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## Original Article

# Reproducibility of elastic modulus measurement of the multifidus using the shear wave elastography function of an ultrasound diagnostic device

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**Abstract.** [Purpose] This study aimed to obtain evidence of the musculo-physiological involvement in the effect of physiotherapy on low back pain by examining the reproducibility of elasticity measurements of the multifidus muscle at different trunk angles via the shear wave elastography function of an ultrasound diagnostic device. [Participants and Methods] This study included 11 healthy adults. Measurements were conducted with participants in the prone position, and the elasticity of the superficial and deeper layers of the multifidus muscle was measured under the following 3 conditions: trunk at neutral position, trunk flexed at 40°, and trunk extended at 20°. Next, intraclass correlation coefficients (1, 1) were calculated to examine the intrarater reliability. [Results] All intraclass correlation coefficients for the superficial and deeper layers of the multifidus muscle were ≥0.85 for all 3 conditions. [Conclusion] Regardless of the trunk position, the elastic modulus measurement of inner muscles via shear wave elastography serves as an assessment of biological changes in individuals with lower back pain in response to interventions.
**Key words:** Shear wave elastography, Multifidus muscle, Lower back pain

## INTRODUCTION

A large-scale survey on lower back pain conducted in Japan revealed that 83% of people experience lower back pain at some point in their lives, and 25% miss work and 10% miss work for ≥4 consecutive days because of lower back pain[1]. Lower back pain greatly undermines the quality of life of workers, and implementing preventive measures against lower back pain is an important challenge to the society regarding loss in labor. Approximately 85% of all lower back pain cases are nonspecific, and muscular or fascial pain is typical among such cases. Causes of nonspecific lower back pain include abnormal lower back muscle activity and impaired local circulation[2]. Dysfunction of the multifidus muscle (MF) in the lumbar area is related to lower back pain and back pain recurrence rate[3]. Stretching is the most effective method for alleviating lower back pain[4]. However, mechanisms that reduce pain remain unclear because biological outcomes of stretching, such as changes in the muscles and blood circulation, are unclear.

Recently, shear wave elastography (SWE) has attracted attention as a modality for easily and noninvasively evaluating tissue hardness. SWE generates an elastic wave of shear waves within a tissue, and tissue elastic modulus can be evaluated by measuring the elastic wave propagation velocity. Furthermore, the elastic modulus is calculated as an absolute value

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(kPa), which permits quantitative evaluations of living tissue hardness[5]). Reliability of elastic modulus measurements in human skeletal muscles via SWE has been reported for surface muscles such as the quadriceps femoris and gastrocnemius. Recent study has reported on the validity of shear modulus of the lumbar multifidus muscles[6]). However, few reports exist of its application to lower back or deep muscles. MF is divided into superficial and deep layers; the shallow layer contributes more to the lumbar extension, whereas the deeper layer contributes to lumbar vertebra stability[7]). Therefore, muscle elastic modulus measurement in the superficial and deep layers has high clinical significance.

This study aimed to investigate the reproducibility of elastic moduli measurements of the MF (superficial and deep) at different trunk angles using SWE for obtaining information that serves as evidence of musculo-physiological involvement in the effect of physiotherapy on low back pain.

## PARTICIPANTS AND METHODS

This study included 11 healthy adults [eight males and three females; average age (standard deviation), 23.0 (5.9) years; average height (standard deviation), 168.2 (3.5) cm; average weight (standard deviation), 60.3 (6.7) kg] Exclusion criteria included a history of disorders in the locomotor or central nervous system and lower back pain at the time of measurement. This study was approved by the ethics board of Hokkaido Chitose College of Rehabilitation (approval number: 18001), and consent was obtained from all participants.

Measurements were conducted with participants in the prone position under the following three conditions (Fig. 1): prone with the trunk at a neutral flexion/extension position (prone position), prone with the trunk flexed at 40° (flexed prone position), and prone with the trunk extended at 20° (extended prone position). For the flexed and extended prone positions, we used an adjustable treatment table with a recliner mechanism. Each participant's neck was rotated to the right or left for achieving a comfortable position.

