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ORIGINAL ARTICLE

Associations between Paraspinal Muscle Morphology, Disc Degeneration, and Clinical Features in Patients with Lumbar Spinal Stenosis

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Objective: The purpose of this study was to examine the relationships between intervertebral disc degeneration in the lumbar spine, paraspinal muscle morphology, and clinical features in patients with lumbar spinal stenosis (LSS). **Methods:** A total of 52 patients with LSS participated in this study. Magnetic resonance imaging was used to assess intervertebral disc degeneration at L4/5 and to measure the standardized cross-sectional areas (SCSAs) of the multifidus and erector spinae muscles. The intensity of low back pain (LBP) and lower limb pain, the level of disability, and the quality of life (QoL) were evaluated using patient-reported outcome measures. The associations between the image findings and clinical features, including the disability score, the pain score for low back pain, and the QoL score, were calculated using Spearman's rank correlation coefficient. **Results:** No associations were found between disc degeneration and clinical features. However, disc degeneration and the SCSA of the multifidus muscle (r=−0.38, P <0.01) and of the erector spinae muscle (r=−0.29, P=0.04) were significantly associated. Analysis of the associations between muscle morphology and clinical features found that the SCSA of the multifidus muscle was associated with LBP (r=0.31, P=0.03). **Conclusions:** These results suggest that there is some correlation between atrophy of the multifidus and pain intensity. Consequently, focusing on the CSA of the multifidus muscle may help to clarify the causes of LBP in patients with LSS. However, because of the cross-sectional nature of this study, causal relationships could not be determined and further research is needed.

Key words: low back pain; lumbosacral region; paraspinal muscles; spinal stenosis

INTRODUCTION

Low back pain (LBP) is a significant public health concern that can result in chronic pain syndrome and disability. LBP occurs at least once in more than half of people worldwide.[1)] One of the causes of LBP is degenerative change, which becomes more significant with age.[2)] Degenerative changes specifically include disc degeneration, muscle atrophy, and fat infiltration. The Pfirrmann classification is an index for measuring degenerative changes in the intervertebral disc and has been used to inform several medical treatments and research.[3)] In addition, the cross-sectional area (CSA) of muscles is often used to assess muscle changes.

Magnetic resonance imaging (MRI) is commonly used to measure such degenerative changes, and there are several reports on the relationship between MRI findings and LBP. It has been reported that the CSAs of muscles such as the multifidus and erector spinae muscle group were reduced

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on MRI images in patients with chronic LBP.[4] It has also been reported that patients with LBP suffer from atrophy of the multifidus muscle but not of the erector spinae muscle.[5] In addition to muscle atrophy, disc degeneration is a typical degenerative change of the lumbar spine, and disc changes are reportedly associated with LBP.[6]

In contrast to the above findings, there is some evidence that muscle CSA is not associated with pain, disability, or quality of life (QoL) in patients with nonspecific LBP.[7] Furthermore, it has been reported that some degeneration occurs even in people without LBP.[8] For instance, Chung et al. suggested that endplates of the intervertebral disc were found in asymptomatic healthy subjects.[9] In a study on the lumbar spine, it was suggested that disc degeneration is not associated with LBP, dysfunction, or QoL.[10] Therefore, the relationship between LBP and the findings of degenerative changes on MRI remains unresolved.

Lumbar spinal stenosis (LSS) is a typical degenerative disease and is a disabling condition associated with narrowing of the spinal canal or the vertebral foramen at one or several levels of the lumbar spine. MRI is the gold standard modality for diagnosing and characterizing the disease, although there are some suggestions that the severity identified via imaging is not related to clinical features such as pain intensity in patients with LSS.[11] Moreover, it has been suspected for some time that LSS causes dysfunction of the erector spinae and multifidus muscles, and it has also been reported that proprioception is impaired and core function is reduced.[12]

Claudication and leg pain are often addressed as major symptoms of LSS, but LBP itself is also a key complaint. However, the causes of LBP in patients with LSS have not been explored. A few studies have investigated the relationship between muscle morphology and clinical features in patients with LSS, including some studies on chronic LBP and herniated disc. However, no study has simultaneously examined the relationship between intervertebral disc degeneration in the lumbar spine, paraspinal muscle morphology, and clinical features in patients with LSS. Therefore, this study was conducted to examine the relationships between intervertebral disc degeneration in the lumbar spine, paraspinal muscle morphology, and clinical features in patients with LSS, a common degenerative disease of the lumbar spine.

