



Original Article

Intraclass correlation coefficient of trunk muscle thicknesses in different positions measured using ultrasonography

YOSHIKI ENDO, RPT, PhD^{1)*}, AKIHIRO ITO, RPT, PhD¹⁾, SYOTA HOTTA, RPT²⁾, AKIHIRO YAKABI, RPT, PhD¹⁾, KO ONODA, RPT, PhD¹⁾, HIROAKI TANI, RPT, MD¹⁾, AKIRA KUBO, RPT, PhD¹⁾

¹⁾ Department of Physical Therapy, International University of Health and Welfare: 2600-1 Kitakanemaru, Otawara, Tochigi 324-8501, Japan

²⁾ Department of Rehabilitation, Shioya Hospital, International University of Health and Welfare, Japan

Abstract. [Purpose] This study aimed to clarify the required number of measurements to calculate trunk muscle thickness at each position. [Participants and Methods] The participants were 30 elderly males aged >65 years. The right lumbar multifidus (L2), lumbar multifidus (L5), erector spinae, transversus abdominis, internal oblique, and external oblique muscle thicknesses were measured on longitudinal images obtained using ultrasonography in the lying, sitting, and standing positions. Two measurement values for each muscle thickness was used to calculate the intraclass correlation coefficient (1.1–1.5). [Results] The intraclass correlation coefficients of the abdominal muscle thickness measurements with “great reliabilities” were as follows: 1.3–1.5 for the external oblique muscle and 1.2–1.5 for the internal oblique and transversus abdominis muscles in the lying position; 1.3–1.5 for the external oblique and transversus abdominis muscles and 1.2–1.5 for the internal oblique muscle in the sitting position; the intraclass correlation coefficient in the standing position was 1.5 for the external oblique muscle 1.1–1.5 for the internal oblique muscle and 1.3–1.5 for the transversus abdominis muscle. In all the positions, the intraclass correlation coefficient of the measurements of the back-muscle thicknesses ranged from 1.1 to 1.5 for the right lumbar multifidus (L2), lumbar multifidus (L5), and erector spinae. [Conclusion] Depending on the posture, the abdominal muscles require multiple measurements, whereas the back muscles only require a single measurement.

Key words: Intraclass correlation coefficient, Trunk muscle thicknesses, Ultrasonography

(This article was submitted Oct. 27, 2020, and was accepted Dec. 22, 2020)

INTRODUCTION

There is an association between trunk muscles and stable limb movements, stability during exercise, and efficient power transmission. To elucidate the mechanisms and methods of exercise therapy, many studies have been conducted in the field of rehabilitation in recent years.

Ultrasonography is used to measure the muscle thicknesses to evaluate the trunk muscles. Ultrasonography has many advantages; it has a very low energy level, is safe for living bodies, is inexpensive, requires no special room, can be used in hospital and rehabilitation rooms, and helps to observe and evaluate skeletal muscle morphology in real time¹⁾. There are other muscle mass assessments including magnetic resonance imaging, computed tomography (CT), and dual-energy X-ray absorptiometry (DXA). However, these techniques are expensive and require large-scale measurements, and CT and DXA have a risk of radiation exposure. Therefore, ultrasonography is easy to be used in a clinical setting for taking measurements.

*Corresponding author. Yoshiaki Endo (E-mail: yendo0117@iuhw.ac.jp)

©2021 The Society of Physical Therapy Science. Published by IPEC Inc.



This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: <https://creativecommons.org/licenses/by-nc-nd/4.0/>)

It is necessary to verify measurement errors to use ultrasonography in clinical practice. Based on the presence or absence of chronic low back pain in the prone position targeting the young and elderly, a study to confirm the reliability of the measurements of the multifidus muscle and posterior paraspinal muscles using ultrasonography was conducted²⁻⁴. Based on the respiratory condition, a comparison study to confirm the reliability of the measurements of the transversus abdominis (TrA), internal oblique (IO), and external oblique (EO) muscles using ultrasonography was conducted^{5, 6}. In these studies, depending on the measurement site and position, there were differences in the number of measurements and ICC results.

