Association of pain history and current pain with sagittal spinal alignment and muscle stiffness and muscle mass of the back muscles in middle-aged and elderly women

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Conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval

All study participants provided informed consent to participate, and the study design was approved by the Ethics Committee of the Kyoto University Graduate School and Faculty of Medicine.

Device Status/Drug Statement

The Manuscript submitted does not contain information about medical device(s)/drug(s).

Study Design: A cross-sectional study.

Objective: To investigate the association of low back pain history (LBPH) and LBP with sagittal spinal alignment, stiffness assessed using ultrasonic shear wave elastography (SWE), and mass of the back muscle in community-dwelling middle-aged and elderly women.

Summary of Background Data: The association of LBPH and LBP with sagittal spinal alignment, stiffness, and mass of the back muscles remains unclear in middle-aged and elderly women.

Methods: The study comprised 19 asymptomatic middle-aged and elderly women [control (CTR) group], 16 middle-aged and elderly women with LBPH (LBPH group), and 23 middle-aged and elderly women with LBP (LBP group). Sagittal spinal alignment in the standing and prone positions (kyphosis angle in the thoracic spine, lordosis angle in the lumbar spine, and anterior inclination angle in the sacrum) was measured using a Spinal Mouse. The stiffness of the back muscles (lumbar erector spinae and multifidus) in the prone position was measured using ultrasonic SWE. The mass of the back muscles (thoracic and lumbar erector spinae, lumbar multifidus, and quadratus lumborum) was also measured.

Results: Multiple logistic regression analysis with a forward selection method showed that the stiffness of the lumbar multifidus muscle was a significant and independent factor of LBPH. The stiffness of the lumbar multifidus muscle was significantly higher in the LBPH group than in the CTR group. Multiple logistic regression analysis also indicated that lumbar lordosis angle in the standing position was a significant and independent factor of LBP. The lumbar lordosis angle was significantly smaller in the LBP group than in the CTR group.

Conclusions: Our results suggest that LBPH is associated with increased stiffness of the lumbar multifidus muscle in the prone position, and that LBP is associated with the decreased lumbar lordosis in the standing position in community-dwelling middle-aged and elderly women.

Keywords: Low back pain; Posture; Paraspinal muscles; Muscle stiffness; Muscle thickness;

Introduction

Approximately 80% of adults experience low back pain (LBP) within their lifetime,[1] and LBP frequently develops in middle-aged and elderly people. Intervertebral discs, intervertebral joints, ligaments, nerves, vertebral body, and lumbar back muscles can all be implicated in LBP. Clarification of the specific cause of LBP is critical for rehabilitation.

Age-related shifts in posture include increased thoracic kyphosis[2] and decreased lumbar lordosis and sacral anterior inclination[3] in the standing position. The incidence rate of hyperkyphosis is 20–40% among elderly people.[4] In terms of the association of low back pain with the alignment of the spine in the standing position, one systematic review[5] demonstrated no difference in the occurrence of lumbar lordosis between healthy subjects and LBP patients. However, the age and sex of the subjects are unspecified in many previous studies. The aforementioned decreased lumbar lordosis with aging puts stress on the intervertebral discs of the lumbar spine, which may contribute to LBP occurrence. In light of the increased risk of osteoporotic fracture in middle-aged and elderly women compared to that in middle-aged and elderly men[6], lumbar lordosis decreases with vertebral body deformity[4] and decreased lumbar lordosis puts stress on the anterior part of the intervertebral discs, which may contribute to LBP occurrence in that population. Therefore, an investigation of the association of LBP with alignment of the spine in the standing position that focuses on middle-aged and elderly women is necessary.

