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Reliability of transversus abdominis and internal oblique muscle thickness measurement using B-mode ultrasound imaging in standing and single leg standing positions

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ABSTRACT

Background: The thickness of the transversus abdominis (TrA) and internal oblique (IO) muscles are measured with high reliability by musculoskeletal ultrasound imaging (MSUSI) in the supine hook-lying and walking position. However, the reliability of the procedure to measure the TrA and IO muscle thickness measurement in the functional positions such as standing and single leg standing positions have not been well established.

Objectives: To examine the reliability of MSUSI for the TrA and IO muscles thickness measurement during standing and single leg standing positions in healthy participants.

Materials and methods: Ten healthy participants (aged 24.10±2.47 years) were recruited to perform MSUSI measurement of TrA and IO muscle thickness during the resting and abdominal drawing in maneuver (ADIM) in the standing and single leg standing positions. The intra-tester reliability of MSUSI measurement was performed by the same investigator in 2 different times (24 to 72 hours apart), while the inter-tester reliability was performed by 2 investigators within the same day. The intraclass correlation coefficient (ICC) whereby $ICC_{3,3}$ was used to determine the intra-tester and $ICC_{2,3}$ was used to determine the inter-tester reliability of TrA and IO muscles thickness measurement using MSUSI. The standard error of measurement (SEM) and coefficient of variation (CV) were calculated.

Results: The MSUSI measurements for TrA and IO muscles thickness showed high reliability in both standing and single leg standing positions ($ICC_{3,3}$ and $ICC_{2,3}$ >0.9). Moreover, the values of SEM ranged between 0.055 to 0.662 mm, MDC ranged between 0.152 to 1.834 mm and CV ranged between 0.543 to 14.001%.

Conclusion: The MSUSI measurement of TrA and IO muscles thickness could be performed with high intra and inter-tester reliability in standing and single leg standing positions among healthy individuals. The study findings on the MSUSI procedure to measure muscle thickness of TrA and IO would be useful for practice guidance in various research and clinical settings.

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Introduction

Musculoskeletal ultrasound imaging (MSUSI) is an alternative method widely used for measuring trunk muscle activation as it is noninvasive and allows visual presentation of deep trunk muscle contraction and thickness.[1-5] Transversus abdominis (TrA) and internal oblique (IO) muscles are deep trunk muscles suggested to provide spinal stability.[6,7] As such, past studies had reported the clinical functioning of TrA and IO muscles thickness during lumbopelvic test among people with low back pain.[1,7] The measurement of muscle thickness represents the morphologic characteristics of the muscles and demonstrate the activation of the muscles by calculating the relative change of muscle thickness during muscle contraction to resting thickness. Past studies that investigated the reliability of the procedures using MSUSI for measuring TrA and IO muscles thickness and activation were performed in supine hook-lying and walking positions.[4,8-12] The results on the reliability of the past studies showed that there were moderate reliability in the standing (ICC=0.55) and walking positions (ICC=0.74). The factors that may affect reliability of MSUSI on abdominal muscles include transducer location, pressure, and stage of breath cycle at which the image is taken.[4,9,10,12] The position of the patient is another important aspect that may influence the reliability of the MSUSI measurements of TrA and IO as different positions such as walking and supine lying demands different levels of muscle activation to control trunk stability.[12] Therefore, it is very appropriate to investigate the reliability of the MSUSI procedure to determine muscle thickness of TrA and IO especially when the technique is applied in a functional position. This study had chosen standing and single leg standing positions as these positions required more postural control than supine hook-lying position. Moreover, the muscle thickness during contraction and resting can be used to indicate the muscle activation. Also, abdominal drawing-in maneuver (ADIM) is recommended to stimulate the activation of the TrA muscle.[13] Furthermore, the TrA and IO activation has not been well established in the functional tasks such as standing and single leg positions. Thus, the main aim of the study was to investigate the reliability of the MSUSI of the TrA and IO in the standing and single-leg standing positions during resting and ADIM. Establishing a reliable procedure for the MSUSI measurements of TrA and IO in a functional position such as single leg standing is pertinent as this may inform the reliable assessment practice of TrA and IO in any of the clinical studies and practice settings.

