Association of low back pain with muscle stiffness and muscle mass of the lumbar back muscles, and sagittal spinal alignment in young and middle-aged medical workers

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ABSTRACT

Background: Muscle stiffness of the lumbar back muscles in low back pain (LBP) patients has not been clearly elucidated because quantitative assessment of the stiffness of individual muscles was conventionally difficult. This study aimed to examine the association of LBP with muscle stiffness assessed using ultrasonic shear wave elastography (SWE) and muscle mass of the lumbar back muscle, and spinal alignment in young and middle-aged medical workers.

Methods: The study comprised 23 asymptomatic medical workers [control (CTR) group] and 9 medical workers with LBP (LBP group). Muscle stiffness and mass of the lumbar back muscles (lumbar erector spinae, multifidus, and quadratus lumborum) in the prone position were measured using ultrasonic SWE. Sagittal spinal alignment in the standing and prone positions was measured using a Spinal Mouse. The association with LBP was investigated by multiple logistic regression analysis with a forward selection method. The analysis was conducted using the shear elastic modulus and muscle thickness of the lumbar back muscles, and spinal alignment, age, body height, body weight, and sex as independent variables.

Findings: Multiple logistic regression analysis showed that muscle stiffness of the lumbar multifidus muscle and body height were significant and independent determinants of LBP, but that muscle mass and spinal alignment were not. Muscle stiffness of the lumbar multifidus muscle in the LBP group was significantly higher than that in the CTR group.

Interpretation: The results of this study suggest that LBP is associated with muscle stiffness of the lumbar multifidus muscle in young and middle-aged medical workers.

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

1. Introduction

The occurrence rate of low back pain (LBP) within the lifetime of adults is about 80% (Waddell, 1987). LBP is induced by stress on the structures around the lumbar spine, such as intervertebral disks, intervertebral joints, ligaments, nerves, and lumbar back muscles. Thus, clarification of the cause of LBP occurrence in rehabilitation is significant. A previous study demonstrated that hard physical work, frequent trunk rotation or flexion motion, and standing up motion are associated with LBP occurrence (Xu et al., 1997). Medical workers, such as nurses, care workers, and therapists, who work at hospitals frequently perform these motions daily. LBP occurs at a high occurrence rate in medical workers. In Japan, the occurrence rate of LBP within the past month is about 50% in nurses who work at hospitals (Ando et al., 2000).

An electromyographic study demonstrated that the activities of the lumbar erector spinae muscle, gluteus maximus muscle, and hamstrings increase during trunk rotation motion in LBP patients (Pirouzi et al., 2006). Moreover, the activities of the erector spinae and rectus abdominal muscles increase during walking in LBP patients (van der Hulst et al., 2010). However, the relation of these electromyographic data with muscle stiffness is unknown. Overuse of the lumbar erector spinae muscle caused by increased activity may lead to circulatory deficiency within the muscle, resulting in increased muscle stiffness and LBP occurrence. On the other hand, LBP may contribute to increased muscle stiffness (i.e., muscle spasm) of the lumbar back muscles, such as the lumbar erector spinae and lumbar multifidus muscles in LBP patients.

Muscle stiffness of the lumbar back muscles in LBP patients is not clearly elucidated because the stiffness of the individual muscle distinguishing subcutaneous fat and fibrous tissue has been difficult to assess quantitatively. However, the assessment has recently become possible by shear elastic modulus measured using ultrasonic shear wave elastography (SWE). Ultrasonic SWE is a non-invasive and safe ultrasound imaging device. The shear elastic modulus, as an index of muscle stiffness, is evaluated by measuring the shear wave propagation speed in the tissues that is generated by an ultrasonic SWE. Previous studies demonstrated that shear elastic modulus measured by SWE is associated with muscle elongation (Maïsetti et al., 2012; Koo et al., 2013) or muscle strength (Ateş et al., 2015).

