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Original Article

Applicability of ultrasonography for evaluating trunk muscle size: a pilot study

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Abstract. [Purpose] Ultrasonography (US) is widely applied to measure the muscle size in the limbs, as it has relatively high portability and is associated with low costs compared with large clinical devices such as magnetic resonance imaging (MRI). However, the applicability of US for evaluating trunk muscle size is poorly understood. This study aimed to examine whether US-measured muscle thickness (MT) in the trunk abdominal and back muscles correlated with MT and muscle cross-sectional area (MCSA) measured by MRI. [Subjects and Methods] Twenty-four healthy young males participated in this study. The MT and MCSA in the subjects were measured by US and MRI in a total of 10 sites, including the bilateral sides of the rectus abdominis (upper, central, and lower parts), abdominal wall, and multifidus lumborum. [Results] The interclass correlation coefficients of US-measured MT on the total 10 sites showed excellent values (n=12, 0.919 to 0.970). The US-measured MT significantly correlated with the MRI-measured MT (r=0.753 to 0.963) and MCSA (r=0.634 to 0.821). [Conclusion] US-measured MT could represent a surrogate for muscle size measured by MRI. The application of US for evaluating trunk muscle size may be a useful tool in the clinical setting.

Key words: Magnetic resonance imaging, Muscle thickness, Muscle cross-sectional area

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INTRODUCTION

The trunk muscles play important roles in successful sports performance and satisfactory physical locomotion, especially athletes and older people[1)]. For example, an increase in trunk muscle size contributes to enhanced performance in sports players[2)], whereas, in contrast, a reduction in the trunk muscle size relates to increased fall risk in elderly people[3)]. Thus, evaluation of trunk muscle size has clinical implication in widely varying populations. In previous studies, trunk muscle size, such as the muscle cross-sectional area (MCSA) and muscle volume (MV), has been measured using magnetic resonance imaging (MRI) and computed tomography (CT)[4–6)]. These methods can clearly analyze the sizes of the muscle and other tissues (e.g., fat). However, to address the measurement of trunk muscle size in the clinical setting, these applications are often inconvenient, owing to the large clinical demand and considerable costs involved. Thus, a surrogate method for measuring trunk muscle size in various large populations is warranted.

B-mode ultrasonography (US) can also visualize muscle and fat tissues similar to MRI and CT. In fact, muscle thickness (MT) measured by US has been widely employed to evaluate the changes in muscle size occurring as a result of resistance training-induced muscle hypertrophy[7, 8)] and age-related muscle atrophy[9, 10)]. In addition, previous studies have reported that

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US-measured MT of muscle groups in the lower and upper limbs strongly correlated with the MCSA or MV measured by MRI and CT[11–14]. Thus, US-measured MT may be available as a surrogate marker for muscle size evaluated using MRI and CT. Recently, MT in several trunk muscles, in addition to limb muscles, has been determined by using US[6, 15–18]. In the previous study, Takai et al.[6] reported that US-measured MT in the psoas major muscle, which affects mainly hip flexion rather than trunk coordination, strongly correlated to MRI-measured MCSA. However, to our best knowledge, the relationship between US-measured MT and MRI-measured muscle size in other trunk muscles, including the abdominal and back muscles, has not yet been determined. In the clinical setting, obtaining this relationship may be useful to increase the applicability of US measurement for the evaluation of trunk muscle size, as it could be applied to assessments of the effect of training/rehabilitation and the risk of sports injury[17]. Therefore, the present study examined whether the MT of the trunk abdominal and back muscles measured using US would correlate with the MT and MCSA measured using MRI. The US-measured MT and MRI-measured MT and MCSA of the rectus abdominis (RA), abdominal wall (AW), and multifidus lumborum (ML) muscles were measured. Previous studies have reported that these trunk muscles display asymmetry in athletes, especially those who play asymmetric sports such as baseball and tennis[19–21]. Moreover, Sanchis-Moysi et al.[21] reported that, although the RA in tennis players shows asymmetric hypertrophy, it is more marked in the distal portions of the muscle, suggesting that the levels of asymmetry in the RA may be different among the portions. Thus, the present study attempted to measure the US-measured MT and MRI-measured MT and MCSA of bilateral parts in all of the trunk muscles. In addition, the US-measured MT and MRI-measured MT and MCSA were measured in the lower, central, and upper portions of the RA.