When the SPSS is used to calculate the ICC, only the ICC corresponding to the number of measurements can be obtained. For this reason, so far, there have been many studies on musculoskeletal research only. However, based on the values calculated with the first and second measurements of each muscle thickness, an analysis of variance table was created using SPSS, and the reliability coefficient (r_1) was calculated. Thereafter, the ICC at the time of k measurements can be simulated by applying the formula. First, based on the values with the first and second measurements of each muscle thickness, an analysis of variance table was created using SPSS, and ICC (1.1) was calculated. The ICC (1.1) is represented as r_1 . Then, using Excel, the intraexaminer reliability ICC (1.k) at the time of the k -time measurement was calculated using the following formula.

$$ICC(1.k) = \frac{kr_1}{1+(k-1)r_1}$$

Using this method, it is possible to determine the number of measurements required to obtain high reliability even if the ICC result in the measurement is low. If this method of calculating the intraexaminer reliability becomes widespread, it will lead to further musculoskeletal research development.

Therefore, in this study, the number of measurements required to perform highly reliable intraexaminer measurements was clarified by measuring multiple trunk muscle thicknesses for each position twice.

PARTICIPANTS AND METHODS

A total of 30 elderly males with an age over 65 years (mean age, 70.7 ± 4.8 years; mean body mass index (BMI), 23.7 ± 2.2 kg/m²: mean \pm standard deviation) were included in this study. They were recruited from those who are registered with the staffing agency. The exclusion criteria included illness, injury, pain in the waist or abdomen, or previous low back pain.

The right lumbar multifidus (L2) (LM (L2)), lumbar multifidus (L5) (LM (L5)), erector spinae (ES), TrA, IO, and EO muscle thicknesses were measured on longitudinal images, which were obtained using ultrasonography (SonoSite 180 Plus, FUJIFILM SonoSite, Inc., Bothell, WA, USA). **Figure 1** shows the muscle thickness measurement method. Based on previous studies^{2, 6-11}, the muscle thicknesses of the LM (L2) and LM (L5) were measured at 2 cm outside of the spinous process of the second and fifth lumbar vertebra, with the probe placed perpendicular to the spinal column. Besides, based on previous studies^{3, 8, 12}, the muscle thickness of the ES was measured at 5 cm outside of the spinous process of the third lumbar vertebra, with the probe placed perpendicular to the spinal column. Considering the measurements' reproducibility, using an oily marker, the muscle thicknesses of the LM (L2), LM (L5), and ES were marked on the spinous processes. Furthermore, based on previous studies^{5, 8, 13}, using an oily marker midway between the costal margin and iliac crest, along the right anterior axillary line, the muscle thicknesses of the TrA, IO, and EO muscles were measured. With an oily marker, each muscle thickness measurement was marked on the skin. The high-brightness region was not included in the measurements. At the end of expiration, measurements were performed twice. Using the pictures obtained using ImageJ, each muscle thickness calculation was performed (**Fig. 2**).

The measurements were done in the lying, sitting, and standing positions. In the lying positions, the abdominal muscles (TrA, IO, and EO) were measured in the supine position, while the back muscles (LM (L2), LM (L5), and ES) were measured in the prone position. The sitting position was maintained with a 90° hip joint and 90° knee flexion with the sole on the floor. In all the positions, the measurements were performed at the natural pelvic tilt and parietal region, ear canal, acromion, and greater trochanter. To prevent excessive pelvic and lumbar anterior-posterior rotations, verbal and manual corrections were

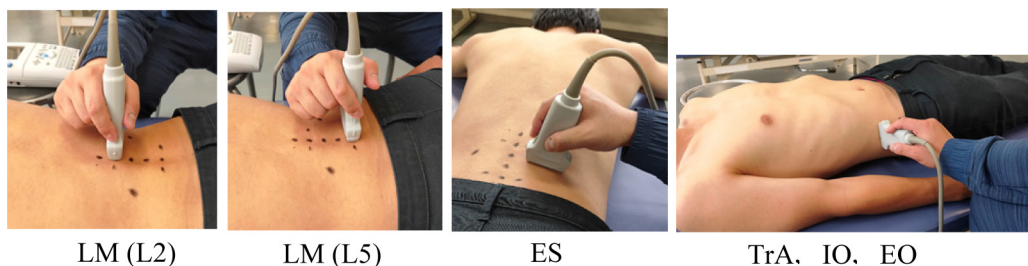


Fig. 1. Position to place the ultrasonography probe.