Previous studies evaluated muscle stiffness of the upper extremity muscles (Leong et al., 2013; Rosskopf et al., 2016), such as the trapezius and supraspinatus muscles; the lower extremity muscles, such as the rectus femoris, gastrocnemius, and soleus muscles (Akagi et al., 2015); the iliotibial band (Tateuchi et al., 2015, 2016); and the abdominal muscles (Hirayama et al., 2015; MacDonald et al., 2016), such as the rectus abdominis, external oblique, and internal oblique muscles. However, no study has evaluated muscle stiffness individually and quantitatively in LBP patients. Furthermore, previous studies demonstrated the association of LBP with decreased muscle mass of the lumbar back muscles, and with changes in sagittal spinal alignment. Decreased muscle mass of the lumbar multifidus muscle (Hides et al., 1996, 2008; Cooper et al., 1992; Barker et al., 2004; Keller et al., 2004; Hodges et al., 2006) or changes in spinal alignment, such as decreased lumbar lordosis in the standing position (Tsuji et al., 2001), cause stress on intervertebral disks or intervertebral joints, which may contribute to LBP occurrence. A decreased muscle mass in the lumbar erector spinae and quadratus lumborum muscles is also associated with LBP occurrence (Kamaz et al., 2007; Lee et al., 2011). Both muscle stiffness of the lumbar back muscles, and muscle mass of the lumbar back muscles and sagittal spinal alignment, are important factors that could be associated with LBP occurrence.

Therefore, this study aimed to examine the association of LBP with muscle stiffness assessed using ultrasonic SWE and muscle mass of the lumbar back muscles, and sagittal spinal alignment in young and middle-aged medical workers.

2. Methods

2.1. Participants

Thirty-two young and middle-aged medical workers in Kyoto Hakuaikai Hospital, Japan were included in the study. The subjects were classified into control (CTR) (n=23; mean age 34.7±10.2) and LBP groups (n=9; mean age 44.7±13.0) according to the presence of LBP. The subjects in the CTR group had no LBP at the time of evaluation and no history of LBP lasting 3 or more months. The LBP group consisted of subjects with bilateral or central LBP (except for unilateral LBP) with a severity rating of ≥3 on the numerical rating scale (NRS) in both static (i.e., lying, sitting, or standing) and dynamic situations (i.e., moving or walking), lasting 3 months or more at the time of evaluation. Medical workers included nurses, care workers, and therapists. Participants were excluded if they had severe orthopedic disorder other than LBP; neurological, respiratory, or circulatory disorders in the present or past; or previous spinal surgery.

The protocol was approved by the Ethics Committee of the Kyoto University Graduate School and Faculty of Medicine. All participants provided written informed consent.

2.2. Low back pain assessment

The duration and degree of LBP, as well as the disabilities of daily living due to LBP, were assessed in the LBP group using a questionnaire. The degree of LBP was examined using the NRS in both static (i.e., lying, sitting, or standing) and dynamic situations (i.e., moving or walking). The disabilities of daily living due to LBP were assessed using the Oswestry disability index (ODI) (Fairbank and Pynsent, 2000). The ODI consists of items, such as pain intensity of LBP during personal care (i.e., washing or dressing etc.), lifting, walking, sitting, standing, sleeping, sex life, social life, and travelling. The item of sex life, which can be removed if not applicable, was not used in this study. The sum of each item was expressed as a percentage, and a large percentage indicated the severe disabilities of daily living due to LBP.