SUBJECTS AND METHODS

Twenty-four healthy young males (age: 22.2 ± 1.3 years, height: 171.5 ± 0.9 cm, weight: 64.7 ± 0.9 kg) participated in this study. All subjects were informed of the experimental procedures and potential risks and provided written consent to participate in the study. The subjects were physical active, but did not include athletes with any specific physical training program. Subjects had not been involved a history of low back pain, previously surgery on abdominal and low back, and contraindications to MRI. All procedures were approved by the Ethics Committee of Ritsumeikan University (IRB-2013-015).

The MT in the trunk muscles were measured using a B-mode ultrasonographic apparatus (SSD-3500SV; Aloka, Japan) with a linear scanner (scanning frequency; 7.5 MHz). The MT for the RA were obtained from three portions, including the upper RA (URA), central RA (CRA), and lower RA (LRA). The MT of the URA and CRA were measured on the second and third layers from the proximal fibrous band to the intermediate fibrous band, respectively[15]. The MT of the LRA was measured on the fourth and most distal layer from the umbilical fibrous band to the pubic area. The MT of each RA was measured over the greatest area, as much as possible. The MT for the AW was evaluated as the total MT of the external abdominal oblique, internal abdominal oblique, and transverses abdominal oblique, and was measured at 15 mm from the muscle tendon junction of the transverse abdominis muscle towards the muscle belly[18]. The MT for the ML was measured on the spinous process of the L5 vertebral level[5, 16, 17]. The MT in the 3 parts of the RA and of the AW were measured in the supine position, while the MT for the ML was measured in the prone position. The subjects were instructed to relax throughout the US measurements. The present study obtained MT at total of 10 sites, including the right and left sides of 5 muscle parts, and the reliability of these MT was assessed on two separate days for 12 healthy men (age: 22.5 ± 1.6 years, height: 169.5 ± 3.3 cm, weight: 63.8 ± 6.4 kg).

The MRI measurements of the MT and MCSA were performed using a 1.5-T magnetic resonance system (Signa HDxt; GE Medical Systems, WI, USA). The subjects were placed in the supine position and instructed to relax, and abdominal transverse acquisition was synchronized with their respiration. The serial axial images were obtained from the first cervical vertebra to the malleolus lateralis using an 8-channel body array coil. The scanning were performed with a conventional T1-weighted fast spin-echo sequence with a echo time/repetition time for 7 ms/respiration, slice thickness for 0.5 cm, interspaced distance for, field of view for 420 × 420 mm, and matrix size for 384 × 384 mm. The MT and MCSA of the RAs, AW, and ML were analyzed using analysis software (OsiriX Version 5.6; Pixmeo, Geneva, Switzerland). The MT and MCSA of the RAs and AW were measured from the image in which the maximum MT could be obtained. The MT and MCSA of the ML were measured at the spinous process of the L5 vertebral level[5, 16, 17].

RESULTS

The results of the reliability of the US-measured MT in the trunk muscles are shown in Table 1. The ICCs of the MT at all 10 sites including the right and lefts sides of the 5 measured muscle parts showed excellent values.

The values of the US-measured MT and MRI-measured MT and MCSA are listed in Table 2. There were no significant differences between US-measured MT and MRI-measured MT.

The coefficient correlations between US-measured MT and MRI-measured MT and MCSA are summarized in Table 3. The US-measured MT in all 10 sites significantly correlated with the MRI-measured MT. Furthermore, the US-measured MT in all 10 sites significantly correlated with the MRI-measured MCSA.

Table 1. Reliability of ultrasonography (US)-measured muscle thickness (MT; cm)