Materials and methods

Subjects

Sample size calculation in this study was based on Walter *et al*.[14] which recommended using sample size calculator (https://wnarifin.github.io/ssc/ssicc.html). An estimated sample size of 10 participants was needed for this study with the minimum acceptable reliability (ICC) was set at 0.75 and a power of 0.8 with an alpha level of 0.05. A total of 10 healthy participants (5 males and 5 females) with mean age 24.1±2.47 years and BMI 20.94±1.51 kg/m^2 participated in the study. Participants with lumbopelvic, hip, lower extremity injury or surgery within the past 12 months, participants with abnormalities that affect the balance, participants who had impaired standing balance and who were not able to perform single leg standing for at least 30 seconds were excluded. Participants were withdrawn if they were unable to stand still during MSUSI measurement, or who were unable to complete all MSUSI measurement conditions. Informed consent was obtained from all the participants prior to their participation in the study. This research was approved by an institutional research and ethics committee (Ethical Approval No. 299/2021, code AMSEC-64EX-034).

Procedure

Ultrasound images of the TrA and IO muscles were obtained using an ultrasound scanner (Canon Xario-100S, TUS-X100S model) in B-mode with a 12-MHz linear array transducer. The aqua sonic gel was applied on participant's skin. The transducer of the ultrasound was placed firmly on the anterolateral aspect of the abdominal wall, superior to the iliac crest and perpendicular to the mid-axillary line while ensuring that the thoracolumbar fascia was aligned with the edge of the screen with TrA and IO muscles. The ultrasound images of TrA and IO were shown in Figure 1. The investigator had to constantly control the pressure of the transducer in all the test position while monitoring the muscles image on the screen. The images of the TrA and IO were captured at the end of participants' expiration during resting and abdominal drawing-in maneuver (ADIM). Before MSUSI, participants were instructed to practice the ADIM in supine hook-lying position (standard position). The participants were given a standard instruction which was "inhale with expanding the abdomen then exhale with flattening the abdomen. At the end of exhalation, pull the navel inward and upward towards the spine and hold it." The procedure was randomized to both the limb dominancy (dominant and non-dominant limbs) and the functional testing positions (standing and single leg standing positions). The images were captured three times for each condition and images were captured in resting position before ADIM to prevent fatigue of the muscles with a one minute rest given between each condition. The thickness of TrA and IO muscles were averaged from 3 images. The MSUSI images were collected in 2 positions including standing and single leg standing (Figure 2A and 2B). Participants were instructed to stand with dominant leg and lift non-dominant leg without dropping the pelvis. The dominant leg was determined by kicking a ball 10 meter 3 times, the leg which was used to kick the ball more frequently was taken as the dominant leg.[15] The images were captured from both sides of of TrA and IO muscle in standing and single leg standing positions. Intra-tester reliability of TrA and IO MSUSI measurements was performed by same investigator at 2 different times within 24 to 72 hours apart. Inter-tester reliability of TrA and IO MSUSI measurement was performed by 2 investigators within the same day and the investigators performed the procedures randomly without any particular order. The thickness of TrA and IO muscles were measured by using ImageJ program (NIH; version 1.8).

Statistical analysis

The analysis of intra-tester and inter-tester reliability of MSUSI measurements were calculated using the intraclass correlation coefficient (ICC). $ICC_{3,3}$ and $ICC_{2,3}$ were used to determine the Intra-tester and inter-tester reliability respectively, and *p*-value was set at $p<0.05$. Response stability was calculated using standard error of the measurement (SEM) and the coefficient of variation (CV).

$SEM = \sqrt{MSE}$ MSE is mean square error.

$CV = (SD/\bar{x}*100)$ $\bar{x}$ is the mean of the data, SD is the standard deviation of the muscle thickness.