Thus far, quantitative assessment of the stiffness of individual muscles isolating subcutaneous fat and fibrous tissue has proved difficult. However, the assessment of muscle stiffness has recently become possible by the use of ultrasonic shear wave elastography (SWE).[7-9] Ultrasonic SWE is a safe, non-invasive ultrasound imaging technique. The shear elastic modulus is an index of muscle stiffness that is evaluated by measuring the shear wave propagation speed in the tissues generated by ultrasonic SWE. Our previous study[10] using ultrasonic SWE demonstrated that the stiffness of the lumbar multifidus muscle in the prone position is high among young and middle-aged medical workers with LBP. Spasm of the lumbar multifidus muscle due to LBP may contribute to further increased muscle stiffness and secondary LBP occurrence. However, the association of LBP with the stiffness of the back muscles has not been clarified in middle-aged and elderly women who are not medical workers. Furthermore, there is an approximately 60% recurrence rate in individuals who once experienced LBP.[11] Thus, the elucidation of particular physical and motion characteristics is needed not only in LBP patients, but also in individuals with history of LBP (LBPH) who had LBP in the past and have no LBP at the present time. Physical and motion characteristics after recovery from LBP, which is the condition that the subject feel no pain during their activities, may contribute to LBP recurrence in individuals with LBPH. Increased stiffness of the back muscles such as the lumbar erector spinae and multifidus muscles is an important factor, which may be associated with LBP recurrence. However, no previous studies have reported on the stiffness of the back muscles in individuals with LBPH.

In terms of the association of LBP with the mass of the back muscles, studies using computed tomography and magnetic resonance imaging images demonstrated decreased mass of the multifidus muscle in LBP patients.[12-17] The lumbar multifidus muscle, which is a deep muscle of the trunk, contributes to stability in the lumbar spine by increasing the compressive force[18,19]. Accordingly, it is assumed that decreased muscle mass of the lumbar multifidus muscle results in instability in the lumbar spine, which in turn puts stress on the intervertebral discs or intervertebral joints, which may contribute to either LBP occurrence or recurrence. Furthermore, the mass of the lumbar erector spinae and quadratus lumborum muscles also decreases in LBP patients[20,21]. However, it is unclear whether the sagittal spinal alignment, stiffness, or mass of the back muscles is associated with LBP and LBPH in middle-aged and elderly women.

Therefore, we aimed to examine the association of LBPH and LBP with those factors in community-dwelling middle-aged and elderly women.

Participants and methods

Participants

Fifty-eight community-dwelling middle-aged and elderly women in Kyoto were included in the present study. The subjects were classified into control (CTR) (n=19; mean age 72.4±5.4), LBPH (n=16; mean age 70.3±6.5), and LBP groups (n=23; mean age 74.3±6.4) according to the presence of LBPH and LBP. The subjects in the CTR group had no history of LBP lasting 3 or more months and no LBP at the time of evaluation. The LBPH group consisted of subjects with bilateral/central or unilateral LBP lasting for 3 months or more in the past and no LBP at the time of evaluation. The LBP group consisted of subjects with bilateral/central or unilateral LBP lasting for 3 months or more at the time of evaluation. The classification of LBPH[22,23] and LBP[24,25] was performed based on previous studies. Participants were excluded if they had any severe orthopedic disorder other than LBP; neurological, circulatory, or respiratory disorders in the present or past; or previous spinal surgery.

The protocol of the present study was accepted by the Ethics Committee of the Kyoto University Graduate School and Faculty of Medicine. All participants in the present study provided informed consent.

Low back pain assessment

The distribution, duration, and degree of LBP, as well as impaired activities of daily living due to LBP, were assessed in the LBP group using a questionnaire based on a previous study.[10] LBP status in the past was assessed in the LBPH group, and LBP status at the time of evaluation was assessed in the LBP group. The degree of LBP was examined using the Numerical Rating Scale (NRS) in both static (i.e., lying, sitting, or standing) and dynamic situations (i.e., moving or walking). Furthermore, the disabilities of daily living due to LBP were assessed using the Oswestry Disability Index (ODI) (excluding the sex life item). The summed score was expressed as a percentage of the total possible score, and a high percentage was indicative of severe disabilities of daily living due to LBP.