2.3. Ultrasound measurement

Images of the lumbar back muscles were taken using an ultrasound imaging device with SWE (Aixplorer, Supersonic Imagine, Aix-en-Provence, France). To assess the muscle mass of the lumbar back muscles, longitudinal ultrasound images of the lumbar erector spinae, multifidus, and quadratus lumborum muscles were taken bilaterally using the B-mode of the ultrasound imaging device with a linear array probe (SuperLinear 10-2), which was laid parallel to the muscle fibers in the prone position (Fig. 1). Ultrasound images were measured once bilaterally for muscle thickness. The measurement sites were defined as 7 cm lateral from the L3 spinous process for the lumbar erector spinae and quadratus lumborum muscles, and 2 cm lateral to the L4 spinous process for the lumbar multifidus muscle (Masaki M et al., 2015). All measurements of the lumbar back muscles were performed with 58-dB gain, 69-Hz dynamic range, and time gain compensation with the neutral position. Dynamic focus depth was also set to the depth of the lumbar back muscles. A previous study showed that the degree of intrarater reliability of the ultrasound technique is high for measuring muscle thickness of the lumbar back muscles (Masaki et al., 2015).

The shear elastic modulus of the lumbar erector spinae and multifidus muscles was evaluated twice bilaterally by measuring the shear wave propagation speed in the tissues generated by an ultrasonic SWE in the prone position to assess the muscle stiffness of the lumbar back muscles (Fig. 2). The shear elastic modulus of the quadratus lumborum muscle, which was located deep within the body surface, was not measured in the present study. A linear array probe was set parallel to the muscle fibers to measure the shear elastic modulus accurately (Eby et al., 2013). The circular regions of interest (ROIs) were set voluntarily in the color-coded box presentation on a B-mode ultrasound imaging with a scale from blue (soft) to red (hard) depending 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. The shear elastic modulus (G) was computed from the shear wave propagation speed (v) and the muscle mass density (ρ) using the following equation:

$$G=\rho v^2$$

where ρ is presumed to be 1000 kg/m^3 (Aubry et al., 2013). Enhanced elastic shear modulus indicates an increase in muscle stiffness.

The mean values of muscle thickness in 1 measurement and the shear elastic modulus in 2 measurements for the right and left muscles were used for statistical analyses. The determination of the ROIs and the computation of muscle thickness and shear elastic modulus were performed by 1 examiner who was blinded to information of the groups.

To examine the intrarater reliability of the ultrasound technique for measuring the shear elastic modulus of the lumbar back muscles, 2 images of each right muscle measured in the prone position were taken in 1 day in 52 young and middle-aged medical workers (age, 23.5±1.5 years; height, 161.8±7.9 cm; weight, 57.4±12.6 kg).

2.4. Measurement of spinal alignment

The Spinal Mouse (Index Ltd., Tokyo, Japan) was used to measure sagittal spinal alignment in the standing position (thoracic kyphosis, lumbar lordosis, and sacral anterior inclination angle) based on a previous study (Masaki et al., 2015). Spinal alignment in the prone position was also measured to identify whether muscle stiffness and muscle mass of the lumbar back muscles were influenced by spinal alignment in the position of ultrasound measurement. Spinal alignment was measured 3 times.

The Spinal Mouse was guided along the midline of the spine, starting at the C7 spinous process and ending at S3. The thoracic kyphosis angle was calculated from the sum of the 11 segmental angles from Th1/2 to Th11/12. The lumbar lordosis angle was calculated from the sum of the 6 segmental angles from Th12/L1 to L5/S1. The sacral anterior inclination angle was calculated from the difference between the sacral angle and the vertical plane. The mean value of spinal alignment in 3 measurements was used for statistical analyses.

2.5. Statistical analyses

Statistical analyses were performed using SPSS version 22.0 (IBM Japan; Tokyo, Japan). Intraclass correlation coefficients [ICCs (1.1), ICC (1.2)] were calculated to examine intrarater reliabilities of the shear elastic modulus measurements. Furthermore, the associations with LBP were investigated by multiple logistic regression analysis with a forward selection method. This analysis was conducted using the shear elastic modulus and muscle thickness of the lumbar back muscles, and sagittal spinal alignment, age, body height, body weight, and sex as independent variables. *P* values of <0.05 were considered significant.

3. Results

Table 1 presents characteristics and LBP status in the CTR and LBP groups. Muscle stiffness and muscle mass of the lumbar back muscle, and spinal alignment are shown in Table 2.

