Research paper

Cite as: Zamani H, Dadgoo M, Akbari M, Sarrafzadeh J, Pourahmadi M: Intra-examiner and inter-examiner reliability of rehabilitative ultrasound imaging for lumbar multifidus and anterolateral abdominal muscles in females with recurrent low back pain: an observational, cross-sectional study. J Ultrason 2021; 21: e286–e293. doi: 10.15557/JoU.2021.0049.

Submitted: 23.06.2021
Accepted: 12.10.2021
Published: 29.11.2021

Intra-examiner and inter-examiner reliability of rehabilitative ultrasound imaging for lumbar multifidus and anterolateral abdominal muscles in females with recurrent low back pain: an observational, cross-sectional study

Hamid Zamani, Mahdi Dadgoo, Mohammad Akbari, Javad Sarrafzadeh, Mohammadreza Pourahmadi

Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

Correspondence: Mahdi Dadgoo, Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran; e-mail: dadgoo.m@iums.ac.ir

DOI: 10.15557/JoU.2021.0049

Keywords

morphometry, sonography, reliability of results, low back pain, intraclass correlation coefficient

Abstract

Aim: To examine the reliability of rehabilitative ultrasound imaging performed to measure the thickness of the transverse abdominis, internal oblique, external oblique, and lumbar multifidus muscles in females with recurrent low back pain. **Material and methods:** A sample of 15 women was recruited. Two independent examiners recorded the thickness of their deep abdominal and spinal muscles by rehabilitative ultrasound imaging. Imaging scans of the transverse abdominis, internal oblique, and external oblique muscles were performed in the supine position and in the midaxillary line, between the lower edge of the ribcage and the iliac crest. Imaging of the lumbar multifidus was done in the prone position and at the level of the L5/S1 zygapophyseal joints. Imaging scans were performed bilaterally in rest and contraction, three times by the first examiner (at baseline, after two hours, and one week later) and once by the second examiner. **Results:** Good to excellent within-session intra-rater (ICC = 0.76, 0.97), good to excellent between-session intra-rater reliability (ICC = 0.73, 0.93), and good to excellent inter-rater reliability (ICC = 0.73, 0.98) were obtained. **Conclusions:** The results showed that rehabilitative ultrasound imaging can be used as an excellent reliable instrument by one or two examiners to measure the thickness of the transverse abdominis, internal oblique, external oblique and lumbar multifidus muscles in females with recurrent low back pain.

Introduction

The point prevalence of activity-limiting low back pain (LBP) is 7.3 percent, indicating that about 540 million people worldwide have LBP which could be considered the first cause of disability worldwide[1]. The pain source in 90% of LBP cases is unknown. It is estimated that 25% of patients with acute low back pain are more likely to have recurrent low back pain (RLBP) in the first year after total recovery[2].

Some studies have reported changes in trunk muscle patterns, such as decreased co-activity, in patients with RLBP[3]. In recent years, changes of movement patterns of the transverse abdominis (TrA) muscle[4] and lumbar multifidus (LM) muscle[5] have been in the center of focus of many studies based on rehabilitative ultrasound imaging (RUSI).

Using any instrument for examining body structures requires certain prerequisites, such as evaluating its validity and reliability. Reliability determines how stable the results of measurements remain over time[6]. B-mode ultrasound has been a commonly used instrument to assess spinal musculature morphometry in LBP patients[7]. However, due to the great variety of LBP types, before using an instrument for examination, it seems necessary to evaluate its reliability in the target group. In some of the past studies, the reliability of RUSI may have been investigated in other types of LBP, and some studies have included only asymptomatic subjects[8]. But individuals with RLBP have been largely neglected so far. Identifying new dimensions of musculature changes in RLBP patients could open a new way for further studies to help these groups. The aim of this study was to examine the intra-rater and inter-rater reliability of RUSI in the TrA, internal oblique (IO), external oblique (EO) and LM muscles in RLBP patients.

Material and methods

Study design

The present study had a cross-sectional, observational, single-group design, and was conducted between March and July 2020. Prior to the study, an approval of the ethics committee was obtained (decision no. IR.IUMS.REC.1398.1368).

Participants

The sample size was determined a priori, based on a previous study conducted by Koppenhaver *et al.*[9] The researchers examined the intra-rater and inter-rater reliability of RUSI in determining thickness of the TrA and LM muscles in non-specific LBP. The lowest intraclass correlation coefficient (ICC) with 95% CI observed in that study was 0.80 for measuring the TrA muscle thickness in the contraction condition[9]. The sample size was estimated using the 'sampicc' command in Stata software. The null hypothesis was selected to be equal to 0.40, power at 80%, type I error at 5%, and three repetitions for each measurement. The result of sampling showed that the participation of at least 10 participants with RLBP is required. In order to allow for 30% attrition, the sample size was increased to 14.28, and thus 15 participants were recruited.