MATERIALS AND METHODS

Subjects

This was a cross-sectional study conducted using convenience sampling, wherein we recruited patients with LSS at L4/5 at Sapporo Maruyama Orthopedic Hospital between January 2018 and July 2019. LSS at L4/5 was diagnosed using MRI and neurological examination by doctors specializing in the spine. Inclusion criteria were (1) age 20–90 years; (2) patients who understand Japanese; (3) no serious pathologies, including pyogenic spondylitis and cauda equina syndrome; and (4) no history of neurological disorders or heart diseases. Eligible subjects completed a consent form. The exclusion criteria were as follows: (1) no availability of MRI data, (2) missing evaluation results, (3) presence of diagnosis of multiple high-grade stenosis, (4) history of spinal surgery, and (5) having serious problems such as the presence of tumor or infection. This study was conducted in compliance with the principles of the Declaration of Helsinki. Ethical approval for the study was granted by Sapporo Maruyama Orthopedic Hospital, #000023.

Methods

Basic demographic data (height, weight, and age) were collected from medical records. MRI findings were used to assess intervertebral disc degeneration at L4/5 and to measure the right and left CSAs of the multifidus and erector spinae muscles. The intensity of LBP and lower limb pain, disability, and QoL were evaluated using three patient-reported outcome measures:

(1) An 11-point numerical rating scale (NRS) for pain intensity: We used an 11-point NRS for assessing the average pain intensity on the day of evaluation for the lower back and lower extremities. A score of 0 indicated no pain, whereas a score of 10 indicated the worst imaginable pain.[13]

(2) The Roland-Morris Disability Questionnaire (RMDQ): The Japanese version of the RMDQ was used.[14] The questionnaire consists of 24 items with a dichotomous scale: yes (1) or no (0). The higher a total score is, the more significant is the disability due to LBP. Concurrent validity, high internal consistency (Cronbach's alpha of all items=0.86), and high test–retest reliability (0.95) of the Japanese versions of the RMDQ have been confirmed.[14]

(3) Euro-Qol 5 Dimension (EQ-5D): We used a Japanese version of the EQ-5D,[15] which is a commonly used measure for assessing the QoL. It has five items with five categorical scales. A higher score indicates a better QoL and the maximum score is 1.[15]