In the reliability analysis of the shear elastic modulus measurement, the ICC values of 1.1 for the erector spinae muscle and lumbar multifidus muscle were 0.784 and 0.913, and the ICC values of 1.2

were 0.879 and 0.954, respectively.

Multiple logistic regression analysis showed that the shear elastic modulus of the lumbar multifidus muscle (odds ratio, 4.13) and body height (odds ratio, 0.82) were significant and independent determinants of LBP. The shear elastic modulus of the lumbar multifidus muscle in the LBP group was significantly higher than that in the CTR group. The height in the LBP group was significantly lower than that in the CTR group (Table 3). Multiple logistic regression analysis also showed that the other factors were not significant independent determinants of LBP.

4. Discussion

Practicing rehabilitation based on the cause of LBP occurrence is important because the cause is attributed to different factors. To the best of our knowledge, this study is the first to examine the association of LBP with muscle stiffness of the lumbar back muscles assessed using ultrasonic SWE in young and middle-aged medical workers. LBP was found to be associated with muscle stiffness of the lumbar multifidus muscle rather than muscle stiffness of the lumbar erector spinae muscle, muscle mass of the lumbar back muscles, or sagittal spinal alignment in young and middle-aged medical workers. Furthermore, LBP was not associated with muscle stiffness of the lumbar erector spinae muscle, which was not consistent with our hypotheses.

Multiple logistic regression analysis showed that the muscle stiffness of the lumbar multifidus muscle in the LBP group was significantly higher than that in the CTR group in the prone position. The activity of the lumbar multifidus muscle in the prone position has not been clearly elucidated, but the activity of the lumbar multifidus muscle in LBP patients has been demonstrated to decrease compared with the healthy subjects during trunk motion (Ng et al., 2002). A possible reason for the association of LBP with muscle stiffness of the lumbar back muscles in the prone position is the frequent trunk flexion or pelvic anterior tilt of the medical workers in the standing position during medical treatment, care, and rehabilitation, as well as frequent extension of their trunk during transferring patients. The lumbar erector spinae muscle, which is a member of the superior muscles of the trunk, is advantageous to generate the extension moment because this muscle has a long extension moment arm for spine extension (Lin et al., 2001). On the other hand, the lumbar multifidus muscle, which is a deep muscle of the trunk, is advantageous to stabilize the lumbar spine (Bergmark, 1989; MacDonald et al., 2006). However, it is disadvantageous to generate the extension moment because it has a shorter extension moment arm of the spine than the lumbar erector spinae muscle (Bogduk et al., 1992). The frequent activity of lumbar multifidus muscle during motions may lead to muscle overuse in medical workers because the activity tends to be higher than that of the lumbar erector spinae during trunk extension motions (Ng and Richardson, 1994). Circulatory difficulty within the lumbar multifidus muscle caused by overuse during the motions may contribute to an increase in muscle stiffness and LBP occurrence.

Muscle stiffness measured using ultrasonic shear wave elastography is influenced by muscle elongation or muscle activity. Another possible reason for the relation of LBP with muscle stiffness in the LBP group could be muscle spasm due to pain. LBP, which is caused from stress on intervertebral disks or intervertebral joints, may induce muscle spasm of the lumbar multifidus muscle. Muscle stiffness of the lumbar multifidus muscle is assumed to increase by muscle contraction. In this case, the overuse caused by muscle spasm of the lumbar multifidus muscle may lead to circulatory difficulty within the muscle, which contributes to secondary LBP occurrence in the future. There is the possibility that the muscle activity and muscle stiffness of the lumbar multifidus muscle, not only in the prone position, but also during the motions in the standing, increases with muscle spasm in LBP patients. Thus, the level of muscle stiffness of the lumbar multifidus muscle measured in the prone position using ultrasonic SWE may reflect the condition of that muscle during the motions in LBP patients.