Spinal alignment measurement

The Spinal Mouse (Index Ltd., Tokyo, Japan) was used to measure sagittal spinal alignment in the standing position according to a previous study.[10] The kyphosis angle in the thoracic spine, lordosis angle in the lumbar spine, and anterior inclination angle in the sacrum were evaluated. Furthermore, alignment of the spine in the prone position was also measured to identify whether the stiffness and mass of the back muscles were influenced by the alignment of the spine in the position used for ultrasound measurement. Spinal alignment in each position was measured 3 times, and the mean value of the 3 measurements was utilized for statistical analyses.

Ultrasound measurement

Images of the back muscles were taken using an ultrasound device with SWE (Aixplorer, Supersonic Imagine, Aix-en-Provence, France) based on a previous study.[10]

To assess the mass of the back muscles, longitudinal ultrasound images of the thoracic (longissimus thoracis) and lumbar (iliocostalis lumborum) erector spinae, lumbar multifidus, and quadratus lumborum muscles were taken bilaterally in the prone position using the B-mode of the ultrasound imaging device with a linear array probe (SuperLinear 10-2), which was positioned parallel to the muscle fibers (Fig. 1). We obtained ultrasound images for muscle thickness once bilaterally at the following measurement sites. The site of the thoracic erector spinae muscle was 4 cm lateral to the T9 spinous process.[26] The site of the lumbar erector spinae and quadratus lumborum muscles was 7 cm lateral to the L3 spinous process.[10] The site of the lumbar multifidus muscle was 2 cm lateral to the L4 spinous process.[10] All measurements of the lumbar back muscles were performed with 58-dB gain and 69-Hz dynamic range. Dynamic focus was set to the position of the back muscles. Time gain compensation was also set to the neutral position in all subjects.

To assess the stiffness of the back muscles, the shear elastic modulus of the lumbar erector spinae and multifidus muscles was evaluated once bilaterally by measuring the shear wave propagation speed in the tissues generated using ultrasonic SWE in the prone position (Fig. 2). The shear elastic modulus of the thoracic erector spinae, which is affected by the reflection of the bone, was not measured. The shear elastic modulus of the quadratus lumborum muscle, which is located deep to the body surface, was also not measured. A linear array probe was set parallel to the muscle fibers to accurately measure the shear elastic modulus based on a previous study.[10] The circular regions of interest (ROIs) were set voluntarily in the color-coded box presentation on B-mode ultrasound imaging with a scale from blue (soft) to red (hard) based on the magnitude of the shear wave speed. Three ROIs with a diameter of 10 mm were set in the color-coded box, with 1 located at the center of the box and the other 2 beside the initial ROI. The mean shear elastic modulus values in each ROI and the mean of the 3 ROIs were computed. We computed the shear elastic modulus from the muscle mass density and the shear wave propagation speed.[27] Enhanced elastic shear modulus indicates a high muscle stiffness. Intraclass correlation coefficient (ICC 1.1) for the lumbar erector spinae muscle and lumbar multifidus muscle in one measurement of muscle stiffness using ultrasonic SWE were 0.784 and 0.913, respectively.[10] One tester performed all the mass and stiffness assessment of the back muscles.

The mean values of muscle thickness and the shear elastic modulus in one measurement each for the right and left muscles were utilized for statistical analyses. The determination of the ROIs, and the computation of muscle thickness and the shear elastic modulus were performed by one examiner who was blinded to the group assignments.

Statistical analyses

We performed statistical analyses using SPSS version 21.0 (IBM Japan; Tokyo, Japan). The factors associated with LBPH and LBP were investigated by multiple logistic regression analysis with a forward selection method. These analyses were conducted using sagittal spinal alignment, the shear elastic modulus and thickness of the back muscles, age, body height, and body weight as independent variables.

Results

The characteristics, the LBPH/LBP status, spinal alignment, and stiffness and mass of the lumbar back muscles in the CTR, LBPH, and LBP groups are shown in Tables 1 and 2.