LM (L2): Lumbar multifidus (L2); LM (L5): Lumbar multifidus (L5); ES: Erector spinae; TrA: Transversus abdominis; IO: Internal oblique; EO: External oblique.

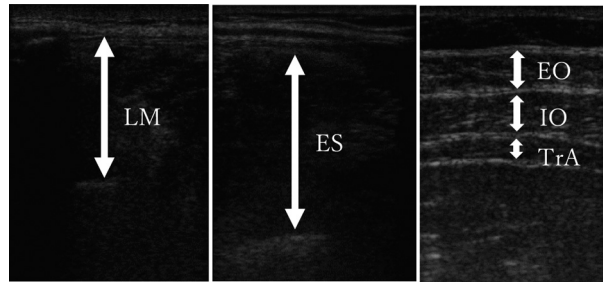


Fig. 2. Ultrasonography image for each muscle.
LM: Lumbar multifidus; ES: Erector spinae; TrA: Transversus abdominis; IO: Internal oblique; EO: External oblique.

made.

A physiotherapist with eight years of experience performed the measurements.

From the values calculated with the first and second measurements of each muscle thickness, ICC (1.1–5) was obtained. For all the analyses, SPSS software version 19.0 (IBM, Tokyo, Japan) and Microsoft Excel (Microsoft Corporation, Washington, USA) were used. The level of significance was set at 5%.

This study was conducted in accordance with the Declaration of Helsinki. The purpose and details of this study were explained to the participants beforehand. The participants provided informed consent; after that, the measurements were performed. The study protocol was approved by the Ethics Committee of the International University of Health and Welfare Hospital (17-IO-101).

RESULTS

This section only presents ICCs with results exceeding 0.9, indicating “excellent reliability”¹⁴. The details are shown in Tables 1–3.

The ICC results of abdomen muscles differed for each muscle and position. The ICCs with results exceeding 0.9 were ICC (1.3–5) of the EO and ICC (1.2–5) of the IO and TrA in the lying position. The ICCs with results exceeding 0.9 were ICC (1.3–5) of the EO, ICC (1.2–5) of IO, and ICC (1.3–5) of TrA in the sitting position. The ICCs with results exceeding 0.9 were ICC (1.5) of EO, ICC (1.1–5) of the IO, and ICC (1.3–5) of TrA in the standing position.

ICC results of back muscles did not change by muscle and position. The ICCs with results exceeding 0.9 were ICC (1.1–5) of LM (L2), LM (L5), and ES in the lying, sitting, and standing positions.

DISCUSSION

Using ultrasonography, multiple trunk muscle thicknesses were measured for each position, and the intraexaminer reliability was examined. As a result, it was suggested that the ICC is determined by the trunk muscles and position. Through the analysis of the results of only two measurements, it became clear how many measurements should be performed to obtain highly reliable measurements. If this method of calculating intraexaminer reliability becomes widespread, it will lead to further musculoskeletal research development.

Abdominal muscle thickness had a different tendency for each position. In this study, the abdominal muscle thickness of IO, EO, and TrA muscles was measured simultaneously. These muscles have different roles, interact with each other, and stabilize the trunk during exercise. Therefore, it is desirable to measure all abdominal muscle thicknesses simultaneously with high reliability.

In the lying and sitting positions, the ICC (1.1) and ICC (1.2) of the abdominal muscle thickness measurements were 0.77–0.94, which indicate “normal reliabilities”–“good reliabilities”, and ICC (1.3), ICC (1.4), and ICC (1.5) were over 0.9, which indicates “great reliabilities”. Therefore, the same examiner is required to perform 3 or more measurements of the abdominal muscle thickness in the supine and sitting positions to obtain a very reliable measurement. A previous research¹⁵ examined the ICC (1.1) of IO, EO, and TrA in 10 young males and females who were grouped with or without low back pain in the four-point kneeling position. As a result, “great reliability” was shown. Our study results are less reliable than those of previous studies because the study participants were healthy older males. It is thought that the muscle strength of the abdominal muscles decreased with age and became more susceptible to the abdominal contents. In the standing position, the ICC (1.1) of the abdominal muscle thicknesses was 0.68–0.91, which indicates “normal reliabilities”–“great reliabilities”, the ICC (1.2), ICC (1.3), and ICC (1.4) were 0.81–0.97, which indicates “good reliabilities”–“great reliabilities”, and ICC (1.5) was over 0.9, which indicates “great reliabilities”. Therefore, the same examiner is required to perform 5 or more measurements of the abdominal muscle thickness in the standing position to obtain a very reliable measurement. Compared to the lying and