The sample populations were recruited by convenience sampling. The study followed the principles of the Declaration of Helsinki. Before the registration, the participants completed a written informed consent form. Each participant was checked for inclusion and exclusion criteria. The inclusion criteria were: 1) diagnosis of RLBP (patients experienced LBP that needed medical attention or limited their activities at least twice during the preceding year)[10]; 2) pain between 30 and 60 at rest, on 0–100 point numeric pain rating scale (NPRS), where 0 represents no pain and 100 is the worst imaginable pain[11], and 3) age between 18 and 50 years. The exclusion criteria included: 1) trauma or injury to the musculoskeletal system; 2) deformity of extremities or lower back and pelvis; 3) rheumatological or neurological diseases; 4) infection; 5) tumors or radicular symptoms; 6) spinal fracture or surgery; 7) pregnancy.

Examiners

Sonography imaging and examinations were performed by two independent and blinded examiners. Both examiners were physiotherapists, with clinical experience ranging between 5 to 8 years, and 2 to 5 years of experience in sonography.

Instrumentation

A convex transducer (C2-8 probe, center frequency: 4.9 MHZ, 128 elements, 51 mmR, B-mode) was used. According to the available evidence, static cross-sectional images acquired from the whole surface of the transducer in the B-mode are adequate for analyzing the structure and diameter of the muscle and its surroundings[12].

Procedure

After the recruitment process, the participants were asked to complete a self-reported demographic and history form which included age, gender, body mass, stature, pain intensity, and repetition of the symptoms. Then, sonography

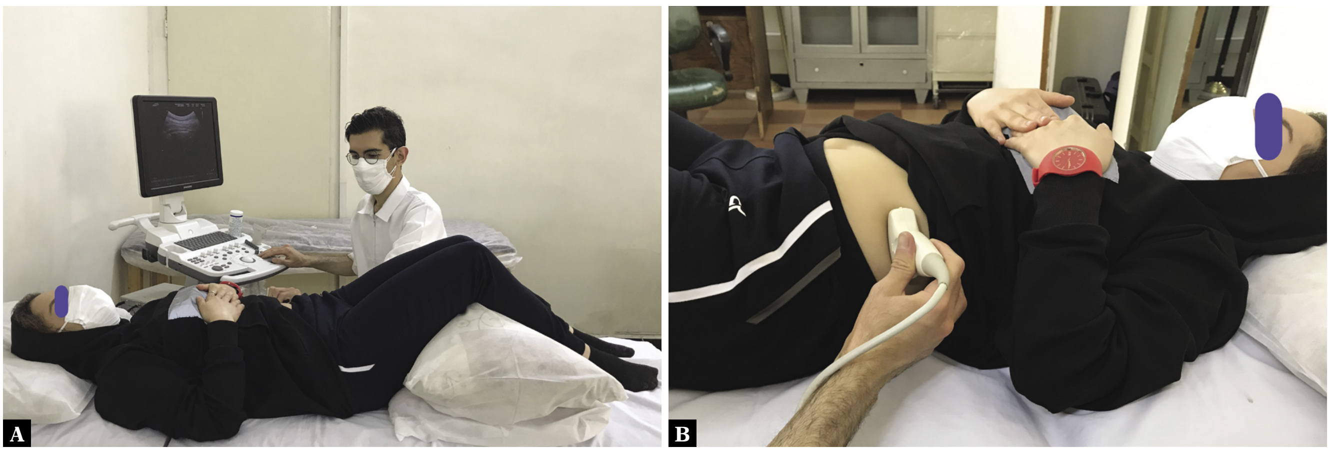

Fig. 1. *Sonography imaging of the transverse abdominis, and the internal oblique and external oblique muscles.* **A.** *Position of the patient.* **B.** *Position of the transducer*