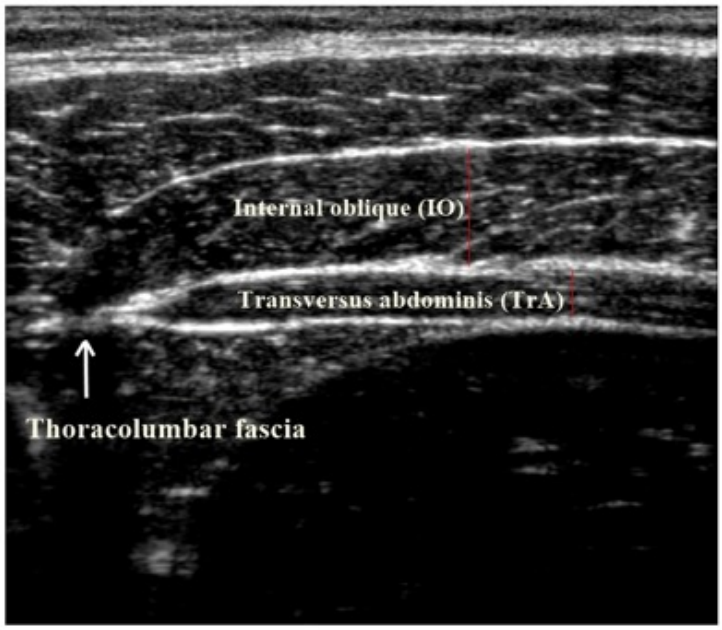

Figure 1. *The TrA and IO muscle image which captured by the MSUSI.*

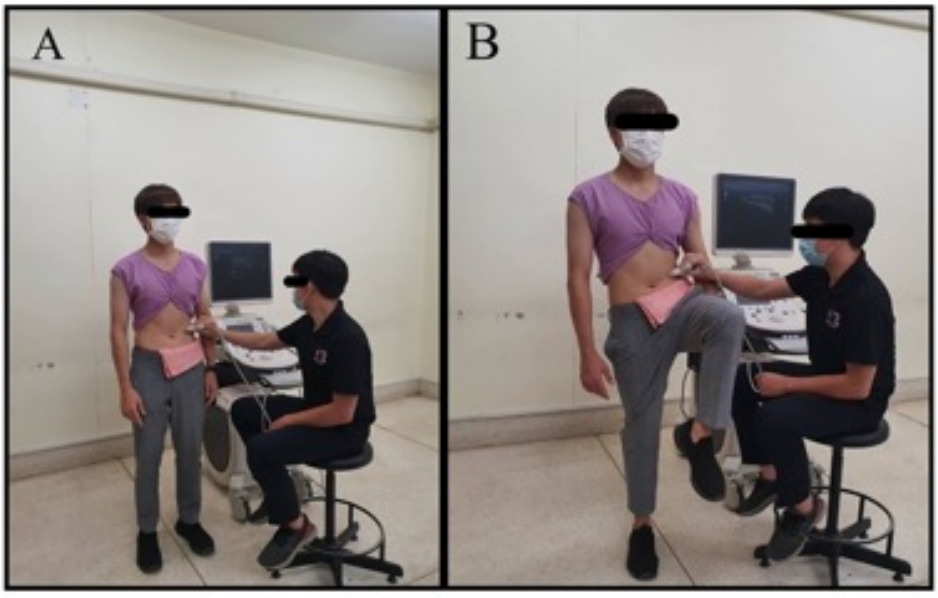

Figure 2. *Position set up for MSUSI measurement of TrA and IO muscles. MSUSI measurement in standing position (A) and in single leg standing position (B).*

Results

There were 10 healthy participants (5 males and 5 females) who participated in this study with mean age 24.1±2.47 years and BMI 20.94±1.51 kg/m^2. Mean and SD of TrA and IO muscle thickness during standing and single leg standing are shown in Table 1. The ICC, SEM, CV, and MDC are presented in Table 2 for intra-tester reliability and Table 3 for inter-tester reliability. During standing and single leg standing position, the ICC of TrA and IO muscle thickness measurements were more than 0.9 both intra-tester and inter-tester reliability. The values of SEM ranged between 0.055 to 0.662 mm, MDC ranged between 0.152 to 1.834 mm and CV ranged between 0.543% to 14.001%.

Table 1 Mean and SD of TrA and IO muscle thickness during standing and single leg standing from investigator 1 trial 1, investigator 1 trial 2 and investigator 2.

