Research Square

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Shear wave elastography assessment of lumbar multifidus muscle elasticity and its correlation with clinical function in patients with lumbar disc herniation

Caina Qiao
China Rehabilitation Research Center
Bing Feng
China Rehabilitation Research Center
Yi Guo
China Rehabilitation Research Center
Zhen Lyu
China Rehabilitation Research Center
Zifeng Li
Renhe Hospital Affiliated to China Three Gorges University
Wenwu Xiao
Renhe Hospital Affiliated to China Three Gorges University
Ye Miao
19126294@qq.com

China Rehabilitation Research Center

Research Article

Keywords: Lumbar disc herniation, Shear wave elastography, Lumbar multifidus muscle, Elastic modulus, Pain, Functional impairment

Posted Date: April 7th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9191466/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at BMC Musculoskeletal Disorders on September 21st, 2026. See the published version at https://doi.org/10.1186/s12891-026-10511-x.

Abstract

Background

Lumbar disc herniation (LDH) is a common degenerative spinal disease causing low back and leg pain, and dysfunction of the lumbar multifidus muscle is closely associated with its pathogenesis. Current research primarily focuses on muscle strength and morphological assessments, with limited studies quantifying the elastic properties of the lumbar multifidus muscle and their correlation with clinical symptoms and function.

Objective

To investigate the characteristics of lumbar multifidus muscle elasticity in LDH patients using shear wave elastography (SWE) and analyze its correlation with pain intensity, functional impairment, and LDH classification, thereby providing a basis for clinical evaluation and precision rehabilitation.

Methods

Thirty-two clinically diagnosed LDH patients (LDH group) and 33 healthy volunteers without low back pain (control group) were enrolled. SWE was used to measure the elastic modulus of the lumbar multifidus muscle in both resting and contracted states. Pain intensity was assessed using the Visual Analog Scale (VAS), lumbar function was evaluated with the Oswestry Disability Index (ODI), and the Macnab classification was obtained from imaging. Differences in the elastic modulus between the two groups were compared, and correlations between the elastic modulus and VAS score, ODI score, and Macnab classification were analyzed in the LDH group.

Results

Resting-state lumbar multifidus muscle thickness was significantly lower in the LDH group than in the control group (1.03 ± 0.28 cm vs. 1.16 ± 0.23 cm, t = 2.047, P = 0.045), as was contracted-state thickness (1.42 ± 0.39 cm vs. 1.62 ± 0.29 cm, t = 2.442, P = 0.017); and resting-state elastic modulus was markedly higher in the LDH group (3.24 ± 0.65 kPa vs. 2.96 ± 0.60 kPa, z = 1.327, P = 0.016), but with no significant intergroup difference in contracted-state elastic modulus (5.00 ± 1.41 kPa vs. 5.78 ± 2.21 kPa, z = 1.327, P = 0.185). In the LDH group, resting-state elastic modulus was moderately positively correlated with VAS scores (r = 0.746, P < 0.001), weakly positively correlated with ODI scores (r = 0.535, P < 0.001), and uncorrelated with Macnab classification (r=-0.041, P > 0.05).

Conclusions

LDH patients exhibit characteristic morphological and elastic changes in the lumbar multifidus muscle, namely muscle atrophy and elevated resting-state stiffness; this resting-state elastic modulus is closely correlated with pain severity and lumbar dysfunction, but unassociated with the Macnab imaging classification of disc herniation. Shear wave elastography (SWE) can quantitatively assess lumbar multifidus muscle elasticity, providing novel objective evidence for the clinical evaluation of LDH and serving as an objective tool for its precision rehabilitation.