Table 3 presents the factor associated with LBPH. Multiple logistic regression analysis showed that the shear elastic modulus of the lumbar multifidus muscle (odds ratio, 1.75) was a significant and independent factor of LBPH, but that the other factors were not. The shear elastic modulus of the lumbar multifidus muscle was significantly higher in the LBPH group than in the CTR group.

Table 3 also presents the factor associated with LBP. Multiple logistic regression analysis also showed that the lumbar lordosis angle in the standing position (odds ratio, 0.94) was a significant and independent factor of LBP, but that the other factors were not. Lumbar lordosis angle was significantly smaller in the LBP group than in the CTR group.

Discussion

This study investigated the association of LBPH and LBP with sagittal spinal alignment in the standing position and stiffness and mass of the back muscles in the prone position. The present study is the first to quantitatively assess the stiffness of the individual muscles and to examine the association of LBP and LBPH with stiffness of the back muscles using ultrasonic SWE in community-dwelling middle-aged and elderly women.

In terms of LBPH, multiple logistic regression analysis showed that the stiffness of the lumbar multifidus muscle was significantly higher in the LBPH group than in the CTR group in the prone position. MacDonald et al. revealed that the activity of the lumbar multifidus muscle delays[22] or decreases[23] during upper extremity motion in individuals with LBPH. However, the activity of the lumbar multifidus muscle in the prone position was not clarified in their studies. The current results of the LBPH group are consistent with those of our previous study[10] that demonstrated increased stiffness of the lumbar multifidus muscle in the prone position in young and middle-aged medical workers, though our previous study examined the stiffness in the subjects who had LBP at the time of evaluation. It is possible that the muscle spasm of the lumbar multifidus muscle that occurred at the time of the LBP in the past was persisting in the LBPH group. It is assumed that erroneous movement learning occurred in individuals with LBPH and that the stiffness of the lumbar multifidus muscle remained even after recovery from LBP. The overuse caused by spasm of the lumbar multifidus muscle can lead to circulatory difficulty within the muscle, which may contribute to LBP recurrence in the future.

Any of the spinal alignment angles in the standing position or the mass of the back muscles were not significant and independent factors of LBPH. The cause of LBP occurrence is varied among the subjects. Thus, it is possible that the spinal alignment in the standing position and the mass of the back muscles measured in the present study are not the cause of the LBP that occurred in the past. Furthermore, the angles of spinal alignment in the prone position were not significant and independent determinants of LBPH. Muscle stiffness and muscle mass of the back muscles were assumed not to be influenced by the alignment of the spine in the prone position, which was the position of the ultrasound measurement.

In terms of LBP, multiple logistic regression analysis showed that the lumbar lordosis angle in the standing position was significantly smaller in the LBP group than in the CTR group. These results are consistent with those of the previous study, which demonstrated that LBP is associated with lumbar lordosis angle in the standing position.[28] Intervertebral discs of the lumbar spine degenerate with aging,[29] and a previous study indicated that lumbar disc degeneration occurs in the majority of elderly women.[30] Takeda[3] et al. demonstrated that decreased lumbar lordosis with aging is associated with anterior degeneration of the lumbar intervertebral discs. Since the subjects in the present study were middle-aged and elderly women, it is possible that the lumbar lordosis angle in the standing position was decreased due to osteoporotic deformity of the vertebral body. Such decreased lumbar lordosis causes lumbar disc anterior degeneration and may contribute to LBP occurrence.

Though the stiffness of the lumbar multifidus muscle was significantly higher in the LBPH group than in the CTR group, the stiffness of the lumbar multifidus muscle was not significant and independent determinant of LBP. Our previous study revealed that the stiffness of the lumbar multifidus muscle in the LBP group was significantly higher in the prone position.[10] The fact that no significant association in the stiffness of the lumbar multifidus muscle was observed in the LBP group in this study might be attributable to the differences in LBP status. LBP status was moderate to severe in the LBPH group in the present study (NRS [static situation] 5.1±2.5, NRS [dynamic situation] 6.1 ± 2.4, ODI 30.0 ± 24.7%) and in the LBP group in our previous study (NRS [static situation] 5.0 ± 1.4, NRS [dynamic situation] 5.0 ± 1.7, ODI 19.6 ± 7.8%),[10] whereas LBP status was relatively mild in the LBP group in the present study (NRS [static situation] 2.5 ± 1.9, NRS [dynamic situation] 3.2 ± 2.4, ODI 13.2 ± 8.5%). The absence of a significant association in the stiffness of the lumbar multifidus muscle in the LBP group of this study may be due to the reduced severity of LBP.

