAPHY AND ULTRASONIC PHANTOM

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SUMMARY

The panoramic ultrasonography (US) can be used to estimate cross-sectional area (CSA) of large muscles. The aim of this study is to determine the reliability of the CSA of the individual quadriceps components – *rectus femoris* (RF), *vastus lateralis* (VL), *vastus medialis* (VM) and *vastus intermedius* (VI) - by panoramic US and to test the validity of the measures in a curved-surface phantom. Twelve subjects participated in the reliability study. The CSA of RF, VL and VI was recorded by panoramic US with subjects at 50% of thigh length (TL), and CSA of VM at 30% TL. The images of US were repeated in 2 days. The results showed that panoramic US is a valid method for measuring curved-surface, with typical error of the mean (TEM) of 0.18 to 0.25 cm^2. The coefficient of variation of CSA measures were 2.18 to 6.84% and intraclass correlation coefficients were 0.958 to 0.996, showing to be reliable method to measure the individual CSA of the quadriceps components.

INTRODUCTION

The ultrasonography (US) is used to analyze muscle architecture of the quadriceps components - *rectus femoris* (RF), *vastus lateralis* (VL), *vastus medialis* (VM), and *vastus intermedius* (VI) [1,2]. However, the cross-sectional area (CSA) of large muscles, as the vastii, cannot be estimated by a single image generated by a conventional ultrasound transducer.

The two-dimensional extended-field-of-view (EFOV) ultrasonography technology was introduced by Weng et al [3] and made it possible to estimate cross-sectional area (CSA) of large muscles. The EFOV demonstrates a good accuracy when measurements were tested in a curved-surface phantom [4]. The technique was considered valid and repeatable to detect training-induced changes in CSA of VL muscle and to quantify the whole quadriceps CSA [5,6]. No study which discusses the reliability of the individual quadriceps muscles was found.

The aim of this study is to determinate the reliability of the CSA of the four quadriceps muscles by panoramic US, and to validate the measures with an ultrasonic phantom with the curved-surface.

METHODS

Validity: One phantom was constructed of Polyvinyl Chloride Plasticized (PVCP) with a curved shape with radius of 7.15 cm, which had an acoustic velocity of 1385 ± 0.48 m/s and attenuation of 0.36 dB,cm^{-1},MHz^{-1} (obtained in the laboratory). Two inclusions were manufactured with PVCP +2% graphite, and placed inside the phantom PVCP, both with an acoustic velocity of 1384 ± 0.9 m/s and attenuation of 0.52 dB,cm^{-1},MHz^{-1}. One of the inclusions was rectangular shaped, with CSA of 10.58 cm^2, measured by caliper. The second piece was circular shaped, with CSA of 5.19 cm^2. The B-mode images were taken in the axial-plane US (MyLab25 Gold, ESAOTE S.p.A., Italia), with a 10-MHz, working in panoramic mode. Twenty images were recorded in three different days, totaling sixty images. The rectangle and circle area were measured.

Reliability: Six males and six females (n=12) participated in study - age 27.58 ± 4.12 years, weight 71.12 ± 14.34 kg and height 1.70 ± 0.10 m. The thigh length (TL) was assumed as the distance from central point of patella to the anterior superior iliac spine. Images were obtained using the equipment of US, with the same settings used to the phantom acquisitions. The images of the VI, VL and RF CSA's were taken at 50% of the TL, and the images of the VM CSA were taken at 30% TL (Figure 1) on the right leg in the knee in full extended position, with the individuals in supine position, as suggested by Noorkoiv *et al* [6]. The transducer was placed transversely and the gel was applied to improve the acoustic transmission. The probe was moving across the thigh, with the aid of a home-made device to guide the transducer. The protocol was repeated in two different days, with an interval of 48 hours, by the same examiner, previously trained. In each subject, five different images were taken per day. Two images were visually selected, totaling four images per subject. The area of each muscle was measured with the software *Image J* version 1.42 (National Institute of Health, USA).

The Shapiro-Wilk test confirmed normality for CSA for each muscle and measurement. The coefficient of variation (CV), absolute difference and intraclass correlation coefficients (ICC) were determined to investigate the variability and reliability of the four quadriceps muscles

CSAs measures intra and inter-day. For the validity of panoramic US for measuring the area of circle and rectangle, absolute difference and typical error of the measurement (TEM) were used. The significance level was set to $p \leq 0.05$. Statistical analyses were carried out with the commercial statistical software SPSS 17.0 (IBM SPSS, Chicago, US).

