



Original Article

## Applicability of ultrasonography for evaluating trunk muscles size in athletes: a study focused on baseball batters

MICHIO WACHI, RPT, MS<sup>1,2</sup>), TADASHI SUGA, PhD<sup>1)\*</sup>, TAKATOSHI HIGUCHI, PhD<sup>3</sup>), JUN MISAKI, MS<sup>1</sup>), RYO TSUCHIKANE, BS<sup>1</sup>), DAICHI TANAKA, BS<sup>1</sup>), YUTO MIYAKE, BS<sup>1</sup>), NOBUHIKO KANAZAWA, MD, PhD<sup>2,4</sup>), TADA0 ISAKA, PhD<sup>1</sup>)

<sup>1</sup>) Faculty of Sport and Health Science, Ritsumeikan University: 1-1-1 Nojihigashi, Kusatsu, Shiga 525-8577, Japan

<sup>2</sup>) Kanazawa Orthopaedic & Sports Medicine Clinic, Japan

<sup>3</sup>) Faculty of Socio-Environmental Studies, Fukuoka Institute of Technology, Japan

<sup>4</sup>) Faculty of Nursing and Rehabilitation, Aino University, Japan

**Abstract.** [Purpose] Recently, we demonstrated that the thicknesses of trunk muscles measured using ultrasonography were correlated strongly with the cross-sectional areas measured using magnetic resonance imaging in untrained subjects. To further explore the applicability of ultrasonography in the clinical setting, the present study examined the correlation between ultrasonography-measured thicknesses and magnetic resonance imaging-measured cross-sectional areas of trunk muscles in athletes with trained trunk muscles. [Subjects and Methods] The thicknesses and cross-sectional areas at total 10 sites of the bilateral sides of the upper, central, and lower parts of the rectus abdominis, abdominal wall, and multifidus lumborum in 30 male baseball batters were measured. [Results] Overall thicknesses and cross-sectional areas of the trunk muscles in baseball batters were higher than those in untrained subjects who participated in our previous study. The ultrasonography-measured thicknesses at all 10 sites of the trunk muscles correlated highly with the magnetic resonance imaging-measured cross-sectional areas in baseball batters. [Conclusion] These results suggest that the thicknesses of the trunk muscles measured using ultrasonography can be used as a surrogate marker for the cross-sectional area measured using magnetic resonance imaging, in athletes who have larger trunk muscles than that of untrained subjects.

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

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### INTRODUCTION

Large size of the trunk muscles helps achieve superior sports performance in athletes<sup>1,2</sup>). To assess the trunk muscle size, muscle cross-sectional area (MCSA) measured using magnetic resonance imaging (MRI) is widely considered the gold standard, as reported most previous studies<sup>1-9</sup>). However, this application is often inconvenient in the clinical setting, due to the huge clinical demand and considerable costs involved. Thus, in the clinical setting, a surrogate method for evaluating trunk muscle size in athletes is necessary.

Ultrasonography (US) can evaluate thickness of muscle groups in lower and upper limbs. Moreover, previous studies have demonstrated that US-measured muscle thickness (MT) of the limbs correlated highly with the MRI-measured MCSA<sup>10,11</sup>). An increasing number of studies are now using US to measure trunk muscle size<sup>12-15</sup>). Therefore, we applied this US technique and then found that the US-measured MT of trunk muscles correlated strongly with MRI-measured MCSA in healthy

\*Corresponding author. Tadashi Suga (E-mail: t-suga@fc.ritsumeiki.ac.jp)

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untrained subjects<sup>16</sup>). However, compared with untrained subjects, athletes associated with various sports, especially those involving trunk rotation, have larger trunk muscles<sup>3, 7-9</sup>). For example, a series study by Sanchis-Moysi et al.<sup>8, 9</sup>) reported that the rectus abdominis (RA) and abdominal wall (AW) are larger in tennis players than in untrained subjects. Such larger trunk muscles in athletes may affect the correlation between US-measured MT and MRI-measured MCSA based on untrained subjects. Thus, whether the correlation between US-measured MT and MRI-measured MCSA exists in athletes remains unknown.

Baseball is a typical sport involving trunk rotation, which is performed during swinging and throwing. During swinging in particular, the trunk muscles play an important role in generating energy from the lower extremities, which is transferred up the kinetic chain to the upper extremities<sup>17</sup>). In fact, trunk muscles express high electromyographic activity during swinging<sup>18</sup>). Moreover, in baseball batters, trunk rotation strength is associated with swing speed<sup>19</sup>), which is an important for superior batting performance because higher swing speed can produce shorter swing time and higher batted ball velocity<sup>20</sup>). Because of a close relationship between muscle size and muscle strength<sup>21</sup>), larger trunk muscles in baseball batters might help achieve to superior swing performance. Based on these findings, the evaluation of trunk muscle size using US might be useful to assess baseball performance and outline training/rehabilitation program in the clinical setting.