Position		Investigator 1 trial 1			
		TrA muscle thickness (mm)		IO muscle thickness (mm)	
		Dominant side	Non-dominant side	Dominant side	Non-dominant side
Stand	Resting	3.55±1.05	3.85±0.81	7.74±2.84	8.43±2.72
	ADIM	5.24±1.61	5.91±1.49	10.67±3.19	10.63±2.53
Single leg stand	Resting	3.69±1.11	4.12±0.90	9.06±3.49	8.40±2.55
	ADIM	5.57±1.20	6.08±1.14	10.96±3.02	10.79±2.45
Position		**Investigator 1 trial 2**			
		TrA muscle thickness (mm)		IO muscle thickness (mm)	
		Dominant side	Non-dominant side	Dominant side	Non-dominant side
Stand	Resting	3.58±1.07	3.87±0.91	9.05±3.28	8.49±2.64
	ADIM	5.24±1.56	5.89±1.48	10.98±3.31	10.80±2.52
Single leg stand	Resting	3.83±1.23	4.08±1.00	9.16±3.49	8.41±2.62
	ADIM	5.53±1.17	6.00±1.12	10.82±2.95	10.65±2.37
Position		**Investigator 2**			
		TrA muscle thickness (mm)		IO muscle thickness (mm)	
		Dominant side	Non-dominant side	Dominant side	Non-dominant side
Stand	Resting	3.55±1.07	3.84±0.80	8.97±3.20	8.64±2.86
	ADIM	5.26±1.57	5.95±1.49	10.85±3.24	10.74±2.64
Single leg stand	Resting	3.71±1.09	4.08±0.89	9.09±3.41	8.47±2.55
	ADIM	5.43±1.15	6.01±1.10	10.97±3.00	10.81±2.45

***Note**: TrA: Transversus abdominis, IO: Internal oblique, mm: millimeter, ADIM: abdominal drawing in maneuver.*

Table 2 $ICC_{3,3}$, SEM and CV of TrA and IO muscle thickness for intra-tester reliability.

Muscle/position/condition		Dominant side				Non-dominant side			
		$ICC_{3,3}$	SEM (mm)	CV (%)	MDC (mm)	$ICC_{3,3}$	SEM (mm)	CV (%)	MDC (mm)
TrA muscle thickness during standing	Resting	0.998	0.055	1.797	0.152	0.960	0.239	6.199	0.662
	ADIM	0.994	0.170	3.269	0.472	0.997	0.114	1.917	0.316
TrA muscle thickness during single leg standing	Resting	0.987	0.187	5.714	0.519	0.989	0.145	3.563	0.402
	ADIM	0.994	0.134	2.498	0.372	0.998	0.245	1.599	0.679
IO muscle thickness during standing	Resting	0.976	0.662	14.001	1.834	0.984	0.281	3.371	0.779
	ADIM	0.991	0.430	4.539	1.192	0.998	0.161	1.887	0.447
IO muscle thickness during single leg standing	Resting	0.999	0.095	1.324	0.263	0.998	0.164	1.975	0.455
	ADIM	0.997	0.228	2.323	0.632	0.997	0.173	1.904	0.480

***Note**: ICC: intraclass correlation coefficient, SEM: standard error of measurement, CV: coefficient of variation, MDC: minimal detectable change, mm: millimeter, ADIM: abdominal drawing in maneuver.*

Table 3 $ICC_{2,3}$, SEM and CV of TrA and IO muscle thickness for inter-tester reliability.

Muscle/position/condition		Dominant side				Non-dominant side			
		$ICC_{2,3}$	SEM (mm)	CV (%)	MDC (mm)	$ICC_{2,3}$	SEM (mm)	CV (%)	MDC (mm)
TrA muscle thickness during standing	Resting	0.992	0.134	3.758	0.372	0.991	0.105	2.741	0.291
	ADIM	0.999	0.055	1.100	0.152	0.998	0.089	1.580	0.248
TrA muscle thickness during single leg standing	Resting	0.999	0.055	1.396	0.152	0.996	0.077	2.041	0.215
	ADIM	0.989	0.173	3.710	0.480	0.992	0.138	2.459	0.382
IO muscle thickness during standing	Resting	0.983	0.551	12.811	1.528	0.987	0.446	5.527	1.237
	ADIM	0.997	0.232	2.502	0.644	0.997	0.214	2.145	0.594
IO muscle thickness during single leg standing	Resting	0.999	0.187	2.068	0.519	0.999	0.071	1.075	0.196
	ADIM	0.999	0.084	0.787	0.232	0.999	0.055	0.543	0.152

***Note**: ICC: intraclass correlation coefficient, SEM: standard error of measurement, CV: coefficient of variation, MDC: minimal detectable change, mm: millimeter, ADIM: abdominal drawing in maneuver.*