The mass of the back muscles was not significant and independent factor of LBP. In previous studies, the mass of the back muscles either decreases[31-33] or does not decrease[34] in LBP patients. The results of this study were consistent with those of the previous study,[34] which found that LBP is not associated with the mass of the back muscles.

There are several limitations in this study. First, only some of the back muscles were targeted in the measurements of muscle stiffness and muscle mass. Furthermore, because this study included only middle-aged and elderly women, it is unclear whether the results in middle-aged and elderly men would be similar. Second, whether increased stiffness of the lumbar multifidus muscle in the LBPH group was caused by the continuation of muscle spasm that occurred at the time of previous LBP or by other causes is unclear, since the activities of the lumbar back muscles were not measured using electromyography during ultrasound measurement. Third, because a diagnosis of the cause of pain in the subjects with LBPH and LBP was not made in the present study, subjects with nonspecific LBPH and nonspecific LBP as well as subjects with specific LBPH and specific LBP (i.e., disease of the lumbar spine, which frequently occurs in middle-aged and elderly women) might have been included. However, we could not identify the specific cause of LBPH and LBP, such as lumbar spondylosis, spondylolisthesis, or scoliosis. Fourth, though we used the Spinal Mouse to measure the kyphosis angle in the thoracic spine, lordosis angle in the lumbar spine, and anterior inclination angle in the sacrum in the standing position, we were unable to measure the pelvic incidence.

This study suggests that LBPH is associated with increased stiffness of the lumbar multifidus muscle rather than sagittal spinal alignment, the stiffness of the lumbar erector spinae muscle, or the mass of the back muscles in community-dwelling middle-aged and elderly women. Because muscle stiffness of the lumbar multifidus muscle may contribute to LBP recurrence, future investigation is necessary to clarify the cause of LBP recurrence and the optimal training for ameliorating the stiffness of the lumbar multifidus muscle to prevent LBP recurrence. Furthermore, the present study also suggests that LBP is associated with decreased lumbar lordosis in the standing position rather than the stiffness and mass of the back muscles in community-dwelling middle-aged and elderly women. The development of strategies for middle-aged and elderly women to prevent decreased lumbar lordosis seems critical to preventing LBP occurrence.

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Table 1. Characteristics and LBPH/ LBP status in the CTR, LBPH, and LBP groups.

	CTR group (n=19)		LBPH group (n=16)		LBP group (n=23)	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Characteristics						
Age (years)	72.4±5.4	64.0–82.0	70.3±6.5	57.0–82.0	74.3±6.4	62.0–88.0
Height (cm)	152.0±5.9	140.5–159.6	152.4±4.8	145.7–161.8	150.1±5.4	139.4–159.2
Weight (kg)	47.8±7.2	37.0–60.0	49.7±5.7	40.2–57.7	51.1±7.1	39.7–63.4
LBPH/ LBP status						
Distribution (bilateral or central /unilateral)	—	—	6/10	—	9/14	—
Duration (months)	—	—	58.7±113.0	3.0–360.0	67.3±86.3	3.0–360.0
NRS (static)	—	—	5.1±2.5	0–8.0	2.5±1.9	0–6.0
NRS (dynamic)	—	—	6.1±2.4	1.0–10.0	3.2±2.4	0–8.0
ODI (%)	—	—	30.0±24.7	2.2–97.8	13.2±8.5	2.2–28.9

CTR: control; LBPH: low back pain history; LBP: low back pain; NRS: Numerical Rating Scale; ODI: Oswestry Disability Index; SD: standard deviation.