Therefore, to further explore the applicability of ultrasonography for evaluating trunk muscle size in the clinical setting, we aimed to determine the correlation between US-measured MT and MRI-measured MCSA of the trunk muscles in baseball batters.

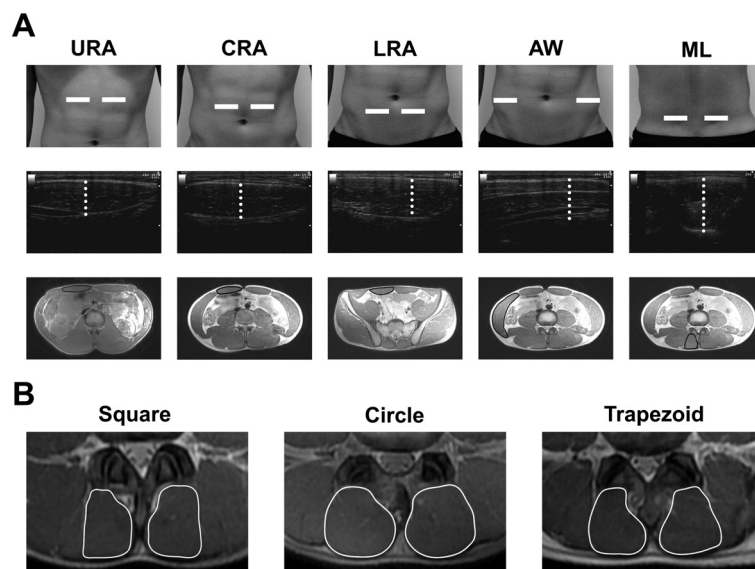
## SUBJECTS AND METHODS

Thirty male collegiate baseball batters (age,  $19.9 \pm 1.0$  years; height,  $173.7 \pm 4.0$  cm; weight,  $72.4 \pm 5.5$  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. To match the characteristics of the baseball batters, the present study did not recruit pitchers. Thus, all baseball batters in this study were position players with duration of baseball experience of at least 10 years ( $12.6 \pm 1.8$  years). Subjects had not been involved in 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).

Representative images of US-measured MT and MRI-measured MCSA are shown in Fig. 1A. The US-measured MTs of the trunk muscles were measured by using a B-mode ultrasonographic apparatus (SSD-3500SV; Aloka, Japan) with a linear transducer (scanning frequency; 7.5 MHz). The methods for measuring MTs of the abdominal and back muscles using US have been previously described<sup>16</sup>). In brief, the MTs for the RA were obtained from three parts, 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<sup>12, 16</sup>). The MT of the LRA was measured on the fourth and most distal layer from the umbilical fibrous band to the pubic area<sup>16</sup>). The MT of each RA was measured over the greatest area, as much as possible<sup>16</sup>). 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<sup>15, 16</sup>). The MT for the multifidus lumborum (ML) was measured on the spinous process at the L5 vertebral level<sup>13, 14, 16</sup>). The MTs 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. In the previous study, we evaluated the reliability of these MT measurements on 2 separate days in 12 healthy males<sup>16</sup>). These intraclass correlation coefficients of the MT at all 10 sites including the bilateral sides of the 5 measured muscle parts showed excellent values (0.919–0.970).

The MRI measurements of the 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 was 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  $420 \times 420$  mm, and matrix size for  $384 \times 384$  mm. The MCSA of the RAs, AW, and ML were analyzed using analysis software (OsiriX Version 5.6; Pixmeo, Geneva, Switzerland). The 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<sup>5, 16</sup>).

The data are expressed as mean  $\pm$  SD. To assess the levels of trunk muscle hypertrophy in baseball batters, the present study compared the US-measured MT and MRI-measured MCSA between baseball batters and untrained subjects ( $n=24$ ; age,  $22.2 \pm 1.3$  years; height,  $171.5 \pm 0.9$  cm; weight,  $64.7 \pm 0.9$  kg) who participated in our previous study<sup>16</sup>). To eliminate the influence of difference in body size on muscle size between baseball batters and untrained subjects, the MT and MCSA were normalized with body weight to one-third or two-third power, respectively. The normalized MT values for the trunk muscles on the right and left sides were compared between the two groups.