The elastic modulus was measured using the SWE function, which is integrated into an ultrasound diagnostic device (Aixplorer, SuperSonic Imagine, Aix-en-Provence, France), and a linear probe (SL10–2, 2.0–10.0 MHz; SWE penetration depth range: 2.5–45 mm; SWE resolution, 2.0 mm) was used. Measurements were obtained at the right MF superficial and deep layers 2 cm outside the fifth lumbar (L5) spinous process[8]). For identifying MF, the iliac crest was first palpated, and the 4th and 5th lumbar spinous processes were confirmed by palpation based on the Jacoby line, which connects the left and right iliac crests. The fifth spinous process was confirmed in the transverse ultrasound B-mode image, and the probe was then positioned on its abscissa. After placing the center of the probe in the MF confirmed in the transverse image, the probe was rotated in the longitudinal direction. As muscle fibers of the MF travel obliquely from 0° to 25°[6]), it is diagonally positioned such that the lower part of the probe is slightly outward. Then, we confirmed the clearly reflected position in the ultrasonic B-mode image of the muscle bundle of the MF and performed SWE measurement. MF layers were distinguished by confirming the difference in the muscle fiber running between the superficial and deep layers using ultrasonic B-mode image. Images of ultrasonic B-mode and a region of interest (RoI) obtained at the time of SWE measurement were color mapped (Fig. 2). While echogenic jelly was sufficiently applied to the body surface to avoid muscle deformation due to
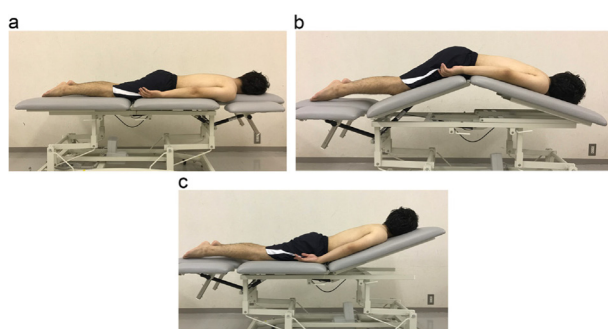


**Fig. 1.** Measurements are conducted with the participants positioned in a prone position with the trunk positioned at a neutral flexion/extension (a), a flexed prone position with the trunk flexed at 40° (b), and an extended prone position with the trunk extended at 20° (c). An adjustable treatment table is used with a recliner mechanism.
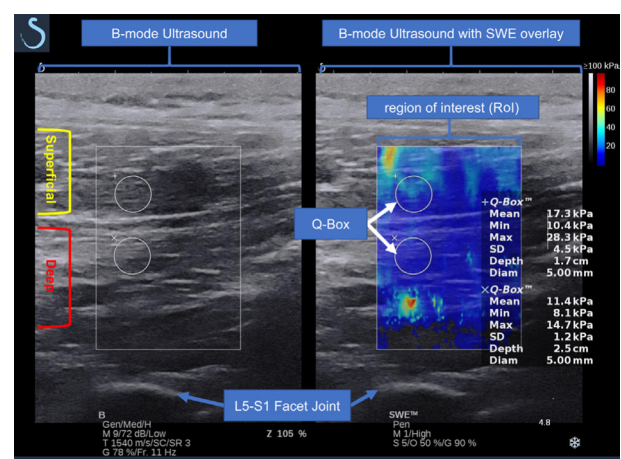


**Fig. 2.** MF at L5 was measured with Aixplorer. B-mode ultrasound image is shown on the left side, and SWE overlay is shown on the right side (inner circle is Q-Box, where superficial and deep layers of MF is shown). The value represents Young's modulus.

SWE: shear wave elastography; MF: multifidus muscle; L5: fifth lumbar spinous process.

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skin pressurization, careful manipulation was conducted by adjusting probe inclination such that the bundle of the MF was reflected to the utmost maximum. To perform quantitative analysis in RoI after measurement, analysis software (Q-Box) installed in the ultrasound system was used. The Q-Box was set to a size surrounding the site at which muscle fibers of the MF in the RoI were clear. Then, the elastic modulus was measured, and average value was obtained. The value obtained with Q-Box is Young's modulus, and that obtained in the same way as in the previous study was divided by 3 to obtain the shear modulus[9] (Fig. 2). Two measurements were randomly performed under each condition.

The intrarater reliability of elastic modulus measurement in the superficial and deep layers of the MF under the three conditions was analyzed using intraclass correlation coefficients (ICCs) (1, 1), and standard errors of measurement (SEMs) were calculated. Analysis was performed using R [version 2.8.1 (2008-12-22)® 2008 The R Foundation for Statistical Computing].

# RESULTS

ICC (1, 1) and SEM data for the elastic modulus of the superficial layer of the MF are presented in Table 1. ICCs (1, 1) were 0.88, 0.95, and 0.85 for the prone, flexed prone, and extended prone positions, and SEMs for these positions were 0.84, 1.24, and 0.60, respectively.

ICC (1, 1) and SEM data for the elastic modulus of the deep layer of the MF are presented in Table 2. The ICCs (1, 1) displayed high values of 0.88, 0.85, and 0.86 for the prone, flexed prone, and extended prone positions, and SEMs in these positions were 0.68, 1.17, and 1.16, respectively. Thus, the values were higher for the flexed and extended prone positions.