Table 2. Spinal alignment and stiffness and mass of the back muscles in the CTR, LBPH, and LBP groups.

	CTR group (n=19)		LBPH group (n=16)		LBP group (n=23)	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Spinal alignment (standing) (°)						
Thoracic kyphosis	39.6±10.3	22.0–57.0	37.3±13.1	17.0–63.0	38.8±10.4	21.0–59.0
Lumbar lordosis	22.7±9.2	3.0–38.0	18.9±7.5	8.0–30.0	12.8±14.7	−15.0–34.0
Sacral anterior inclination	8.4±5.1	1.0–20.0	7.4±6.0	−3.0 to 19.0	2.4±11.1	−19.0–25.0
Spinal alignment (prone) (°)						
Thoracic kyphosis	34.7±11.3	10.0–57.0	27.9±12.2	7.0–47.0	31.6±7.0	21.0–45.0
Lumbar lordosis	18.6±6.8	6.0–30.0	15.8±10.4	−4.0 to 34.0	13.9±7.9	−3.0–29.0
Sacral anterior inclination	100.4±5.5	86.0–109.0	99.1±6.1	91.0–110.0	98.4±5.6	90.0–107.0
Shear elastic modulus (prone) (kPa)						
Lumbar erector spinae	3.1±0.8	2.0–4.7	3.2±0.8	2.1–5.0	3.8±1.1	1.6–6.3

Lumbar multifidus	4.6±1.1	2.5–6.5	5.6±1.7	3.3–9.8	5.1±1.3	2.7–9.2
Muscle thickness (cm)						
Thoracic erector spinae	0.75±0.25	0.37–1.24	0.66±0.19	0.31–1.12	0.70±0.19	0.41–1.05
Lumbar erector spinae	1.41±0.24	1.03–1.99	1.51±0.29	1.09–2.37	1.46±0.43	0.79–2.64
Lumbar multifidus	2.29±0.38	1.46–2.97	2.39±0.51	1.76–3.33	2.56±0.65	1.65–4.16
Quadratus lumborum	0.80±0.25	0.52–1.52	0.77±0.20	0.48–1.15	0.84±0.16	0.62–1.26

CTR: control; LBPH: low back pain history; LBP: low back pain; SD: standard deviation.

Table 3. Results of multiple logistic regression analysis.

Dependent variables	Independent variables	Non-standard partial regression coefficient	P value	Odds ratio	95% Confidence interval	
					Lower	Upper
Low back pain history (Yes=1, No=0)	Shear elastic modulus of the lumbar multifidus (kPa)	0.56	0.06	1.75	0.97	3.17
χ^2 value $P = 0.04$						
Low back pain (Yes=1, No=0)	Lumbar lordosis angle (°)	−0.07	0.02	0.94	0.88	0.99
χ^2 value $P = 0.01$						