**Fig. 1.** Representative images of ultrasonography (US)-measured muscle thickness (MT) and magnetic resonance imaging (MRI)-measured muscle cross-sectional area (MCSA) of the trunk muscles

Panel A shows the probe positions for the US measurements (upper panel) and representative images of US-measured MT (center panel) and MRI-measured MCSA (lower panel) of the trunk muscles in a subject. The white dotted line in the US-measured MT image (center panel) denotes the MT. The black line in the MRI-measured MCSA image represents the MCSA. Panel B shows representative images of different forms of MCSA of the multifidus lumborum (ML) obtained from MRI measurements. URA: upper rectus abdominis; CRA: central rectus abdominis; LRA: lower rectus abdominis; AW: abdominal wall

## RESULTS

Although body height did not differ significantly between baseball batters and untrained subjects, body weight was significantly higher in baseball batters than in untrained subjects.

The mean values of US-measured MT and MRI-measured MCSA of the trunk muscles in baseball batters and untrained subjects are listed in Table 1. Overall the normalized MT and MCSA values relative to body weight were significantly higher in baseball batters than in untrained subjects. However, only the normalized MCSA value of the ML did not differ significantly between the two groups.

The coefficient correlations between US-measured MT and MRI-measured MCSA in baseball batters are shown in Table 2. The US-measured MT of the 5 trunk muscle parts on both sides correlated significantly with the MRI-measured MCSA in baseball batters ( $r=0.692-0.926$ ). However, the coefficient correlations between the US-measured MT and MRI-measured MCSA of the ML on both sides ( $r=0.702$  and  $0.692$  for the right and left sides, respectively) were relatively lower than that for other trunk muscles ( $r=0.800-0.926$  and  $0.852-0.898$  for the right and left sides, respectively). Similarly, the coefficient correlations between the US-measured MT and MRI-measured MCSA of the total ML on both sides ( $r=0.697$ ) were also relatively lower than that for other trunk muscles ( $r=0.831-0.897$ ).

The different forms of MCSA of the ML obtained from MRI measurements in baseball batters are shown in Fig. 1B. The MCSA of the ML was identified as having several forms such as square, circle, and trapezoid.

## DISCUSSION

The primary findings of the present study were that trunk MT measured using US correlated highly with the MCSA measured using MRI in baseball batters. These results were similar to our previous findings for untrained subjects<sup>16</sup>). Thus, the present findings further extend the applicability of US for evaluating trunk muscle size by showing high correlations between US-measured MT and MRI-measured MCSA of trunk muscles in baseball batters who have larger trunk muscle compared with untrained subjects.

Previous studies have reported that compared to untrained subjects, larger trunk muscles are observed in athletes associ-

**Table 1.** Mean values of ultrasonography-measured muscle thickness (MT) and magnetic resonance imaging-measured muscle cross-sectional area (MCSA) of the trunk muscles in baseball players and untrained subjects

	Right side			Left side		
	Baseball batters		Untrained subjects	Baseball batters		Untrained subjects
	Absolute value	Normalized value	Normalized value	Absolute value	Normalized value	Normalized value
Upper rectus abdominis						
MT (cm)	1.54 ± 0.26	0.37 ± 0.06	0.34 ± 0.05*	1.52 ± 0.27	0.36 ± 0.06	0.34 ± 0.05*
MCSA (cm <sup>2</sup> )	8.26 ± 1.65	0.48 ± 0.09	0.44 ± 0.10*	8.34 ± 1.52	0.47 ± 0.09	0.42 ± 0.10*
Lower rectus abdominis						
MT (cm)	1.63 ± 0.26	0.39 ± 0.06	0.35 ± 0.05*	1.68 ± 0.26	0.40 ± 0.07	0.35 ± 0.05*
MCSA (cm <sup>2</sup> )	8.32 ± 1.66	0.48 ± 0.09	0.43 ± 0.08*	8.48 ± 1.64	0.48 ± 0.10	0.41 ± 0.08*
Lower rectus abdominis						
MT (cm)	1.85 ± 0.34	0.44 ± 0.08	0.39 ± 0.05*	1.90 ± 0.32	0.45 ± 0.08	0.37 ± 0.06*
MCSA (cm <sup>2</sup> )	8.49 ± 1.80	0.49 ± 0.10	0.43 ± 0.08*	8.51 ± 1.72	0.48 ± 0.10	0.42 ± 0.07*
Abdominal wall						
MT (cm)	3.14 ± 0.55	0.75 ± 0.13	0.59 ± 0.08*	3.15 ± 0.58	0.74 ± 0.14	0.59 ± 0.09*
MCSA (cm <sup>2</sup> )	32.07 ± 4.52	1.85 ± 0.25	1.58 ± 0.19*	32.66 ± 3.89	1.85 ± 0.23	1.59 ± 0.21*
Multifidus lumborum						
MT (cm)	3.15 ± 0.28	0.76 ± 0.07	0.68 ± 0.11*	3.23 ± 0.28	0.77 ± 0.07	0.67 ± 0.09*
MCSA (cm <sup>2</sup> )	8.26 ± 1.29	0.49 ± 0.07	0.49 ± 0.08	8.47 ± 1.38	0.48 ± 0.07	0.47 ± 0.09

The MT and MCSA were normalized with body weight to one-third or two-third power, respectively. Normalized values in untrained subjects were obtained from our previous study<sup>16</sup>. \*Significant difference from normalized value in baseball batters.