1 Introduction

Lumbar disc herniation (LDH) is a clinical syndrome caused by lumbar disc degeneration, annulus fibrosus rupture, and nucleus pulposus herniation compressing nerve roots or the cauda equina. It primarily manifests as low back pain, leg pain, lower limb numbness, and limited mobility, severely affecting patients' quality of life and functional independence [1–3]. The classic pathophysiological model involves mechanical compression and chemical radiculitis theories, where the herniated nucleus pulposus directly compresses nerve roots while releasing inflammatory mediators that trigger an inflammatory response in the nerve roots and surrounding tissues, leading to pain and dysfunction [4–5]. However, growing research suggests that mechanical compression alone is not the sole explanation for all clinical symptoms. Changes in the local biomechanical environment of the lumbar spine, particularly dysfunction of stabilizing muscles, play a critical role in the onset and chronicity of LDH [6–7]. Among these, the multifidus muscle, as a core stabilizer of the spine, has been shown via traditional imaging (e.g., MRI, B-ultrasound) to exhibit morphological atrophy in LDH patients, such as reduced cross-sectional area and fatty infiltration. However, morphological changes are the result of long-term adaptation or disuse, whereas alterations in muscle mechanical properties (e.g., stiffness, elasticity) may occur earlier and are directly related to immediate muscle function [8]. Recent studies have confirmed that changes in muscle elasticity can occur early in patients with chronic low back pain [10]. Abnormal increases in muscle stiffness may stem from muscle spasms, fibrosis, tissue edema, or aberrant co-contraction patterns, all of which impair lumbar motor control efficiency, increase abnormal loads on lumbar segments, and exacerbate pain and dysfunction, creating a vicious cycle [11]. Existing research indicates that changes in muscle elastic modulus can objectively reflect muscle functional status [12]. However, quantitative studies on the elastic properties of the multifidus muscle in LDH patients remain limited, and their correlation with clinical symptoms and dysfunction has yet to be clearly established.

Shear Wave Elastography (SWE) is an ultrasound diagnostic technology that quantifies tissue elastic modulus by measuring shear wave propagation speed on the basis of two-dimensional imaging. It offers real-time, non-invasive, and precise advantages and has been widely applied in the evaluation of musculoskeletal system diseases [13–14]. This study employs SWE to measure changes in the elastic modulus of the multifidus muscle in LDH patients and analyze its correlation with pain and functional impairment, aiming to provide new objective evidence for the clinical assessment of LDH and the selection of rehabilitation treatment targets.

2 Materials and Methods

2.1 Design

This study is a cross-sectional case-control study.

2.2 Time and Location

The experiment was conducted from October 2024 to December 2025 in the Ultrasound Department of Beijing Bo'ai Hospital, China Rehabilitation Research Center.

2.3 Subjects

The LDH group consisted of 32 patients with confirmed LDH selected from Beijing Bo'ai Hospital, China Rehabilitation Research Center, while the control group included 33 healthy volunteers without a history of low back pain from neighboring communities during the same period. This study was approved by the Medical Ethics Committee of Beijing Bo'ai Hospital, China Rehabilitation Research Center (Approval No. : 2024-120-01), and all participants provided written informed consent.

2.3.1 Inclusion Criteria

LDH group: □ Strict adherence to the clinical diagnostic criteria for LDH, with lumbar MRI confirming the presence of disc herniation [15]; □ Selection of L4-L5 segment LDH patients with clearly identified symptomatic sides; □ Age 20–65 years; □ Low back pain with or without radiating leg pain, with a disease duration of ≥ 3 months from the first onset of symptoms; □ Patients had not received any lumbar-related rehabilitation or medication therapy in the past month; □ Patients were conscious and able to cooperate with the treatment.

Control group: □ Age, gender, and body mass index (BMI) matched with the LDH group; □ No history of chronic low back pain, no episodes of acute low back pain in the past year, and no symptoms such as radiating leg pain or numbness; □ Lumbar MRI excluded imaging abnormalities such as lumbar disc herniation or degenerative changes; □ No history of major spinal or neurological diseases; □ No strenuous exercise within 24 hours prior to testing.

2.3.2 Exclusion Criteria

Both groups excluded: □ Previous history of lumbar spine surgery; □ Comorbid conditions such as lumbar spondylolisthesis, spinal stenosis, spinal fractures, tumors, infections, or ankylosing spondylitis; □ Severe osteoporosis or systemic metabolic diseases; □ Other neurological disorders (e.g., stroke, Parkinson's disease) or psychiatric conditions; □ Pregnant or lactating women; □ Individuals unable to cooperate with ultrasound examinations or questionnaire completion.