MRI and Disc Degeneration Assessment

MRI scans were obtained using a 1.5-T unit (SIGNA

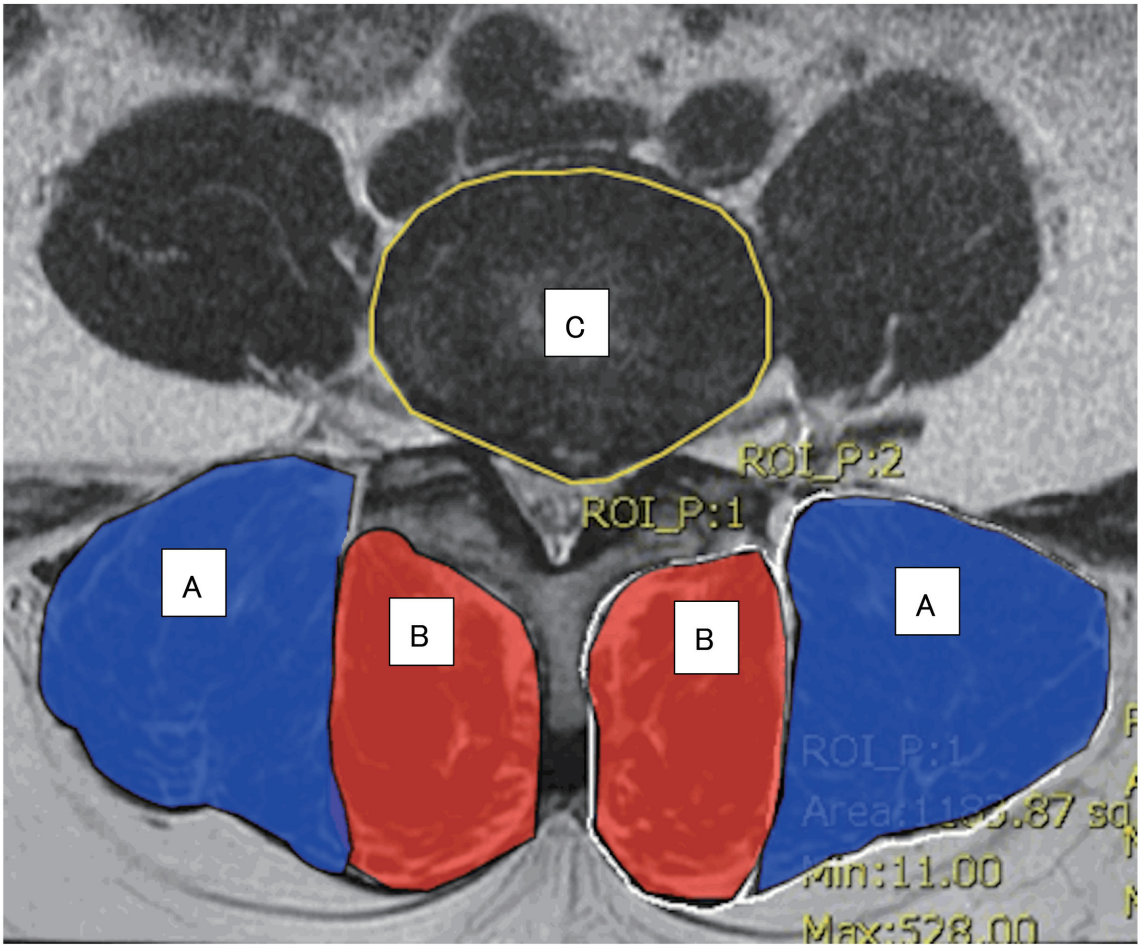

Fig. 1. Axial T2 MRI image at the L4/5 level showing how the total cross-sectional areas of the multifidus and erector spinae muscles and the total cross-sectional area of the L5 vertebra were measured. A, erector spinae muscles; B, the multifidus muscles, C, the L5 vertebra.

Creator; GE Healthcare, Milwaukee, WI, USA). Imaging was performed by placing a pillow under the knees with the patient in the supine position and the body arranged symmetrically. T2-weighted images were used for measurements. Sagittal plane and horizontal plane (L4/5) images were produced.

Disc degeneration was assessed on sagittal T2-weighted images using the five-level grading system proposed by Pfirrmann to evaluate the changes in the signal intensity of the intervertebral disc and its internal structure, uniformity, and height. This MRI-based grading system considers disc signal intensity, disc structure, the distinction between nucleus and annulus, and the disc height to classify disc degeneration into five grades; the validity of this system has been assessed.[16)]

Paraspinal Muscle Measurements

We measured the CSAs of the multifidus and erector spinae muscles on a horizontal section at L4/5 (**Fig. 1**). Regions of interest were manually defined for CSA measurement of the erector spinae and multifidus muscles on each side at L4/5. Measurements were done using the ImageJ software (version 1.52). To determine muscle CSA, the position of the connection with the fascia was manually marked using a freehand selection pointer and a touchscreen pen on a touchscreen monitor. The CSAs of the erector spinae and multifidus muscles on the left and right sides at both levels were combined. To give a standardized CSA (SCSA), the muscle CSA was divided by the CSA of the vertebral body at the L4/5 lumbar intervertebral disc level to compensate for the effect of individual relative body size.