**Table 2.** Coefficient correlations between ultrasonography-measured MT and magnetic resonance imaging-measured MCSA in baseball batters

	Right side	Left side	Total
Upper rectus abdominis	0.859*	0.898*	0.878*
Central rectus abdominis	0.926*	0.873*	0.897*
Lower rectus abdominis	0.847*	0.852*	0.848*
Abdominal wall	0.800*	0.864*	0.831*
Multifidus lumborum	0.702*	0.692*	0.697*

\*Significant correlation

ated with various sports, especially those involving trunk rotation<sup>3, 7-9</sup>). Of those, a series of study by Sanchis-Moysi et al.<sup>8, 9</sup>) determined that the RA and AW were larger in tennis players than in untrained subjects. The present findings also showed that the US-measured MT and MRI-measured MCSA in the RA and AW were higher in baseball batters than in untrained subjects. On the other hand, the difference in the ML size between athletes and untrained subjects is poorly understood. Peltonen et al.<sup>7</sup>) reported that the erector spinae (which include the ML) in adolescent female athletes (i.e., gymnasts, figure skaters, and ballet dancers) was larger than that in age-matched untrained subjects. In contrast, Asaka et al.<sup>3</sup>) reported that although the RA in elderly rowers was larger than that in age-matched untrained subjects, the erector spinae did not differ between the groups. In addition, Kubo et al.<sup>6</sup>) reported that although the RA and AW in professional soccer players were larger than those in youth soccer players, the erector spinae did not differ between the groups. In the present study, we also found that although the US-measured MT of the ML was greater in baseball batters than in untrained subjects, the MRI-measured MCSA did not differ between the groups. Thus, compared to the RA and AW, the ML size may not be affected by long-term sports training. These findings suggest that abdominal muscles, but not the back muscles, have specifically developed in baseball batters.

The present findings showed that the US-measured MT of the 5 trunk muscle parts on both sides correlated highly with the MRI-measured MT in baseball batters ( $r=0.697-0.897$ ). These correlation coefficients for baseball batters in the present study were similar to those for untrained subjects in our previous study ( $r=0.703-0.754$ )<sup>16</sup>). However, the present study found that the correlation coefficient in the ML ( $r=0.697$ ) was relatively lower than that for other muscles with strong correlation ( $r=0.831-0.897$ ). The ML consists of deep and superficial regions. The superficial region contributes to extension and rotation of the lumbar spine, whereas the deep region stabilizes the lumbar spine<sup>22</sup>). In fact, the superficial and deep regions in the ML express different levels of electromyographic activation during dynamic movement<sup>23, 24</sup>), including trunk rotation<sup>24</sup>). These differences between the regions might lead to development of a specific morphology in athletes. In the present study, MCSA of the ML displayed several forms such as square, circle, and trapezoid among baseball batters (Fig. 1B). Thus, these different forms of the ML might explain the relatively low correlation between US-measured MT and MRI-measured MCSA in baseball batters. In addition, this reason might be useful to explain the discrepancy of the difference in US-measured MT and MRI-measured MCSA of the ML between baseball batters and untrained subjects.

Previous studies have reported that specific hypertrophy in trunk muscles are observed in athletes associated with various

sports<sup>3, 7-9</sup>). Of those, a series of by Sanchis-Moysi et al.<sup>8, 9</sup>) determined that the RA and AW in tennis players could be characterized by asymmetrical hypertrophy. Similarly, Hides et al.<sup>5</sup>) determined the asymmetry of the ML in cricket players. Asymmetry of the trunk muscles in athletes may impair functional capacity during dynamic movement<sup>13</sup>). In addition, the asymmetry in trunk muscles is associated with the risk of low back pain<sup>4, 5, 13, 14</sup>). Thus, the present findings may be useful to assess asymmetry in addition to hypertrophy of the trunk muscles in athletes.

In conclusion, the present findings demonstrated that US-measured MT of the trunk muscles correlated highly with MRI-measured MCSA in baseball batters. Thus, we suggest that in the clinical setting, US-measured MT of the trunk muscles can be used as a surrogate marker for MRI-measured MCSA in athletes. However, the present study recruited only baseball batters. Further studies are needed to examine the applicability of US for evaluating trunk muscle size in athletes associated with various sports. Furthermore, there is a growing need to establish predictive models of trunk MCSA using US-measured MT by increasing the sample size of athletes.

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