Table 1. Intraclass correlation coefficient of trunk muscle thickness in the lying position

	EO	IO	TrA	LM (L2)	LM (L5)	ES
ICC (1.1)	0.80	0.89	0.85	0.98	0.97	0.94
ICC (1.2)	0.89	0.94	0.92	0.99	0.99	0.97
ICC (1.3)	0.92	0.96	0.94	0.99	0.99	0.98
ICC (1.4)	0.94	0.97	0.96	0.99	0.99	0.98
ICC (1.5)	0.95	0.98	0.97	1.00	0.99	0.99

Table 2. Intraclass correlation coefficient of trunk muscle thickness in the sitting position

	EO	IO	TrA	LM (L2)	LM (L5)	ES
ICC (1.1)	0.80	0.85	0.77	0.94	0.93	0.96
ICC (1.2)	0.89	0.92	0.87	0.97	0.97	0.98
ICC (1.3)	0.92	0.95	0.91	0.98	0.98	0.99
ICC (1.4)	0.94	0.96	0.93	0.98	0.98	0.99
ICC (1.5)	0.95	0.97	0.94	0.99	0.99	0.99

Table 3. Intraclass correlation coefficient of trunk muscle thickness in the standing position

	EO	IO	TrA	LM (L2)	LM (L5)	ES
ICC (1.1)	0.68	0.91	0.79	0.97	0.96	0.96
ICC (1.2)	0.81	0.95	0.88	0.98	0.98	0.98
ICC (1.3)	0.86	0.97	0.92	0.99	0.99	0.99
ICC (1.4)	0.89	0.97	0.94	0.99	0.99	0.99
ICC (1.5)	0.91	0.98	0.95	0.99	0.99	0.99

sitting positions, performing many measurements in the standing position is necessary to obtain very reliable measurements. This is because the abdominal shape changes due to the abdominal contents became large in the antigravity position. Besides, in the standing position, the abdominal muscle thickness measurements (EO, IO, and TrA) differed for each muscle. In the EO, the ICC (1.5) was 0.91, which indicates “great reliabilities”; in the IO, ICC (1.1), ICC (1.2), ICC (1.3), ICC (1.4), and ICC (1.5) were over 0.9, which indicates “great reliabilities”; and in the TrA, ICC (1.3), ICC (1.4), and ICC (1.5) were over 0.9, which indicates “great reliabilities”. For very reliable measurements, five times or more, one or more times, and three or more times are required when measuring the EO, IO, and TrA muscles, respectively. A large number of measurements are required for the EO muscle because it tends to have a strong tendency toward age-related atrophy. There are studies on age-related changes in the muscle fiber composition of the abdominal muscles from tissue samples¹⁶⁾. As a result, among the abdominal muscles, EO muscle showed a strong tendency toward age-related atrophy, supporting our study results.

The ICC (1.1) of the measurements of the back muscle thicknesses (LM (L2), LM (L5), and ES) was over 0.9, which indicates “great reliabilities” in all the positions (supine, sitting, and standing positions). Therefore, when the same examiner is measuring the back muscle thicknesses in all the positions, to obtain reliable measurements, the measurements should be performed one or more times. Compared to abdominal muscles, the back muscles can be measured with high reliability with a few measurements. First, the back muscle is closer to the vertebra that forms the skeleton compared to the abdominal muscle, and the stability of the muscle itself is easy to be maintained. Another reason is that the probe could be placed in the correct position by placing a marker on the spinous process, which is a bone index.