All measurements were taken twice by one investigator, and the average of the two measurements was used. At the time of assessment, the evaluator was unaware of any patient clinical data, and the evaluator did not access any previous

Table 1. Demographic data for the 52 participants

Gender (n of female), (%)	21 (36.2)
Age (years), mean (SD)	68.9 (9.6)
Height (cm) (SD)	160.41 (9.1)
Weight (kg) (SD)	63.63 (13.46)
Pain intensity over the lower back (0–10), mean (SD)	4.06 (2.34)
Pain intensity over the lower limb (0–10), mean (SD)	7.52 (3.21)
Roland-Morris Disability Questionnaire (0–24), mean (SD)	10.59 (5.22)
Euro-QoL 5 Dimensions (0.00–1.00), mean (SD)	0.58 (0.19)
Pfirrmann grade (1–5), mean (SD)	4.4 (0.74)
Grade I (n), (%)	0 (0)
Grade II (n), (%)	2 (3.9)
Grade III, (n), (%)	2 (3.9)
Grade IV (n), (%)	21 (51.8)
Grade V (n), (%)	27 (40.4)

Table 2 . Associations between Pfirrmann disc degeneration classification and muscle morphology/clinical features

	Correlation coefficient (*r*)	P value
Multifidus SCSA	−0.38	<0.01
Erector spinae SCSA	−0.29	0.04
NRS	0.08	0.55
RMDQ	0.1	0.47
EQ-5D	−0.29	0.57

Values are Spearman's ρ values.
SCSA, standardized cross-sectional area; NRS, numerical rating scale; RMDQ, Roland-Morris Disability Questionnaire; EQ-5D, Euro-QoL 5 Dimensions.

radiological reports.

STATISTICAL ANALYSIS

Basic characteristics are summarized using descriptive statistics. The associations between image findings and clinical features, including the disability score, pain score, and QoL, were assessed using Spearman's rank correlation coefficient. Correlations >0.7, 0.5–0.7, 0.3–0.5, and <0.3 were considered to be very strong, strong, moderate, and weak, respectively.[17] All statistical analyses were performed using JMP pro14 (SAS Institute, Cary, NC, USA).

RESULTS

A total of 52 patients (mean [SD] age, 68.9 [9.6] years) participated in this study. The demographic characteristics of the subjects are presented in **Table 1**.

Table 2 shows the associations between the Pfirrmann classification and muscle morphology and clinical features. No associations were found between disc degeneration and clinical features. However, there was a significant moderate association between intervertebral disc degeneration and the SCSA of the multifidus muscle (r=−0.38, P <0.01). For the erector spinae muscle, a weak, but significant, association with the Pfirrmann classification (r=−0.29, P=0.04) was detected.

Table 3 shows the associations between clinical features and the SCSA of the multifidus muscle. There was a significant moderate association between the multifidus muscle SCSA and LBP (r=0.31, P=0.03).

Table 4 shows the associations between clinical features and the SCSA of the erector spinae muscle. The SCSA of the erector spinae muscle showed a moderate, but significant, association with disability (r=0.26, P=0.02).

DISCUSSION

This study investigated the relationships between the morphology of the multifidus and erector spinae muscles,

Table 3. Associations between standardized cross-sectional area of the multifidus muscle and clinical features

	Correlation coefficient	P value
NRS for LBP	0.31	0.03
RMDQ	0.11	0.46
EQ-5D	0.14	0.32

Values are Spearman's ρ values.
LBP, Low back pain.

Table 4. Associations between standardized cross-sectional area of the erector spinae muscle and clinical features

	Correlation coefficient	P value
NRS for LBP	0.26	0.59
RMDQ	0.33	0.02
EQ-5D	–0.12	0.39

Values are Spearman's ρ values.

intervertebral disc degeneration, and clinical features in patients with LSS.

We found that intervertebral disc degeneration and the SCSAs of the multifidus and erector spinae muscles were significantly associated. In a previous study, Corniola et al. reported that there were no associations between disc degeneration and pain intensity, the Oswestry Disability Index (ODI) score, or the EQ-5D score in subjects with degenerative disc disease of the lumbar spine.[18] Moreover, they did not find any association between disc degeneration and functional performance. Another study reported that there was no correlation between pain intensity and Modic changes in patients with LBP who were indicated for surgery.[19]

The present study also supports the abovementioned findings, suggesting that disc degeneration does not affect clinical features such as pain intensity. Disc degeneration is a natural phenomenon that occurs with aging, and it has been observed in asymptomatic cases.[8,20] Furthermore, it is known that pain is caused by several issues other than structural changes, such as psychological factors, social factors, and central sensitization.[21] However, we observed a significant association between disc degeneration and the morphology of the multifidus and erector spinae muscles. A previous study demonstrated that degeneration of the disc, degeneration of nerve roots, and injuries in a rat model caused atrophy of the multifidus muscle.[22] Based on these findings, it may be meaningful to investigate the relationship between disc degeneration and muscle function in the future.