2.3.3 Sample Size Estimation

Sample size estimation was performed using G*Power 3.1 software, based on a bivariate normal distribution correlation test model. According to previous literature, the reported r-value was 0.45 (moderate correlation). The significance level was set at $\alpha = 0.05$ (two-tailed), with a test power of $1-\beta = 0.80$, and a 1:1 sample size ratio between the two groups. The calculation results indicated a required sample size of 27 cases. Considering a 15% dropout rate, the final recruitment plan was 32 cases per group. This study ultimately included 32 cases in the LDH group and 33 cases in the control group, meeting the sample size requirements. [16]

2.4 Research Methods

2.4.1 General Data Collection

Demographic data such as age, gender, height, weight, and BMI were recorded for all participants. For the LDH group, additional data included disease duration (months), symptomatic side, and Macnab classification. The Macnab classification [17] is an internationally recognized classic method for diagnosing and treating discogenic low back pain, proposed by the renowned spine surgeon John Macnab in 1971. It is primarily based on two core theories: local chemical radiculitis and mechanical compression, and clinically classifies LDH into bulging, protrusion, extrusion, and sequestration types.

2.4.2 Shear Wave Elastography Measurements

Shear wave elastography was performed using a Siemens ACUSON Oxana S2000 ultrasound diagnostic system (equipped with a 9L4 high-frequency linear array probe set to 9MHz). The thickness and elastic modulus values of the lumbar multifidus muscles were measured in all participants. Participants were positioned prone with a pillow supporting the abdomen, maintaining a neutral lumbar spine and relaxed muscles, and arms naturally placed at the sides. The L4/L5 spinous processes were marked, and the probe was placed approximately 1.5-2 cm lateral to the spinous processes on the affected side (LDH group) or bilaterally (control group). To minimize measurement bias, all ultrasound procedures were conducted by a sonographer with 14 years of clinical experience, who was blinded to the participants' group assignments and functional assessment results.

The probe was rotated to align parallel to the spine and placed at the marked position. The maximum cross-section of the multifidus muscle was obtained in 2D ultrasound mode to measure its thickness. Then, the SWE mode was activated to generate a color-coded tissue elasticity map, where blue, green, yellow, and red represent soft tissue elasticity from soft to hard, respectively. Higher tissue stiffness corresponds to higher elastic modulus values. A square sampling box measuring 0.15 cm × 0.15 cm was placed at the center of the multifidus muscle belly, avoiding the myofascia, adipose tissue, and bones. The tissue elasticity map displayed the shear wave propagation speed in m/s (see Fig. 1). Five to ten shear wave propagation speed values were measured for each muscle of interest, and the average was calculated. The measurement was repeated three times for the same muscle, and the mean of the three averages was taken as the final shear wave propagation speed for that muscle. Finally, the elastic modulus value (E) of the muscle was calculated using the formula: $E = 3\rho c^2$, where ρ is the muscle

density (ρ ≈ 1,000 kg/m³) and c is the shear wave propagation spe ed [18]. Talking was prohibited during the examination.

Measurements of the contracted multifidus muscle were performed after the resting state measurements. Before measurement, subjects were instructed to perform three lumbar extension contraction exercises using the "superman" maneuver to activate the multifidus muscle. Subjects lay prone with their bodies straight, arms extended forward and upward, and palms facing downward. After familiarization, formal measurements began. With the aid of visual feedback, subjects were guided to perform lumbar extension contractions and maintain 30% of their maximum contraction force stably.Once muscle contraction stabilized, thickness was measured in 2D ultrasound mode, followed by elastic modulus measurement in SWE mode, using the same method as above.

Caption: Figure A shows the elastic ultrasound measurement of the resting state (MF) of the lumbar multifidus muscle in the healthy group; B shows the elastic ultrasound measurement of the resting state (MF) of the lumbar multifidus muscle in the LDH group; C shows the elastic ultrasound measurement of the contracted state (MF-S) of the lumbar multifidus muscle in the control group; D shows the elastic ultrasound measurement of the contracted state (MF-S) of the lumbar multifidus muscle in the LDH group; E shows the color scale beside the tissue elasticity map.

Figure 1: Shear wave elastography image of the lumbar multifidus muscle

2.4.3 Clinical Functional Assessment

Only LDH group patients underwent the following assessments on the examination day:

Visual Analog Scale (VAS): A 10 cm straight line was used, with "0" (no pain) and "10" (most severe pain) marked at each end. Patients indicated their average pain level over the past week by marking the corresponding position on the line, and the same researcher measured and recorded the score.