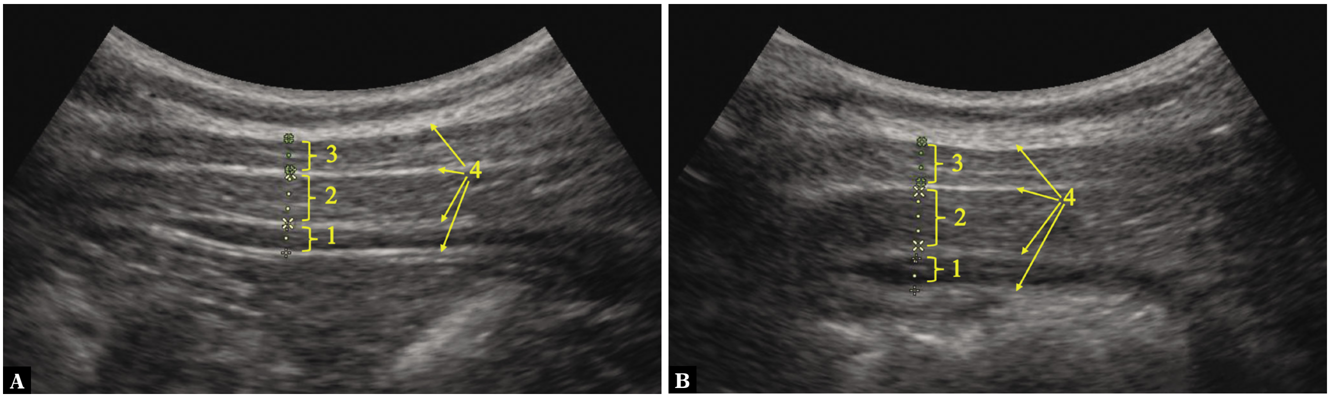

Fig. 2. *Sonography image of the transverse abdominis, and the internal oblique and external oblique muscles* **A.** *Rest condition.* **B.** *Abdominal draw in maneuver. 1 – transverse abdominis; 2 – internal oblique; 3 – external oblique; 4 – fascial layer*

imaging of the TrA, IO, EO and LM muscles was performed three times in rest and contraction, and their average was measured. The imaging and measurements of all muscles were performed bilaterally from the left and right side. Two hours later and seven days after the first imaging examination, the examiner A performed it again.

Transverse abdominis, internal and external oblique muscles

The participants were asked to lie supine, and place their hands on the chest. The hip and knee joints were flexed, and a pillow was placed below the knees to support them (Fig. 1A). The transducer was positioned transversely on the midaxillary line at a point between the lower edge of the ribcage and the superior border of the iliac crest (Fig. 1B)[13], while a clear picture of the muscle belly and the fascial lines were seen in the center field of view. The fascial lines were hyperechoic (i.e. appeared bright white), and the adjacent muscle tissues were more hypoechoic (appeared darker)[14]. To ensure the same conditions in all participants, images of the rest condition were taken at the end of normal exhalation and measured from the thickest region of the muscle belly (Fig. 2A). The thickness of the anterolateral abdominal muscles was also measured in abdominal draw-in maneuver (ADIM) (Fig. 2B)[15]. To perform the ADIM, the participants were instructed to take a relaxed breath in and out, hold the breath out, then draw in your lower abdomen without moving your spine, and contract the abdominal muscles by pulling the navel up and in toward the spine[9].

Lumbar multifidus

For the imaging of the LM muscle at rest, the participants were positioned prone and instructed to place their hands symmetrically next to the trunk (Fig. 3A). The examiners found the L5/S1 zygapophyseal joints by palpation and also on the ultrasound image. Next, they placed the transducer on them longitudinally and recorded parasagittal images (Fig. 3B)[16]. According to the evidence, in the parasagittal plane, the zygapophyseal joints and overlying LM muscle bulk at 2 to 3 vertebral levels could be visualized and were thus suitable for measuring the LM muscle thickness[17] (Fig. 4A). After the images were taken at rest, the participants were instructed to flex the elbows at approximately 90° and abduct the shoulders at approximately 120°. Then, they lifted their head, trunk and upper extremities, and held with maximum effort for ultrasound imaging at muscle contraction. A sample ultrasound image at maximum contraction is provided in Fig. 4B[18,19].

Fig. 3. *Sonography imaging of the lumbar multifidus muscles.* **A.** *Position of the patient.* **B.** *Position of the transducer*