Pain intensity was moderately associated with the SCSA of the multifidus muscle, whereas disability and QoL were not associated with the morphology of this muscle. A study of ballet dancers with LBP reported that the lower the multifidus CSA, the higher the levels of back pain.[23] In that study, in addition to the multifidus muscle, the erector spinae and the iliopsoas muscles were measured and examined, but no significant association with LBP was detected.[23] Although a few studies have focused on LSS, Fortin et al. reported that there was no correlation between the CSA of the multifidus muscle and pain intensity or ODI score.[24] In a study conducted by Barker et al., the CSAs of the multifidus and iliopsoas muscles were associated with the duration of symptoms, whereas ODI scores were not associated with the symptoms.[21] In the current study, pain intensity was associated with the CSA of the multifidus muscle alone, but this cross-sectional study cannot ascertain whether atrophy of the multifidus muscle caused the pain. It is also possible that pain could have reduced the muscle function, based on a previous study that found an association between symptom length and muscle CSA. Indeed, it has been reported that atrophy of the back muscles reduces muscle function, which can result in dysfunction and pain.[25] Moreover, another study on LSS suggested that atrophy of the multifidus muscle is a predictor of functional ability.[26]

We found a weak association between the SCSA of the erector spinae muscles and disability (RMDQ score). Although several studies have investigated the CSA and the clinical manifestations of the erector spinae muscles, most of them have demonstrated a low association with the clinical manifestations of LBP. Gildea et al. reported that ballet dancers showed an association between LBP intensity and the multifidus muscle, but they found no association with the erector spinae muscle.[23] In a study conducted on community-based individuals, neither the multifidus nor the erector spinae muscle was associated with pain intensity or disabil-

ity.[27] The moderate association found between the erector spinae muscle and the RMDQ score in the present study may be because a decrease in the strength of the erector spinae muscle causes disability. It has been reported that there is an association between muscle CSA and muscle strength.[28] Sung et al. reported that the erector spinae muscle of patients with LBP was more easily fatigued than that of patients without LBP.[29] These results indicate that when the CSA of the erector spinae muscle is small, it is possible that the muscle strength is weak, which may cause fatigue and disorders affecting activities of daily living.

The results of this study suggest that, in patients with LSS, LBP and disability are associated with the CSA of the multifidus and the erector spinae muscles, respectively. This indicates that a greater focus on muscle CSA in clinical practice may help to elucidate the causes of LBP and disability in patients with LSS.

LIMITATIONS

This study has several limitations. First, the CSA of a muscle may not indicate the quality of the muscle. One study indicated that fat infiltration (FI) is more highly associated with clinical features than CSA is.[27] It has also been reported that FI can increase without increasing the muscle CSA.[30] Therefore, it is advisable to investigate muscle morphology in more detail by measuring fat replacement and FI. Another limitation is the bias in the grade of intervertebral disc degeneration. In this study, the majority of subjects had intervertebral disc degeneration of Pfirrmann grades 4 and 5. The reason for this may be that severe intervertebral disc degeneration was prevalent in this study because it focused only on patients with LSS who were indicated for surgery. In the future, by including patients with LBP with lower grades of disc degeneration, it will be possible to investigate more accurately the relationship between muscle morphology and LBP.

CONCLUSIONS

This study demonstrated a correlation between disc degeneration and muscle morphology in patients with LSS. There was also a moderate correlation between the morphology of the multifidus muscle and pain intensity. This finding may help to clarify the causes of LBP in patients with LSS by encouraging a focus on the CSA of the multifidus muscle. Future studies on subjects with a wider range of disc degeneration and assessing the relationship between FI and clinical features in patients with LSS could generate additional insights.

CONFLICTS OF INTEREST

The authors declare that no conflicts of interest exist.

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