Oswestry Disability Index (ODI) questionnaire [19]: Includes 10 dimensions (pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sexual life, social life, traveling), each scored 0–5. The total score is converted to a percentage (0-100%), with higher scores indicating more severe dysfunction. It has passed reliability and validity tests.

2.5 Primary Outcome Measures

Compare the thickness and elastic modulus of the lumbar multifidus muscle between the LDH group and the control group, and analyze the correlation between the elastic modulus of the lumbar multifidus muscle in the LDH group and VAS, ODI, and Macnab classification.

2.6 Statistical Analysis

Data analysis was performed using SPSS 26.0 statistical software. All measurement data were tested for normality using the Shapiro-Wilk test. Normally distributed measurement data are expressed as

mean ± standard deviation ($\bar{x}\pm s$), and intergroup comparisons were made using the independent samples t-test. Non-normally distributed measurement data are expressed as median (interquartile range) [M(P25, P75)], and intergroup comparisons were made using the Wilcoxon rank-sum test. Categorical data are presented as rates (%), and intergroup comparisons were made using the χ^2 test. The correlation between the elastic modulus of the multifidus muscle in the LDH group and VAS/ODI scores followed a bivariate normal distribution and was analyzed using Pearson correlation. The correlation with Macnab classification (ordinal data) was analyzed using Spearman rank correlation. The significance level was set at $P < 0.05$.

3 Results

3.1 Comparison of Baseline Data

There were no significant differences between the LDH group and the control group in age, gender, height, weight, BMI, or laterality ($P>0.05$), indicating comparability (Table 1). The average disease duration in the LDH group was (12.24±9.54) months, ranging from 3 to 22 months. According to Macnab classification, there were 8 cases of protrusion type (25%), 13 cases of extrusion type (38%), 6 cases of sequestration type (19%), and 5 cases of free fragment type (16%). The VAS score in the LDH group was (5.19±3.81) points, and the ODI score was (43.17±21.03) points (Table 2).

Table 1 Comparison of Baseline Characteristics Between Groups ($\bar{x}\pm s$ or n(%))

Item	Control group (n=33)	LDH group (n=32)	Statistic	P-value
Age (years)	38.32±12.12	43.23±11.72	t=1.657	0.102
BMI (kg/m^2)	23.47±4.08	23.95±3.78	t=0.488	0.627
Gender (Male/Female) (n(%))	13（41.94%）/20（58.06%）	9（29.03%）/23（70.97%）	χ^2=0.613	0.434
Side (Left/Right)	33/33	15/17	χ^2=0.13	0.95

Table 2 General Information of the LDH Group (n=32)

Item		Value($\bar{x}$±s)
Disease duration		12.24±9.54
Macnab classification (n(%))	Bulging type	8（25%）
	Protrusion type	13（38%）
	Extrusion type	6(19%)
	Sequestration type	5(16%)
VAS score		5.19±3.81
ODI score		43.17±21.03

3.2 Comparison of Multifidus Muscle Shear Wave Elastography Results Between Groups

By comparing the thickness and elastic modulus of the lumbar multifidus muscles between the two groups, it was found that the resting-state thickness (1.03±0.28cm vs. 1.16±0.23cm,, t=2.047,, P=0.045) and the contracted-state thickness (1.42±0.39cm vs. 1.62±0.29cm, t=2.442, P=0.017),) of the multifidus muscles in the LDH group were significantly smaller than those in the control group, with statistical significance (P<0.05), as shown in Figure . Regarding the elastic modulus, the resting-state elastic modulus of the multifidus muscles in the LDH group (3 2.24±0.65kPa vs. 2.96±0.60kPa, z=1.327, P=0.016) was significantly higher than that of the control group, with statistical significance (P<0.05). However, the contracted-state elastic modulus of the multifidus muscles in the LDH group (5 ;.00±1.41kPa vs. 5.78±2.21kPa, z=1.327, P=0.185) showed no statistically significant difference (P>0.05), as shown in Figure 3.