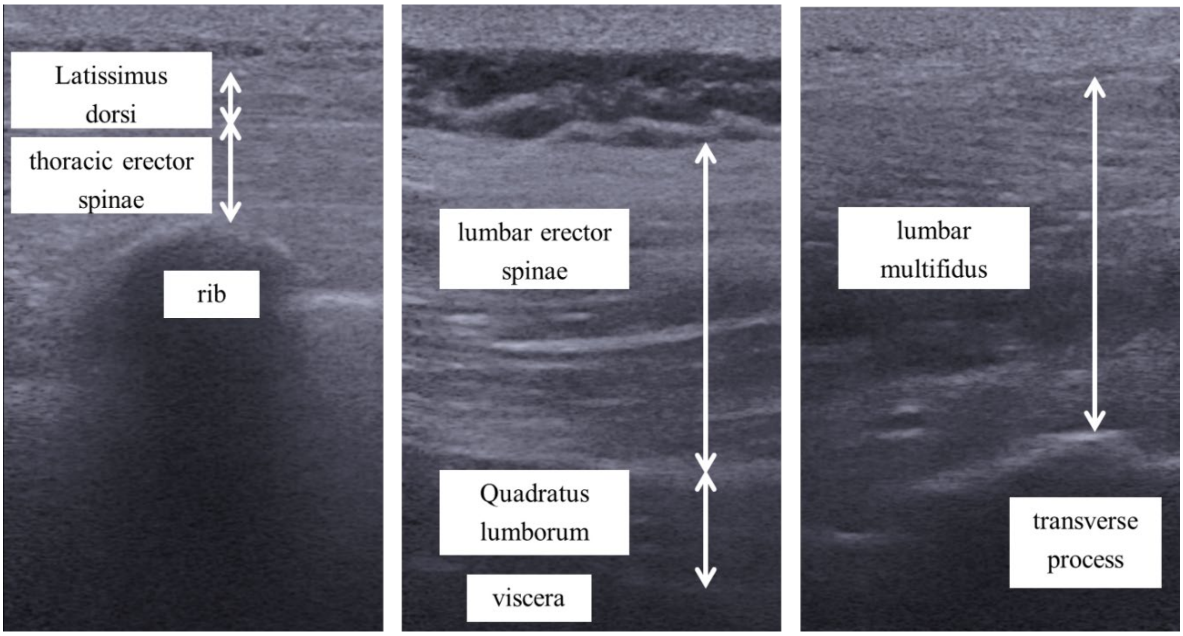

Fig. 1. Thickness measurement of the back muscles in community-dwelling middle-aged and elderly women.

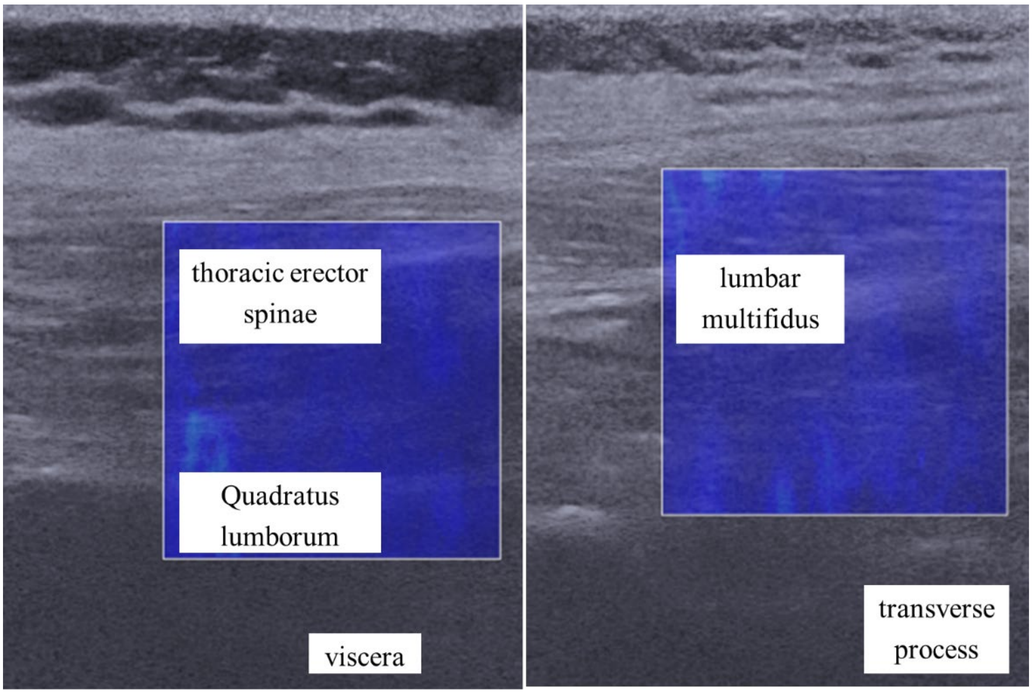

Fig. 2. Stiffness measurement of the back muscles in community-dwelling middle-aged and elderly women.