Previous study (Chan et al., 2012) demonstrated muscle stiffness of the lumbar back muscles using a strain imaging method of the ultrasound imaging device, which is different from ultrasonic SWE used in the present study. They targeted only the lumbar multifidus muscles in the LBP patients and suggested that no significant difference exists in the muscle stiffness of the lumbar multifidus muscle in the prone position between healthy subjects and LBP patients. However, measuring muscle stiffness quantitatively using the strain imaging method is difficult because the evaluation depends on the rater's control of the compression added to the probe, and the absolute value cannot be measured. The ultrasonic SWE used in the current study can measure muscle stiffness more quantitatively than a strain imaging method because the former is less dependent on the evaluation technique.

No significant difference in the muscle stiffness of the lumbar erecter spinae muscle was found between the CTR and LBP groups in the present study. Although the activity of the lumbar erector spinae muscle is reported to increase during trunk rotation motion (Pirouzi et al., 2006) or walking (van der Hulst et al., 2010), the activity of the lumbar erecter spinae muscle in the LBP group might not have increased during motions in the present study.

Significant difference was not observed in the muscle mass of the lumbar back muscles between the CTR and LBP groups in the present study. Previous studies using computed tomography and magnetic resonance imaging demonstrated that the muscle mass of the lumbar back muscles, such as the lumbar erector spinae, multifidus, and quadratus lumborum muscles, either decreases (Kamaz et al., 2007; Wallwork et al., 2009; Lee et al., 2011) or does not decrease (Danneels et al., 2000) in the LBP patients. The results of the present study were consistent with those of the previous study, which demonstrated that LBP is not associated with the muscle mass of the lumbar back muscles. No significant difference was found in each angle of spinal alignment in the prone position between the CTR and LBP groups. Thus, muscle stiffness and muscle mass were assumed to be not influenced by spinal alignment in the prone position, which is the position of ultrasound measurement.

No significant difference existed in each angle of spinal alignment in the standing position between the CTR and LBP groups. Previous studies demonstrated that lumbar lordosis in the standing position decreases (Tsuji et al., 2001) or does not decrease (Chaléat-Valayer et al., 2011; Laird et al., 2014) in the LBP patients. The results of the present study were consistent with those of the previous studies that demonstrate no association with spinal alignment in the standing position and LBP.

Furthermore, body height in the LBP group was significantly lower than that in the CTR group. Previous study (Heuch et al., 2015) longitudinally examined the association of LBP with body height. This previous study demonstrated that taller subjects have a higher risk of LBP recurrence because the stress on tissues around the lumbar spine increases during motions. This inconsistency may be attributed to the flexion of the lumbar spine, which compensatorily becomes excessive during medical treatment, care, rehabilitation, and transferring patients in medical workers, who have shorter body height (i.e., shorter upper extremities). Thus, shorter body height may contribute to increased muscle stiffness of the lumbar multifidus muscles, or the stress on intervertebral disks or intervertebral joints.

The present study has several limitations. First, the measurements of muscle stiffness and muscle mass targeted only a part of the lumbar back muscles. Second, whether an increase in muscle stiffness of the lumbar multifidus muscle is caused by overuse or muscle spasm is unclear because the activities of the lumbar back muscles were not measured using electromyography during ultrasound measurement. Third, not only nonspecific LBP patients but also specific LBP (i.e., the disease of the lumbar spine) patients might have been included because the LBP of the subjects was not diagnosed in the present study. Therefore, examination of the association of LBP with muscle stiffness and muscle mass of the lumbar back muscles, and spinal alignment after classifying LBP patients in detail based on the disease of the lumbar spine is necessary.

The present study suggests that LBP is associated with muscle stiffness of the lumbar multifidus muscle in young and middle-aged medical workers. Further studies should examine training for improving muscle stiffness of the lumbar multifidus muscle effectively. Furthermore, assessment of the association of LBP with muscle stiffness of the lumbar back muscles in LBP patients who have different occupations or ages from those of the subjects in the present study is needed.