3. 3 Correlation Analysis of Multifidus Muscle Elastic Modulus and Clinical Scores in Patients with Lumbar Disc Herniation

The resting-state elastic modulus values of the multifidus muscles, which showed significant differences between the LDH group and the control group, were selected for correlation analysis. The results revealed that the resting-state elastic modulus of the multifidus muscles in the LDH group was moderately positively correlated with VAS scores (r = 0.746, P < 0.001), as shown in Figure 4, indicating that higher resting-state elastic modulus was associated with greater pain severity. It was also weakly positively correlated with ODI scores (r= 0.535, P < 0.001), as shown in Figure 5, suggesting that higher resting-state elastic modulus was linked to more severe lumbar dysfunction. However, no significant linear correlation was found between the resting-state elastic modulus and Macnab classification (r=-0.041, P > 0.05), as shown in Figure 6, indicating that the resting-state elastic modulus was unrelated to the imaging classification of lumbar disc herniation.

4 Discussion

This study utilized shear wave elastography (SWE) technology to systematically evaluate the elastic modulus characteristics of the lumbar multifidus muscles in patients with lumbar disc herniation (LDH) during both resting and contracted states. It also explored, for the first time, the relationship between these characteristics and clinical indicators such as pain, functional impairment, and Macnab classification. The study yielded two major findings.

The first key finding is that LDH patients often exhibit biphasic changes in multifidus muscle function: during the resting state, the stiffness of the affected multifidus muscles is significantly higher than that of the healthy control group, indicating abnormal baseline-level hypertonia. However, during active contraction, the stiffness shows no significant difference compared to healthy individuals. This phenomenon of "resting hypertonia" suggests that the multifidus muscles in LDH patients may be in a state of chronic tension maintained by passive mechanisms. The underlying mechanisms may involve: First, neuroreflex-driven protective spasms. Studies in rats and rabbits have confirmed that pain stimuli can directly mediate abnormalities in neuromuscular control [20–21]. Burnett et al. [22] further extended this mechanism to clinical settings, noting that chronic pain and nerve root irritation can increase the excitability of alpha motor neurons through central sensitization and segmental reflexes at the spinal level, leading to persistent muscle hypertonia even in non-contracted states (at rest). From a physiological perspective, this is essentially a protective spasm in response to spinal segmental instability, aimed at limiting further disc displacement; however, it is also the root cause of functional impairment, such as reduced muscle flexibility and limited relaxation capacity. Second, it may be related to muscle degeneration and connective tissue remodeling. Research by [23] Dickx et al. demonstrated that long-term pain-induced disuse and biomechanical imbalance can lead to adverse remodeling of the multifidus muscles, including increased deposition of type I and III collagen fibers, fat infiltration, and fibrosis. The increase in these non-contractile connective tissue components directly alters the passive viscoelastic properties of the muscle, resulting in decreased tissue elasticity and increased resting stiffness.

The concurrent observation of reduced multifidus muscle thickness (morphological atrophy) and increased resting stiffness (functional tension) in this study confirms the complex coexistence of morphological degeneration and functional compensation in the multifidus muscles of LDH patients. This phenomenon shares similarities with the mechanism observed by Smith et al. [24] in the vastus lateralis of knee osteoarthritis patients: due to joint instability or pain, local muscles compensate by increasing activation to maintain stability, and prolonged compensation leads to excessive recruitment of specific motor units, ultimately resulting in reduced muscle compliance and increased stiffness.

The second key finding of this study is that the resting stiffness value (shear wave elastic modulus) of the multifidus muscles in LDH patients shows a significant positive correlation with pain intensity (VAS score) and dysfunction index (ODI score), but no significant association with the imaging-based classification of disc herniation (Macnab classification). This discovery quantitatively establishes, for the first time, the intrinsic link between the mechanical properties of the multifidus muscles in a relaxed state and clinical symptoms in LDH patients. Resting stiffness exhibits a moderate positive correlation

with VAS scores (r = 0.746) and a strong positive correlation with ODI scores (r = 0.535). From a physiological perspective, this indicates that the passive tension of muscles in a non-contracted state is a key biomechanical factor influencing patients' pain perception and daily functional capacity. The study by Bailey et al. [25] provides a mechanistic explanation for this phenomenon: excessively high resting muscle tension reduces lumbar segmental compliance (flexibility), increases load stress on joint surfaces, and disrupts normal movement patterns (e.g., flexion-extension rhythm), thereby directly exacerbating dysfunction. Thus, this study further corroborates that even before patients begin movement, their high-tension muscles already pose a potential risk for pain and activity limitations.