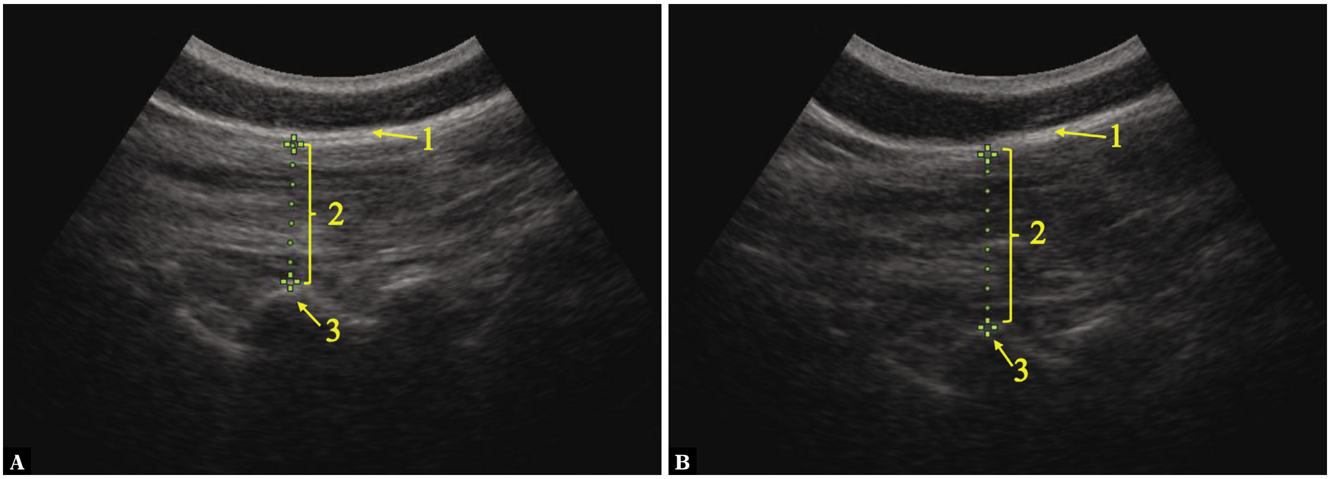

Fig. 4. *Sonography image of the lumbar multifidus in level of L5/S1 zygapophyseal joints.* **A.** *Rest condition.* **B.** *Contraction condition. 1 – fascial layer; 2 – lumbar multifidus; 3 – L5/S1 zygapophyseal joint*

Statistical analysis

All statistical analyses were performed using SPSS version 21.0 (SPSS Inc., IBM Corp., Armonk, NY, USA). The reliability of all measurements was evaluated using the ICC with 95% CIs model (3, k) for the intra-rater and model (2, k) for the inter-rater reliability[20]. The interpretation for the ICC with 95% CI was as follows: ≤0.20 poor, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good, and 0.81–1.00 excellent[21]. Using the SPSS, the ICC model (2, k) was computed by selecting the options including two-way random, average measure, and absolute agreement. The ICC model (3, k) was also computed by selecting two-way mixed and average measure.

Standard error of measurement (SEM) was used to evaluate the precision of the instrument, and was calculated as follows: pooled SD $\times\sqrt{1 - \text{ICC}}$. One SEM represents that the clinicians can be 68% certain that the true measurement value lies within ± 1 SEM from the clinical measurement. Measurement error was also expressed as the SEM%, which can be calculated as SEM/mean × 100. The SEM% shows measurement error independently of the measurement unit.

The minimum detectable change at the 95% confidence level (MDC_{95}) was calculated as $\sqrt{2} \times 1.96 \times SEM$, which shows the magnitude of change that is necessary to provide confidence that a change was not a result of random variation or measurement error. The 95% LOA were also computed as the mean difference ± 1.96 × SD.

Results

Ultimately, a total of 15 patients were included in the analysis. The age of the patients ranged from 20 to 49 years. Each participant reported a different number of recurrences of pain during the preceding year, which varied between 2 to 7 times. The mean pain intensity was 57.33 ± 4.58.

Measurement data from the intra-rater (within-day and between-session) and inter-rater reliability analysis, including the ICC with 95% confidence interval, SEM, SEM%, MDC_{95}, mean difference, and 95% LOA, are presented in (Tab. 1 and Tab. 2).

Discussion

The primary aim of this study was to evaluate the intra-rater and inter-rater reliability of sonography in measuring the thickness of the TrA, IO, EO, and LM muscles, at rest and contraction, in females with RLBP. Morphometric measurement of the structures and muscles using sonography has been a common method in scientific studies, as reported in the literature. Some of them examined healthy subjects[8,22] or various types of LBP patients[16].

In this study, the results have shown that intra-rater reliability is good to excellent, and especially in within-day intra-rater reliability, superior results were acquired. Inter-rater reliability, despite being lower than intra-rater reliability, showed an acceptable score, averaging just over 80. Many previous studies have generally obtained the same conclusion[13,22,23].

Reliability is a multifaceted criterion, not a fixed property. The sonography instrument, the examiner(s), and the participant(s) may contribute to the determined reliability level. According to the present study and a review of previous research, the experience and skills of the examiners are different in almost all cases. It is even possible that the examiner's familiarity with the 3D anatomy of the area, perception of the image taken, and the cursor recording affect the final reliability result. Consequently, the lower level of inter-rater reliability can be justified. This can also be seen in the results of studies conducted among examiners with varying degrees of experience[12,24,25]. There is evidence that experience may improve the precision of measurement procedures[26,27]. Some previous studies exploring the factors affecting reliability examined inter-rater reliability in a fixed ultrasound image with an excellent result (ICC 0.96) which was higher than other inter-rater reliability in the same studies. This shows that the difference in imaging steps between examiners may have a great impact on reliability[9,28].