Discussion

The current study demonstrated high intra-tester and inter-tester reliability for MSUSI procedure to measure muscle thickness of TrA and IO muscle during standing and single leg standing positions ($ICC_{3,3}$ and $ICC_{2,3}$ >0.9). Moreover, the reproducibility of the measurement procedures were considered to be reliable as the overall SEM were 0.055 to 0.662 mm and CV ranged between 0.543% to 14.001%. which is within the acceptable measurement error of SEM less than 5% and CV were less than 15%.[14] Therefore, the results of ICC, CV and SEM showed that the use of MSUSI in this study was reliable to measure thickness of TrA and IO muscle in standing and single leg standing positions. Previous study of Mangum *et al*.[12] assessed the reliability of MSUSI for TrA muscle on tabletop, seated, standing and walking positions among the university students and they found that the MSUSI were reliable in all position. The intraclass correlation coefficient value (ICC>0.90) in the current study was comparable with the previous study which reported reliability values in tabletop position (ICC=0.903), seated position (ICC=0.613), standing position ICC=0.553), and walking position (ICC=0.737).[12] The investigators followed the exact procedure and measurement timeline from the previous study which could explain the high reliability results demonstrated by the MSUSI procedure. Previous study participants were university students, and the procedure was not tested in the single leg stand position. However, the current study participants were community adults and the current study measured in both standing and single leg standing positions thereby providing further knowledge and new data on TrA and IO during the single leg standing position which might help for subsequent research.

Using an average of three measurements of the muscle thickness values from the MSUSI procedure is reported to decrease the SEM by over 50%.[15] The fact that the current study also followed this recommendation of using an average of three measures might had contributed to high reliability of the study findings. The SEM and CV reported as intra-tester reliability measures for TrA muscle in the current study (SEM range, 0.055 to 0.245 mm and CV range, 1.797 to 6.199%) was lower than Teyhen *et al*,[16] who reported SEM of TrA (range, 0.31-0.87 mm). Similarly in the current study, the SEM and CV related to inter-tester reliability measures of TrA (SEM range, 0.055 to 0.173 mm and CV range, 1.100 to 3.758%) was lower to Springer *et al*,[17] who demonstrated SEM of TrA muscle to range between 0.13 to 0.35 mm. The study findings might therefore imply that the MSUSI procedure was highly reliable to measure muscle thickness during standing and single leg standing positions.

The present study showed high intra-tester reliability across day for TrA and IO (ICCs range, 0.960 to 0.999) and SEM range 0.055 to 0.551 mm. The high reliability might be explained due to using better resolution of the TrA and IO ultrasound images with a B-mode 12-MHz linear array transducer. Previous studies suggested using a linear transducer contributed for excellent reliability.[4,5,9,10,12,18] Linear transducers commonly have higher frequency, reduced penetration and better resolution which helped to capture a clear TrA and IO muscle structures on the MSUSI images. Furthermore, a standardized protocol was used to place the transducer whereby positioning of the transducer was established to be halfway between the lower rib and iliac crest and placed at the area of participants' abdomen capturing the thoracolumbar fascia of TrA and IO muscle on the ultrasound screen. Additionally, the participants were instructed to breath normally and the measurement using the imaging was performed at the end of the expiration, hence such standardization procedures of measurement could have helped to perform the MSUSI procedure with high reliability. All of the above procedures might have contributed to reduce the margin of measurement errors and resulted in high reliability. MSUSI measurement can be used clinically to make decision on muscle thickness change regarding to intervention such as spinal stabilization exercise.

Some limitation of current study should be considered. One of the limitations was the age, as all the participants in this study were 20-30 years old so this might cause generalization to lower age groups. In addition, participants in this study were healthy participants so the results of this study might be relevant to only healthy participants and

not applicable to a clinical population such as low back pain. Further studies could examine the reliability of performing the procedures in different populations such as chronic low back pain. Nevertheless, the current study had established a clear MSUSI procedure and measurement protocol to measure muscle thickness of TrA and IO during functional tasks such as standing and single leg standing. The current study provided a first-hand knowledge in the single leg standing positions with regard to the TrA and IO muscle activations which was not studied before. The results of this study showed that MSUSI was a reliable procedure for measuring TrA and IO muscles thickness. Thus, the MSUSI procedure could be used in future studies to determine the muscle activation and thickness of TrA and IO muscles in functional position such as single leg standing. The procedural information and findings might provide guidance to future clinical research on the functional assessment of for TrA and IO muscles in symptomatic population such as people with low back pain.

Conclusion

MSUSI could be performed as a non-invasive procedure with high reliability to measure muscle thickness of the TrA and IO muscles during functional tasks such as standing and single leg standing among the healthy individuals.