# DISCUSSION

Elastic modulus measurement of the superficial and deep layers of the MF under different trunk angles using SWE revealed high ICCs (1, 1) of at least 0.85 in both layers. Generally, an ICC (1, 1) of ≥0.81 is judged as almost perfect[10]. Thus, elastic modulus measurement of the MF via SWE may show good reproducibility regardless of the trunk angle.

SEM of the superficial layer of the MF was larger in the flexed prone position than in the prone position, whereas that of the deep layer was larger in the flexed and extended prone positions than in the prone position. SEM indicates the degree of average error in a participant; therefore, SEM could have been affected by individual differences in the flexibility of the lumbar area and other characteristics of participants as the trunk angle was changed.

Thus, elastic modulus measurement of inner muscles via SWE serves as an assessment of biological changes in individuals with lower back pain in response to interventions.

Our study limitations include the possibility that flexibility of the lumbar area of an individual affected the muscle elastic modulus, indicating that in standing or sitting positions, lumbar deep muscle activity occurs for maintaining posture, which may affect the elastic moduli of these muscles. Thus, flexibility of the lumbar area, muscle activity, and a consistent posture should be considered during measurements. Furthermore, our participants were healthy adults, and their muscle elastic moduli differ from those of older individuals or individuals with lower back pain. These factors should be considered as issues for further research.

**Table 1.** ICCs (1, 1) and SEMs of elastic moduli of the superficial layer of the multifidus (shear modulus) (n=11)

| Position | ICC (1, 1) (95% CI) | SEM |
|---|---|---|
| Prone | 0.88 (0.64–0.96) | 0.84 |
| Flexed prone | 0.95 (0.86–0.98) | 1.24 |
| Extended prone | 0.85 (0.57–0.95) | 0.60 |

ICC: intraclass correlation coefficients; SEM: standard error of measurement; CI: Confidence interval.

**Table 2.** ICCs (1, 1) and SEMs of elastic moduli of the deep layer of the multifidus (shear modulus) (n=11)

| Position | ICC (1, 1) (95% CI) | SEM |
|---|---|---|
| Prone | 0.88 (0.65–0.96) | 0.68 |
| Flexed prone | 0.85 (0.57–0.95) | 1.17 |
| Extended prone | 0.86 (0.59–0.96) | 1.16 |

ICC: intraclass correlation coefficients; SEM: standard error of measurement; CI: Confidence interval.

# REFERENCES

1) Fujii T, Matsudaira K: Prevalence of low back pain and factors associated with chronic disabling back pain in Japan. Eur Spine J, 2013, 22: 432–438. [Medline] [CrossRef]

2) van Tulder MW, Assendelft WJ, Koes BW, et al.: Spinal radiographic findings and nonspecific low back pain. A systematic review of observational studies. Spine, 1997, 22: 427–434. [Medline] [CrossRef]

3) Freeman MD, Woodham MA, Woodham AW: The role of the lumbar multifidus in chronic low back pain: a review. PM R, 2010, 2: 142–146, quiz 1, 167. [Medline] [CrossRef]

4) Hayden JA, van Tulder MW, Malmivaara AV, et al.: Meta-analysis: exercise therapy for nonspecific low back pain. Ann Intern Med, 2005, 142: 765–775. [Medline] [CrossRef]

5) Brandenburg JE, Eby SF, Song P, et al.: Ultrasound elastography: the new frontier in direct measurement of muscle stiffness. Arch Phys Med Rehabil, 2014, 95: 2207–2219. [Medline] [CrossRef]

6) Creze M, Nyangoh Timoh K, Gagey O, et al.: Feasibility assessment of shear wave elastography to lumbar back muscles: a radioanatomic study. Clin Anat, 2017, 30: 774–780. [Medline] [CrossRef]

7) Moseley GL, Hodges PW, Gandevia SC: Deep and superficial fibers of the lumbar multifidus muscle are differentially active during voluntary arm movements. Spine, 2002, 27: E29–E36. [Medline] [CrossRef]

8) Arokoski JP, Kankaanpää M, Valta T, et al.: Back and hip extensor muscle function during therapeutic exercises. Arch Phys Med Rehabil, 1999, 80: 842–850. [Medline] [CrossRef]

9) Royer D, Gennisson JL, Deffieux T, et al.: On the elasticity of transverse isotropic soft tissues (L). J Acoust Soc Am, 2011, 129: 2757–2760. [Medline] [CrossRef]

10) Landis JR, Koch GG: The measurement of observer agreement for categorical data. Biometrics, 1977, 33: 159–174. [Medline] [CrossRef]

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