Tab. 1. *Intra-rater reliability of examiner A*

Status	Muscles		Ultrasound measurements	
			Within-day (two hours)	Between-day (one week)
Rest	Right TrA	ICC (95% CI)	0.90 (0.71, 0.97)	0.85 (0.55, 0.95)
		SEM (mm)	0.27	0.30
		SEM%	8.34	8.95
		MDC95 (mm)	0.75	0.83
		Mean difference (95% CI) (mm)	–0.01 (–0.29, 0.27)	–0.21 (–0.53, 0.10)
		95% LoA (mm)	–1.69, 1.66	–1.73, 1.31
	Left TrA	ICC (95% CI)	0.88 (0.64, 0.96)	0.82 (0.47, 0.94)
		SEM (mm)	0.25	0.35
		SEM%	8.16	11.15
		MDC95 (mm)	0.69	0.97
		Mean difference (95% CI) (mm)	–0.01 (–0.27, 0.26)	–0.15 (–0.51, 0.22)
		95% LoA (mm)	–1.43, 1.42	–1.78, 1.48
	Right IO	ICC (95% CI)	0.82 (0.46, 0.94)	0.85 (0.56, 0.95)
		SEM (mm)	0.53	0.50
		SEM%	11.25	10.34
		MDC95 (mm)	1.47	1.38
		Mean difference (95% CI) (mm)	0.15 (–0.39, 0.69)	–0.40 (–0.91, 0.12)
		95% LoA (mm)	–2.29, 2.59	–2.92, 2.12
	Left IO	ICC (95% CI)	0.76 (0.29, 0.92)	0.84 (0.53, 0.95)
		SEM (mm)	0.59	0.49
		SEM%	11.68	9.81
		MDC95 (mm)	1.63	1.36
		Mean difference (95% CI) (mm)	0.47 (–0.11, 1.06)	–0.36 (–0.85, 0.14)
		95% LoA (mm)	–1.90, 2.85	–2.74, 2.03
	Right EO	ICC (95% CI)	0.96 (0.87, 0.99)	0.91 (0.75, 0.97)
		SEM (mm)	0.26	0.39
		SEM%	5.97	8.59
		MDC95 (mm)	0.72	1.08
		Mean difference (95% CI) (mm)	–0.12 (–0.41, 0.16)	–0.24 (–0.64, 0.16)
		95% LoA (mm)	–2.65, 2.39	–2.76, 2.29
	Left EO	ICC (95% CI)	0.80 (0.41, 0.93)	0.91 (0.73, 0.97)
		SEM (mm)	0.69	0.41
		SEM%	13.47	7.71
		MDC95 (mm)	1.91	1.14
		Mean difference (95% CI) (mm)	–.091 (–0.78, 0.60)	–0.29 (–0.72, 0.14)
		95% LoA (mm)	–3.12, 2.94	–2.95, 2.37
	Right LM	ICC (95% CI)	0.97 (0.90, 0.99)	0.80 (0.41, 0.93)
		SEM (mm)	1.05	2.75
		SEM%	3.69	9.77
		MDC95 (mm)	2.91	7.62
		Mean difference (95% CI) (mm)	–0.93 (–2.13, 0.28)	1.57 (–1.20, 4.35)
		95% LoA (mm)	–12.84, 10.98	–10.50, 13.65
	Left LM	ICC (95% CI)	0.97 (0.92, 0.99)	0.90 (0.69, 0.96)
		SEM (mm)	0.97	1.70
		SEM%	3.43	5.94
		MDC95 (mm)	2.69	4.71
		Mean difference (95% CI) (mm)	–0.04 (–1.06, 0.97)	–0.71 (–2.53, 1.10)
		95% LoA (mm)	–11.02, 10.93	–11.24, 9.81
Contraction	Right TrA	ICC (95% CI)	0.91 (0.74, 0.97)	0.73 (0.19, 0.91)
		SEM (mm)	0.31	0.55
		SEM%	6.39	10.95
		MDC95 (mm)	0.86	1.52
		Mean difference (95% CI) (mm)	0.01 (–0.32, 0.33)	–0.35 (–0.89, 0.19)
		95% LoA (mm)	–2.01, 2.02	–2.42, 1.73