	First day	Second day	Difference	ICC	95%CI
Upper rectus abdominis					
Right side	1.35 ± 0.22	1.34 ± 0.18	0.05 ± 0.02	0.960	0.873−0.988
Left side	1.30 ± 0.20	1.31 ± 0.18	0.04 ± 0.03	0.965	0.890−0.990
Central rectus abdominis					
Right side	1.36 ± 0.18	1.38 ± 0.17	0.04 ± 0.03	0.963	0.883−0.989
Left side	1.35 ± 0.18	1.35 ± 0.16	0.04 ± 0.03	0.959	0.871−0.988
Lower rectus abdominis					
Right side	1.54 ± 0.21	1.51 ± 0.23	0.05 ± 0.04	0.959	0.871−0.988
Left side	1.54 ± 0.24	1.52 ± 0.19	0.06 ± 0.04	0.946	0.832−0.984
Abdominal wall					
Right side	2.20 ± 0.40	2.20 ± 0.45	0.10 ± 0.04	0.970	0.903−0.991
Left side	2.13 ± 0.35	2.13 ± 0.34	0.11 ± 0.08	0.921	0.760−0.976
Multifidus lumborum					
Right side	2.73 ± 0.43	2.80 ± 0.42	0.12 ± 0.13	0.919	0.755−0.976
Left side	2.71 ± 0.41	2.74 ± 0.34	0.08 ± 0.07	0.965	0.888−0.990

The trunk muscle thicknesses and the difference between first and second days are presented as Mean ± SD. ICC: intraclass correlation coefficients, CI: confidence interval

Table 2. Values of US-measured MT and magnetic resonance imaging (MRI)-measured MT and muscle cross-sectional area (MCSA)

	US-measured MT (cm)		MRI-measured MT (cm)		MRI-measured MCSA (cm^2)	
	Right side	Left side	Right side	Left side	Right side	Left side
Upper rectus abdominis	1.38 ± 0.20	1.36 ± 0.21	1.38 ± 0.19	1.35 ± 0.19	7.07 ± 1.56	6.78 ± 1.66
Central rectus abdominis	1.41 ± 0.20	1.39 ± 0.20	1.42 ± 0.17	1.41 ± 0.16	6.90 ± 1.27	6.62 ± 1.19
Lower rectus abdominis	1.54 ± 0.22	1.49 ± 0.24	1.52 ± 0.22	1.52 ± 0.22	6.91 ± 1.26	6.76 ± 1.17
Abdominal wall	2.37 ± 0.35	2.37 ± 0.40	2.35 ± 0.36	2.34 ± 0.41	25.30 ± 3.63	25.48 ± 3.74
Multifidus lumborum	2.73 ± 0.50	2.68 ± 0.41	2.82 ± 0.36	2.79 ± 0.33	7.91 ± 1.58	7.60 ± 1.57

Values are presented as Mean ± SD.

Table 3. Coefficient correlations between US-measured MT and MRI-measured MT and MCSA

	MT			MCSA		
	Right side	Left side	Total	Right side	Left side	Total
Upper rectus abdominis	0.936*	0.948*	0.941*	0.728*	0.778*	0.754*
Central rectus abdominis	0.932*	0.935*	0.933*	0.699*	0.808*	0.753*
Lower rectus abdominis	0.963*	0.949*	0.950*	0.644*	0.821*	0.731*
Abdominal wall	0.925*	0.963*	0.946*	0.634*	0.764*	0.703*
Multifidus lumborum	0.815*	0.753*	0.789*	0.815*	0.650*	0.739*

* Significant correlation; p<0.001

DISCUSSION

The present study showed that US-measured MT in the trunk muscles significantly correlated with the MCSA, as well as MT, measured by MRI. Thus, our results suggest that a simple US measurement may be efficient in evaluating trunk muscle size, similar to MRI.

In previous studies, it has been well established that US-measured MT in the lower and upper limbs is adequate for evaluating muscle size[11–14]. Moreover, recent studies have proposed that US-measured MT may also be applicable for evaluating trunk muscle size[6, 15–18] and Takai et al.[6] further reported that US-measured MT in the psoas major muscle of the trunk strongly correlated with MRI-measured MCSA. Importantly, the psoas major muscle mainly affects hip flexion rather than trunk coordination[22], whereas, in contrast, the present study measured both abdominal and back muscles (i.e., the RA, RW, and ML), and these muscles all affect trunk stability and movement. In addition, these muscles have been shown to play important roles in sports performance and physical locomotion[2, 3]. To our knowledge, however, no previous study has examined the relationship between US-measured MT and MRI-determined MCSA in the abdominal and back muscles. Therefore, the present findings further indicate the availability of US measurements for evaluating trunk muscle size by showing remarkable relationships between US-measured MT and MRI-measured MCSA.