Future issues include the following. First, this study targeted healthy elderly people. For future clinical use, it is necessary to examine the reliability of ultrasound images for patients with trunk muscle dysfunction. Second, this study was evaluating the intraexaminer reliability. In the future, it will be necessary to examine the interrater reliability to further improve the reliability of the measurements. Third, considering in more detail what should be noted at the time of measurement is necessary for measuring with higher reliability. There is a study that showed that the cause of the change in the muscle thickness is not only muscle activity but also many other factors such as the muscles’ structure, muscle contraction types, and measurement technique which are involved in the change¹⁾. In this study, those considerations are insufficient. Those points should be considered in more detail.

Funding

This work was supported by JSPS KAKENHI Grant no. 20K23259.

Conflict of interest

The authors declare that they have no conflicts of interest related to this work.

ACKNOWLEDGMENT

The authors would like to thank Enago (www.enago.jp) for English language review. The author is grateful to the participants and co-author for assistance with data acquisition.

REFERENCES

- 1) Hodges PW: Ultrasound imaging in rehabilitation: just a fad? *J Orthop Sports Phys Ther*, 2005, 35: 333–337. [[Medline](#)] [[CrossRef](#)]
- 2) 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. [[Medline](#)] [[CrossRef](#)]
- 3) Stokes M, Hides J, Elliott J, et al.: Rehabilitative ultrasound imaging of the posterior paraspinal muscles. *J Orthop Sports Phys Ther*, 2007, 37: 581–595. [[Medline](#)] [[CrossRef](#)]
- 4) Sions JM, Velasco TO, Teyhen DS, et al.: 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. [[Medline](#)] [[CrossRef](#)]
- 5) Misuri G, Colagrande S, Gorini M, et al.: In vivo ultrasound assessment of respiratory function of abdominal muscles in normal subjects. *Eur Respir J*, 1997, 10: 2861–2867. [[Medline](#)] [[CrossRef](#)]
- 6) Hides JA, Richardson CA, Jull GA: Magnetic resonance imaging and ultrasonography of the lumbar multifidus muscle. Comparison of two different modalities. *Spine*, 1995, 20: 54–58. [[Medline](#)] [[CrossRef](#)]
- 7) Endo Y, Onoda K, Kubo A: Perinatal changes in the spinal curvature angle and trunk muscle thickness of a primipara with postpartum lower back pain: a case study. *Rigakuryoho Kagaku*, 2018, 33: 835–838 (In Japanese). [[CrossRef](#)]
- 8) Endo Y, Onoda K, Kubo A: Changes in muscle thicknesses of the trunk muscles with posture. *Rigakuryoho Kagaku*, 2017, 32: 527–530 (In Japanese). [[CrossRef](#)]
- 9) Endo Y, Onoda K, Kubo A: Correlation between the cross-sectional area of the multifidus muscle at each vertebral level and body composition. *Rigakuryoho Kagaku*, 2018, 33: 733–737 (In Japanese). [[CrossRef](#)]
- 10) Endo Y, Kubo A, Kimura K, et al.: Difference in the cross sectional area of the right and left multifidus muscle of the waist at each lumbar level. *Jpn Phys Ther Assoc*, 2017, 44: 42–46 (In Japanese).
- 11) Kiesel KB, Uhl TL, Underwood FB, et al.: Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. *Man Ther*, 2007, 12: 161–166. [[Medline](#)] [[CrossRef](#)]
- 12) Watanabe K, Miyamoto K, Masuda T, et al.: Use of ultrasonography to evaluate thickness of the erector spinae muscle in maximum flexion and extension of the lumbar spine. *Spine*, 2004, 29: 1472–1477. [[Medline](#)] [[CrossRef](#)]
- 13) Bunce SM, Moore AP, Hough AD: M-mode ultrasound: a reliable measure of transversus abdominis thickness? *Clin Biomech (Bristol, Avon)*, 2002, 17: 315–317. [[Medline](#)] [[CrossRef](#)]
- 14) Shrout PE, Fleiss JL: Intraclass correlations: uses in assessing rater reliability. *Psychol Bull*, 1979, 86: 420–428. [[Medline](#)] [[CrossRef](#)]
- 15) Critchley DJ, Coutts FJ: Abdominal muscle function in chronic low back pain patients: measurement with real-time ultrasound scanning. *Physiother Elsevier Ltd*, 2002, 88: 322–332.
- 16) Ito J, Inokuchi S: Myofibrous organization in human abdominal muscles. *Showa Univ J Med Sci*, 1989, 1: 79–87.