5. Conclusions

The results of the present study suggest that LBP is associated with muscle stiffness of the lumbar multifidus muscle rather than muscle stiffness of the lumbar erector spinae muscle, muscle mass of the lumbar back muscles, or sagittal spinal alignment in young and middle-aged medical workers.

Conflicts of interest statement

No funding sources and potential conflicts of interest were disclosed for the present study.

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Table 1

Characteristics and LBP status in the CTR and LBP groups.

	CTR group (n=23)		LBP group (n=9)	
	Mean (SD)	Range	Mean (SD)	Range
Characteristics				
Age (years)	34.7 (10.2)	22.0–52.0	44.7 (13.0)	29.0–67.0
Height (cm)	164.1 (7.5)	153.0–177.0	157.4 (6.6)	151.0–170.0
Weight (kg)	56.9 (8.9)	42.0–73.0	52.1 (9.4)	41.0–70.0
Sex (male/female)	8/15		1/ 8	
LBP status				
Duration (months)	—	—	98.0 (73.1)	6.0–240.0
NRS (static)	—	—	5.0 (1.4)	4.0–8.0
NRS (dynamic)	—	—	5.0 (1.7)	2.0–8.0
ODI (%)	—	—	19.6 (7.8)	6.0–30.0

CTR: control, LBP: low back pain, NRS: numerical rating scale, ODI: Oswestry disability index, SD: standard deviation.

Table 2

Muscle stiffness and muscle mass of the lumbar back muscles, and spinal alignment in the CTR and LBP groups.

	CTR group (n=23)		LBP group (n=9)	
	Mean (SD)	Range	Mean (SD)	Range
Shear elastic modulus (kPa)				
Lumbar erector spinae	3.5 (1.1)	1.8–6.4	3.7 (1.1)	2.2–5.9
Lumbar multifidus	4.8 (0.8)	3.6–6.1	5.6 (1.1)	3.3–6.8
Muscle thickness (cm)				
Lumbar erector spinae	2.82 (0.67)	1.55–4.58	2.45 (0.19)	2.11–2.67
Lumbar multifidus	2.86 (0.39)	2.27–3.94	2.77 (0.33)	2.37–3.29
Quadratus lumborum	0.93 (0.27)	0.49–1.84	0.88 (0.17)	0.56–1.21
Spinal alignment (standing) (°)				
Thoracic kyphosis	41.1 (8.4)	26.0–58.0	41.8 (12.0)	24.0–63.0
Lumbar lordosis	25.7 (9.6)	2.0–41.0	25.4 (8.4)	14.0–38.0
Sacral anterior inclination	12.9 (5.7)	−2.0 to 22.0	10.3 (5.6)	1.0–18.0
Spinal alignment (prone) (°)				
Thoracic kyphosis	21.5 (10.6)	0–33.0	19.9 (6.6)	10.0–29.0
Lumbar lordosis	21.1 (7.6)	7.0–37.0	20.3 (7.2)	9.0–30.0
Sacral anterior inclination	102.0 (6.5)	92.0–114.0	100.9 (5.3)	94.0–108.0

CTR: control, LBP: low back pain, SD: standard deviation.

Table 3

Results of multiple logistic regression analysis with a forward selection method.

Dependent variables	Independent variables	Non-standard partial regression coefficient	*P* value	Odds ratio	95% Confidence interval	
					Lower	Upper
Low back pain (Yes=1, No=0)	Shear elastic modulus of lumbar multifidus (kPa)	1.42	0.03	4.13	1.17	14.63
χ^2 value p = 0.002	Height (cm)	−0.20	0.02	0.82	0.69	0.97