Herein, the reliabilities of US measurement in a total of 10 sites, comprising both the right and left sides of 5 muscle parts, were examined, and the ICC scores were found to range from 0.919 to 0.970. ICC scores >0.9 are considered excellent, and these scores were similar to that of previous studies[6, 11, 12]. Thus, the US-measured MT of the trunk muscles in the present study seems reliable. Given these results, we next examined the relationships between US-measured MT and MRI-measured MT and MCSA in the trunk muscles. Consequently, we found that US-measured MT in all 10 sites highly correlated with MRI-measured MT. In contrast, the relationships between US-measured MT and MRI-measured MCSA in all-10 sites showed moderate correlations, ranging from 0.634 to 0.821. These moderate values were relatively low compared with those in several previous studies[6, 11, 13]. For example, Abe et al.[11] reported that the correlation coefficient between US-measured MT and MRI-measured MCSA in the hamstring muscle was 0.873. Furthermore, Ogawa et al.[13] reported that the relationship between US-measured MT and MRI-measured MCSA in the adductors showed a strong correlation, at 0.922. We speculated that the reason for this discrepancy may be that, in the previous studies, the limb muscles were unaffected by the subject's respiratory motions, whereas the abdominal muscles, such as RAs and AW, show morphological changes upon breathing. The present study collected the US-measured MT of the abdominal muscles between the inspiratory and expiratory phases, similar to MRI measurements; however, a slight difference in the collection timing between US and MRI may explain the relatively low correlations observed, as compared to the previous studies. In addition, the US measurements of the MT of the MF in the present study were obtained in the prone position, as described in previous studies[16, 17]. In contrast, the MRI measurement of the MF was performed in the supine position, as described in previous studies[5, 16]. Thus, difference in the measured position of the MF between US and MRI measurements might be part of the reason for the relatively low correlation.

Takai et al.[6] reported that the relationships between US-measured MT and MRI-measured MCSA in the right and left sides of the psoas major muscle were 0.947 and 0.916, respectively. The psoas major shows morphological changes upon breathing, albeit very minor. Moreover, the authors measured the MT and MCSA using different position for US (i.e., prone position) and MRI (i.e., supine position) measurements. As another reason for this observed difference between the present and previous studies, it should be noted that the psoas major muscle, as well as many limb muscles, is circular, while RAs, AW, and MF muscles are in the form of an ellipse, crescent, and trapezoid, respectively. Thus, a difference in the measured muscle form might also be responsible for the relative low correlation noted in the present study. In fact, Yi et al.[23] reported that the relationship between US-measured MT and MRI-measured MCSA in the supraspinatus, which shows a triangle form, was a moderate correlation (0.76). Similarly, Sipilä and Suominen[14] showed that there was a moderate correlation (r=0.76) between US-measured MT and CT-measured MCSA in the knee extensors. Moreover, Miyatani et al.[12] reported that the relationship between US-measured MT and MRI-measured MV in the knee extensors showed a weak correlation (r=0.47) when compared with the elbow flexors, elbow extensors, and ankle plantar flexors. Naturally, compared with muscles with typical, circular forms, muscles with a unique form seem to be relatively difficult to precisely measure by US. Therefore, to obtain a higher correlation between the US and MRI measurements, further studies are needed to examine the most adequate method for predicting MRI-measured muscle size.

The present findings showed that measurement of the MT of the trunk muscles using US was significantly, but not strongly, correlated with MRI-measured MCSA. Core strength training induces hypertrophy of the trunk muscles[4], and in turn, increased trunk muscles are related to enhanced performance in athletes[2]. In contrast, older individuals commonly experience trunk muscle atrophy[3], which may impair functional capacity and quality of life. Hence, the evaluation of trunk muscle size could be useful to a large segment of the populations. However, in these groups, not everyone can undergo MRI and CT measurements due to contraindications. Moreover, these technologies are associated with considerable costs. Taken together, US has a higher indication and lower cost, and is a useful tool for evaluating trunk muscle size. In addition, trunk muscles display asymmetry in athletes, especially those who play asymmetric sports[19–21], and such asymmetry is often associated with sports injuries, especially lower back pain[15–17]. Therefore, as US has greater portability and can provide faster feedback, it could be applied to assess the risk of low back pain in the clinical setting.

The present findings demonstrated that US-measured MT of the trunk muscles significantly correlated with the MRI-measured MT and MCSA. This suggests that US-measured MT can represent a surrogate for muscle size measured by MRI. Therefore, the clinical application of US for evaluating trunk muscle size in various populations appears useful.

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