Contraction	Left TrA	ICC (95% CI)	0.94 (0.83, 0.98)	0.93 (0.80, 0.98)
		SEM (mm)	0.30	0.36
		SEM%	5.85	6.97
		MDC95 (mm)	0.83	1.00
		Mean difference (95% CI) (mm)	0.01 (–0.30, 0.32)	–0.09 (–0.46, 0.29)
		95% LoA (mm)	–2.38, 2.40	–2.76, 2.59
	Right IO	ICC (95% CI)	0.90 (0.70, 0.97)	0.83 (0.49, 0.94)
		SEM (mm)	0.41	0.55
		SEM%	7.57	10.23
		MDC95 (mm)	1.14	1.52
		Mean difference (95% CI) (mm)	0.22 (–0.22, 0.66)	–0.13 (–0.69, 0.43)
		95% LoA (mm)	–2.33, 2.77	–2.73, 2.47
	Left IO	ICC (95% CI)	0.79 (0.37, 0.93)	0.88 (0.65, 0.96)
		SEM (mm)	0.66	0.43
		SEM%	11.16	7.36
		MDC95 (mm)	1.83	1.19
		Mean difference (95% CI) (mm)	0.61 (–0.07, 1.30)	–0.47 (–0.91, –0.03)
		95% LoA (mm)	–2.23, 3.45	–2.88, 1.94
	Right EO	ICC (95% CI)	0.97 (0.91, 0.99)	0.85 (0.55, 0.95)
		SEM (mm)	0.22	0.56
		SEM%	5.25	12.61
		MDC95 (mm)	0.61	1.55
		Mean difference (95% CI) (mm)	–0.21 (–0.45, 0.03)	–0.30 (–0.88, 0.29)
		95% LoA (mm)	–2.73, 2.31	–3.15, 2.56
	Left EO	ICC (95% CI)	0.91 (0.74, 0.97)	0.80 (0.41, 0.93)
		SEM (mm)	0.41	0.64
		SEM%	8.61	12.45
		MDC95 (mm)	1.14	1.77
		Mean difference (95% CI) (mm)	–0.41 (–0.84, 0.01)	–0.35 (–0.99, 0.30)
		95% LoA (mm)	–3.07, 2.24	–3.17, 2.48
	Right LM	ICC (95% CI)	0.97 (0.90, 0.99)	0.74 (0.24, 0.91)
		SEM (mm)	1.07	2.83
		SEM%	2.98	7.95
		MDC95 (mm)	2.96	7.84
		Mean difference (95% CI) (mm)	–0.98 (–2.18, 0.22)	1.46 (–1.35, 4.26)
		95% LoA (mm)	–13.08, 11.12	–9.40, 12.32
	Left LM	ICC (95% CI)	0.97 (0.92, 0.99)	0.92 (0.77, 0.97)
		SEM (mm)	1.01	1.56
		SEM%	2.78	4.33
		MDC95 (mm)	2.80	4.32
		Mean difference (95% CI) (mm)	0.58 (–0.45, 1.61)	0.11 (–1.51, 1.74)
		95% LoA (mm)	–10.90, 12.05	–10.68, 10.91

TrA – transverse abdominis; ICC (95% CI) – intraclass correlation coefficient with 95% confidence interval; SEM – standard error of measurement; MDC95 – minimal detectable change with 95% confidence interval; LoA – limits of agreement; IO – internal oblique; EO – external oblique; LM – lumbar multifidus

No correlation could be found between reliability and the rest or contraction condition. For example, reliability at rest and contraction in within-session intra-rater reliability was on average 88.25 and 92.0, respectively. For comparison, the rates in inter-rater reliability were 86.0 and 84.0, respectively. Other studies also found that that contraction alone cannot determine a specific pattern for reliability[12,22].

Examination of the mean of SEMs shows that this index has increased in the state of contraction in most cases. In addition, the average of this amount has increased in the inter-rater test compared to the intra-rater test. Koppenhaver *et al*. obtained a similar result[9]. The same is true of mean differences in this study. Differences in the participant's adherence to the examiner's instructions for contraction when recording the ultrasound image may affect the SEM. Furthermore, the examiner's instructions regarding contractions can be affected by the patient's pain. This highlights the role of participant-related factors in determining reliability. However, few studies have used ultrasound or compression biofeedback to coordinate the contraction in the target muscle and reducing the error of participant-related factors and its effect on reliability[23].