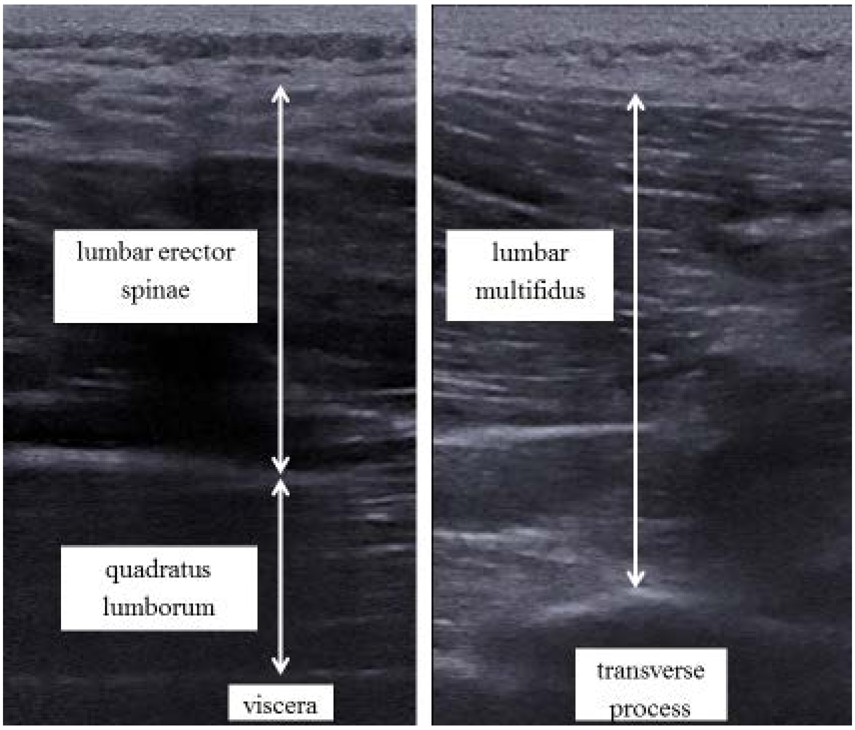

Fig. 1. Muscle thickness measurement of the lumbar back muscles in young and middle-aged medical workers.

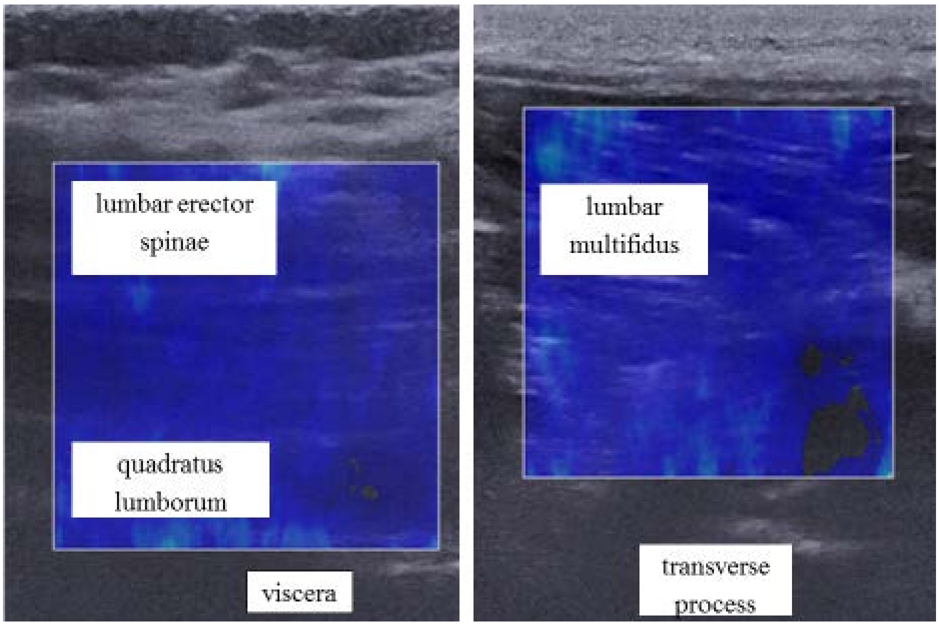

Fig. 2. Muscle stiffness measurement of the lumbar back muscles in young and middle-aged medical workers.