References

[1] Miura T, Yamanaka M, Ukishiro K, Tohyama H, Saito H, Samukawa M, et al. Individuals with chronic low back pain do not modulate the level of transversus abdominis muscle contraction across different postures. Man Ther. 2014; 19(6): 534-40. doi: 10.1016/j.math.2014.05.010.

[2] Mangum LC, Henderson K, Murray KP, Saliba SA. Ultrasound assessment of the transverse abdominis during functional movement. J Ultrasound Med. 2018; 37(5): 1225-31. doi: 10.1002/jum.14466.

[3] Mannion AF, Pulkovski N, Toma V, Sprott H. Abdominal muscle size and symmetry at rest and during abdominal hollowing exercises in healthy control subjects. J Anat. 2008; 213(2): 173-82. doi: 10.1111/j.1469-7580.2008.00946.x.

[4] Rankin G, Stokes M, Newham DJ. Abdominal muscle size and symmetry in normal subjects. Muscle Nerve. 2006; 34(3): 320-6. doi: 10.1002/mus.20589.

[5] Sitilertpisan P, Joseph L, Paungmali A, Paungmali U, Chunchai T. Investigation of the contraction ratio of transversus abdominis and internal oblique muscles during lumbopelvic stability test. MLTJ. 2020; 10: 86. doi: 10.32098/mltj.01.2020.10.

[6] Oliva-Lozano JM, Muyor JM. Core muscle activity during physical fitness exercises: a systematic review. Int J Environ Res Public Health. 2020; 17(12). doi: 10.3390/ijerph17124306.

[7] Watson T, Graning J, McPherson S, Carter E, Edwards J, Melcher I, et al. Dance, balance and core muscle performance measures are improved following a 9-week core stabilization training program among competitive collegiate dancers. Int J Sports Phys Ther. 2017; 12(1): 25-41.

[8] Gnat R, Saulicz E, Miądowicz B. Reliability of real-time ultrasound measurement of transversus abdominis thickness in healthy trained subjects. Eur Spine J. 2012; 21(8): 1508-15. doi: 10.1007/s00586-012-2184-4.

[9] 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(8): 480-6. doi: 10.2519/jospt.2007.2416.

[10] 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(1): 87-94. doi: 10.1016/j.apmr.2008.06.022.

[11] Koppenhaver SL, Hebert JJ, Parent EC, Fritz JM. Rehabilitative ultrasound imaging is a valid measure of trunk muscle size and activation during most isometric sub-maximal contractions: a systematic review. Aust J Physiother. 2009; 55(3): 153-69. doi: 10.1016/s0004-9514(09)70076-5.

[12] Mangum LC, Sutherlin MA, Saliba SA, Hart JM. Reliability of ultrasound imaging measures of transverse abdominis and lumbar multifidus in various positions. Pm R. 2016; 8(4): 340-7. doi: 10.1016/j.pmrj.2015.09.015.

[13] Lee DH, Hong SK, Lee YS, Kim CH, Hwang JM, Lee Z, et al. Is abdominal hollowing exercise using real-time ultrasound imaging feedback helpful for selective strengthening of the transversus abdominis muscle?: A prospective, randomized, parallel-group, comparative study. Medicine (Baltimore). 2018; 97(27). doi: 10.1097/md.0000000000011369.

[14] Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Stat Med. 1998; 17(1): 101-10. doi: 10.1002/(sici)1097-0258(19980115)17:1<101::aid-sim727>3.0.co;2-e.

[15] van Melick N, Meddeler BM, Hoogeboom TJ, Nijhuis-van der Sanden MWG, van Cingel REH. How to determine leg dominance: The agreement between self-reported and observed performance in healthy adults. PLoS One. 2017; 12(12): e0189876. doi: 10.1371/journal.pone.0189876.

[16] 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(6): 346-55. doi: 10.2519/jospt.2005.35.6.346.

[17] Springer BA, Mielcarek BJ, Nesfield TK, Teyhen DS. Relationships among lateral abdominal muscles, gender, body mass index, and hand dominance. J Orthop Sports Phys Ther. 2006; 36(5): 289-97. doi: 10.2519/jospt.2006.2217.

[18] Prentice CLS, Milanese S, Massy-Westropp N, Maranna S. The reliability of rehabilitative ultrasound to measure lateral abdominal muscle thickness: A systematic review and meta-analysis. Musculoskelet Sci Pract. 2021; 53: 102357. doi: 10.1016/j.msksp.2021.102357.