Tab. 2. *Inter-rater reliability of examiners A and B*

Muscles		Ultrasound measurements	
		Rest	Contraction
Right TrAa	ICC (95% CI)b	0.85 (0.57, 0.95)	0.74 (0.21, 0.91)
	SEM (mm)c	0.30	0.56
	SEM%	8.80	10.83
	MDC95 (mm)	0.83	1.55
	Mean difference (95% CI) (mm)	–0.10 (–0.41, 0.21)	–0.05 (–0.62, 0.50)
	95% LoA (mm)	–1.62, 1.42	–2.21, 2.10
Left TrA	ICC (95% CI)	0.82 (0.28, 0.94)	0.94 (0.81, 0.98)
	SEM (mm)	0.44	0.35
	SEM%	12.62	6.79
	MDC95 (mm)	1.22	0.97
	Mean difference (95% CI) (mm)	0.55 (0.17,0.93)	–0.10 (–0.50, 0.29)
	95% LoA (mm)	–1.47, 2.56	–2.92, 2.71
Right IO	ICC (95% CI)	0.82 (0.47, 0.94)	0.83 (0.51, 0.94)
	SEM (mm)	0.68	0.59
	SEM%	12.77	10.48
	MDC95 (mm)	1.88	1.63
	Mean difference (95% CI) (mm)	0.58 (–0.10, 1.26)	0.38 (–0.22, 0.98)
	95% LoA (mm)	–2.55, 3.71	–2.43, 3.20
Left IO	ICC (95% CI)	0.87 (0.60, 0.95)	0.88 (0.63, 0.96)
	SEM (mm)	0.52	0.53
	SEM%	9.91	8.68
	MDC95 (mm)	1.44	1.47
	Mean difference (95% CI) (mm)	0.15 (–0.41, 0.71)	0.05 (–0.54, 0.64)
	95% LoA (mm)	–2.67, 2.97	–2.98, 3.08
Right EO	ICC (95% CI)	0.87 (0.62, 0.96)	0.82 (0.42, 0.94)
	SEM (mm)	0.48	0.71
	SEM%	9.89	14.31
	MDC95 (mm)	1.33	1.97
	Mean difference (95% CI) (mm)	0.39 (–0.08, 0.86)	0.75 (0.10, 1.40)
	95% LoA (mm)	–2.23, 3.01	–2.56, 4.05
Left EO	ICC (95% CI)	0.85 (0.55, 0.95)	0.84 (0.54, 0.95)
	SEM (mm)	0.53	0.65
	SEM%	9.57	11.83
	MDC95 (mm)	1.47	1.80
	Mean difference (95% CI) (mm)	0.15 (–0.41, 0.72)	0.36 (–0.31, 1.04)
	95% LoA (mm)	–2.55, 2.86	–2.84, 3.57
Right LM	ICC (95% CI)	0.88 (0.64, 0.96)	0.73 (0.21, 0.91)
	SEM (mm)	2.25	2.72
	SEM%	8.30	7.94
	MDC95 (mm)	6.24	7.53
	Mean difference (95% CI) (mm)	–0.55 (–2.97, 1.87)	–1.27 (–3.94, 1.40)
	95% LoA (mm)	–13.28, 12.18	–11.54, 9.00
Left LM	ICC (95% CI)	0.96 (0.89, 0.99)	0.98 (0.94, 0.99)
	SEM (mm)	1.10	0.78
	SEM%	3.80	2.19
	MDC95 (mm)	3.05	2.16
	Mean difference (95% CI) (mm)	–0.06 (–1.27, 1.15)	–0.59 (–1.45, 0.27)
	95% LoA (mm)	–10.88, 10.76	–11.38, 10.20

TrA – transverse abdominis; ICC – intraclass coefficient correlation; SEM – standard error of measurement; MDC – minimal detectable change; LoA – limits of agreement; IO – internal oblique; EO – external oblique; LM – lumbar multifidus

Study limitations

First, despite the extensive clinical experience of the examiners, they did not have a comparable experience in sonography. Second, the participants had to perform three contractions for each muscle, and had to maintain the contraction until the correct image was recorded. However, they may gradually get tired and, as a result, the quality of the contractions will be different from normal. Previous studies have found that patients with LBP usually show a decrease in endurance and higher fatigability in the trunk muscles[29].

Conclusion

According to the analysis performed in the present study, RUSI can be used for the measurement of thickness of the TrA, IO, EO, and LM muscles in RLBP patients. Due to excellent intra-rater reliability, RUSI can be performed for the assessment of the deep trunk muscles in RLBP patients by one examiner. Examination by two independent examiners is also a reliable and acceptable method.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication or claim authorship rights to this publication.