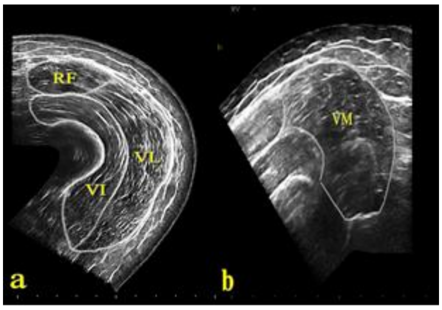

Figure 1: Anatomical cross-sectional area of quadriceps components at 50% of thigh length (a) and 30% (b).

RESULTS AND DISCUSSION

The results for the CSAs quadriceps muscles reliability and variability are presented in Table 1. The ICC showed good reliability for quadriceps muscles inter and intra-session. Our reliability results, using panoramic US image corroborate with previous studies. Noorkoiv *et al* [6] found R=0.998 for the whole quadriceps muscles CSA at 50% of thigh length. Athiainen *et al* [5] analyzed the reliability of VL at the mid-thigh and reported a R=0.997.

In addition, our good variability results, presented in terms of CV and absolute differences intra and inter-sessions, corroborate the high reliability. The small values of the absolute differences intra and inter-sessions do not exceed 1.62 cm^2 for VM. The CV of VM is greater than for the other muscles (6.38% and 6.84%, intra and inter-sessions respectively). The difficulty to visualize the limits of this muscle can explain the higher values for VM at 30% of thigh length than other for muscles.

The overall average CSA of RF was 9.05 ± 2.43 cm^2, similar to values of 8.68 ± 1.95 cm^2 reported for single-image conventional axial US B-mode [2]. Ahtiainen et al. [5] found a VL CSA of 28.32 ± 4.96 cm^2 for a sample of 27 males at 50% of thigh length. Our study was composed of both genders, and showed a mean value of 23.04 ± 6.69 cm^2. However, analyzing only males, it is obtained an average VL CSA 28.29 ± 5.20 cm^2. The sum of average CSA of all muscles in this study (71.82 ± 7.63 cm^2) was lower than the whole quadriceps CSA measured at the 50% of thigh length by Noorkoiv et al. (84.70 ± 13.50 cm^2) [6]. This difference could be explained by male sample used in that study. With only males, our study resulted in an average of 85.10 ± 7.84 cm^2. Furthermore, the CSA of VM was taken at 30% TL.

The validity statistics are presented in Table 2. The values of the average for the rectangle and circle CSA using US panoramic and real measurements (caliper), absolute difference and TEM are presented.

Table 2: Mean (± SD) of US panoramic and caliper CSA measures of rectangle and circle, absolute difference and typical error of the mean (TEM).

	US (cm^2)	**caliper (cm^2)**	**Absolute difference**	**TEM (%)**
Rectangle	10.75 ± 0.60	10.58	0.18	3.94
Circle	5.44 ± 0.31	5.19	0.25	4.04

According to Fornage *et al.* [4] curve-surface phantons generate measurements shorter than those with the flat phantom, with relative errors less than 4%, similar to values of this study. A curved-deformation was observed in the images of rectangle and circle. The deformation was consistent with a circle with radius of 6.62 ± 0.44 cm, as used for the ultrasonic phantom.

CONCLUSIONS

The results indicated that the panoramic US can be considered a valid method for measuring curved-surface. This technique proved to be reliable to measure the individual CSA of the quadriceps components.

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Table 1: Intra- and intersession reliability of first and second measurements of quadriceps muscles CSA: absolute difference (AD_{iff}), coefficient of variation (CV) and intraclass correlation coefficients (ICC).

	Muscles	**1st measure (cm^2)**	**2nd measure (cm^2)**	**AD_{iff} (cm^2)**	**CV% (min-max)**	**ICC (R)**
Inter-session	RF	9.13±2.19	8.83±2.40	0.49±0.29	3.85 (0.84-7.3)	0.990
	VL	23.39±7.14	23.24±7.19	0.73±5.56	2.18 (0.5-6.68)	0.996
	VI	21.9±6.73	21.62±6.99	0.91±0.73	3.27 (0.01-8.85)	0.993
	VM	18±5.71	18.07±5.68	1.46±0.84	6.38 (0.14-17.03)	0.976
Intra-session	RF	8.83±2.40	9.09±2.32	0.72±0.6	6.17 (0.07-14.44)	0.958
	VL	23.24±7.19	23.10±6.74	1.06±1.09	3.49 (0-10.06)	0.988
	VI	21.62±6.99	21.45±6.21	1.1±0.83	4.17 (0.04-12.98)	0.989
	VM	18.07±5.68	18.01±5.01	1.62±0.94	6.84 (0.09-18.44)	0.966