References

1. GBD 2015 Disease and Injury Incidence and Prevalence Collabolators: Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1545–1602.
2. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F *et al.*: A systematic review of the global prevalence of low back pain. Arthritis Rheum 2012; 64: 2028–2037.
3. Viggiani D, Nelson-Wong E, Davidson BS, Callaghan JP: A comparison of trunk control in people with no history, standing-induced, and recurrent low back pain during trunk extension. J Man Manip Ther 2020; 28: 94–102.
4. Teyhen DS, Gill NW, Whittaker JL, Henry SM, Hides JA, Hodges P: Rehabilitative ultrasound imaging of the abdominal muscles. J Orthop Sports Phys Ther. 2007; 37: 450–466.
5. Hodges PW, Richardson CA: Altered trunk muscle recruitment in people with low back pain with upper limb movement at different speeds. Arch Phys Med Rehabil 1999; 80: 1005–1012.
6. Bartko JJ, Carpenter WT, Jr: On the methods and theory of reliability. J Nerv Ment Dis 1976; 163: 307–317.
7. Wallwork TL, Stanton WR, Freke M, Hides JA: The effect of chronic low back pain on size and contraction of the lumbar multifidus muscle. Man Ther 2009; 14: 496–500.
8. Wallwork TL, Hides JA, Stanton WR: Intrarater and interrater reliability of assessment of lumbar multifidus muscle thickness using rehabilitative ultrasound imaging. J Orthop Sports Phys Ther 2007; 37: 608–612.
9. Koppenhaver SL, Hebert JJ, Fritz JM, Parent EC, Teyhen DS, Magel JS: Reliability of rehabilitative ultrasound imaging of the transversus abdominis and lumbar multifidus muscles. Arch Phys Med Rehabil 2009; 90: 87–94.
10. Stanton TR, Latimer J, Maher CG, Hancock MJ: How do we define the condition 'recurrent low back pain'? A systematic review. Eur Spine J 2010; 19: 533–539.
11. Haefeli M, Elfering A: Pain assessment. Eur Spine J 2006; 15 Suppl 1 (Suppl 1): S17–S24.
12. Djordjevic O, Djordjevic A, Konstantinovic L: Interrater and intrarater reliability of transverse abdominal and lumbar multifidus muscle thickness in subjects with and without low back pain. J Orthop Sports Phys Ther 2014; 44: 979–988.
13. Critchley DJ, Coutts FJ: Abdominal muscle function in chronic low back pain patients: measurement with real-time ultrasound scanning. Physiotherapy 2002; 88: 322–332.
14. Sions JM, Velasco TO, Teyhen DS, Hicks GE: Reliability of ultrasound imaging for the assessment of lumbar multifidi thickness in older adults with chronic low back pain. J Geriatr Phys Ther 2015; 38: 33–39.
15. Hebert JJ, Koppenhaver SL, Parent EC, Fritz JM: A systematic review of the reliability of rehabilitative ultrasound imaging for the quantitative assessment of the abdominal and lumbar trunk muscles. Spine 2009; 34: E848–E856.
16. Koppenhaver SL, Hebert JJ, Fritz JM, Parent EC, Teyhen DS, Magel JS: Reliability of rehabilitative ultrasound imaging of the transversus abdominis and lumbar multifidus muscles. Arch Phys Med Rehabil 2009; 90: 87–94.
17. Hides J, Richardson C, Jull G, Davies S: Ultrasound imaging in rehabilitation. Aust J Physiother 1995; 41: 187–193.
18. Kiesel KB, Uhl TL, Underwood FB, Rodd DW, Nitz AJ: Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. Man Ther 2007; 12: 161–166.
19. Macintosh JE, Bogduk N: The biomechanics of the lumbar multifidus. Clin Biomech 1986; 1: 205–213.
20. Shrout PE, Fleiss JL: Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979; 86: 420–428.
21. Tsurumaru D, Miyasaka M, Nishimuta Y, Asayama Y, Nishie A, Kawanami S *et al.*: Differentiation of early gastric cancer with ulceration and resectable advanced gastric cancer using multiphasic dynamic multidetector CT. Eur Radiol 2016; 26: 1330–1337.
22. Hides JA, Miokovic T, Belavý DL, Stanton WR, Richardson CA: Ultrasound imaging assessment of abdominal muscle function during drawing-in of the abdominal wall: an intrarater reliability study. J Orthop Sports Phys Ther 2007; 37: 480–486.
23. Teyhen DS, Miltenberger CE, Deiters HM, Del Toro YM, Pulliam JN, Childs JD *et al.*: The use of ultrasound imaging of the abdominal drawing-in maneuver in subjects with low back pain. J Orthop Sports Phys Ther 2005; 35: 346–355.
24. Wallwork TL, Hides JA, Stanton WR: Intrarater and interrater reliability of assessment of lumbar multifidus muscle thickness using rehabilitative ultrasound imaging. J Orthop Sports Phys Ther 2007; 37: 608–612.
25. Teyhen DS, George SZ, Dugan JL, Williamson J, Neilson BD, Childs JD: Inter-rater reliability of ultrasound imaging of the trunk musculature among novice raters. J Ultrasound Med 2011; 30: 347–356.
26. Singer RN: Motor learning and human performance: an application to motor skills and movement behaviors. Macmillan, New York 1980.
27. Hides JA, Wong I, Wilson SJ, Belavý DL, Richardson CA: Assessment of abdominal muscle function during a simulated unilateral weight-bearing task using ultrasound imaging. J Orthop Sports Phys Ther 2007; 37: 467–471.
28. Teyhen DS, Miltenberger CE, Deiters HM, Del Toro YM, Pulliam JN, Childs JD *et al.*: The use of ultrasound imaging of the abdominal drawing-in maneuver in subjects with low back pain. J Orthop Sports Phys Ther 2005; 35: 346–355.
29. Davarian S, Maroufi N, Ebrahimi I, Farahmand F, Parnianpour M: Trunk muscles strength and endurance in chronic low back pain patients with and without clinical instability. J Back Musculoskelet Rehabil 2012; 25: 123–129.