More clinically significant is the lack of a significant correlation between muscle stiffness and MRI-based Macnab classification. This result aligns with the conclusions of Askar et al. [26], reaffirming a common observation in clinical practice: the degree of morphological compression shown in imaging does not fully explain patients' subjective symptoms. This suggests that patients' pain and functional limitations are not solely determined by the mechanical compression of disc herniation but are also closely related to the resulting soft tissue dysfunction (particularly the resting hypertonicity of the multifidus muscles).

Based on the above findings, the quantitative muscle elasticity information provided by SWE technology adds a crucial functional dimension to clinical rehabilitation assessment. It bridges the gap from "structural visualization" (imaging) to "functional measurement" (muscle mechanics). Previous studies have attempted to use muscle stiffness as an objective indicator of rehabilitation efficacy [27–28]. Kliziene et al [29] demonstrated that core stability training can improve the activation timing of the multifidus muscle in patients with chronic low back pain and potentially alter its mechanical properties. Saeki et al [30] further constructed a structural equation model, confirming that the elastic modulus of the multifidus muscle can influence pain and functional impairment, thereby altering lumbar structure and mechanical properties. Therefore, from an assessment perspective, for patients with pain inconsistent with imaging findings, special attention should be paid to palpation and functional evaluation of the multifidus muscle, with SWE serving as an effective tool for objectively assessing muscle tension. From a treatment perspective, therapeutic targets should expand beyond merely relieving mechanical compression (e.g., traction) to reducing the resting hypertonicity of the multifidus muscle. Improving muscle compliance through manual therapy, physical agents, or motor learning may be a key factor in alleviating pain and enhancing function [31]

However, this study also has certain limitations: First, as a cross-sectional study, it cannot establish a causal relationship between increased resting stiffness of the multifidus muscle and the onset of LDH. Second, the sample size is relatively limited, and the findings are specific to patients with L4-L5 segment involvement, necessitating caution in generalizing the conclusions. Future research could explore the following directions: conducting longitudinal studies to track dynamic changes in muscle elasticity during disease progression and rehabilitation; expanding sample sizes and performing multicenter validation; investigating the correlation between SWE assessment results and techniques such as

surface electromyography and motion analysis to provide a more comprehensive understanding of muscle dysfunction mechanisms; and ultimately designing interventional studies to validate the efficacy of personalized rehabilitation protocols based on SWE assessments.

5 Conclusion

The findings indicate that patients with LDH exhibit characteristic increased resting stiffness of the lumbar multifidus muscle, which is closely correlated with the degree of pain and functional impairment, but not with the imaging-based herniation type. Utilizing shear wave elastography to quantitatively assess the elastic modulus of the multifidus muscle provides a new objective basis for clinical functional evaluation, mechanistic investigation, and rehabilitation efficacy monitoring in LDH, thereby facilitating the advancement of precision rehabilitation practices for the condition.

Abbreviations

LDH Lumbar Disc Herniation

SWE Shear Wave Elastography

MF Multifidus muscle at rest

MF-S Multifidus muscle in contraction

VAS Visual Analogue Scale

ODI Oswestry Disability Index

Declarations

Ethics Approval and Consent to Participate

This study was approved by the Medical Ethics Committee of China Rehabilitation Research Center, Beijing Bo'ai Hospital (Approval No.: 2024-120-01, November 15, 2024). All procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki. Clinical trial registration: Not applicable.

Consent to Participate

All participants consented to participate in this study and signed informed consent forms.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare no competing interests.

Funding

Not applicable.

Authors' Contributions

All authors contributed to this study. Caina Qiao: Methodology, Writing – original draft. Bing Feng: Ultrasound measurements. Yi Guo: Measurement data organization. Zhen Lyu: Participant recruitment. Zifeng Li: Data analysis and statistics. Wenwu Xiao: Data review. Miao Ye: Review and editing.

Acknowledgments

We extend our gratitude to all the patients and volunteers who participated in this study. We thank Teacher Miao Ye from the Department of Exercise Therapy at our hospital for their strong support. We appreciate the guidance and assistance from Teacher Yi Guo and Teacher Bing Feng from the Department of Ultrasound. We are grateful to Teacher Zhen Lyu from the Department of Spine Surgery for their support in case recruitment and technical aspects. We also thank Teacher Zifeng Li, a statistics expert, for their guidance on data analysis.

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Figures

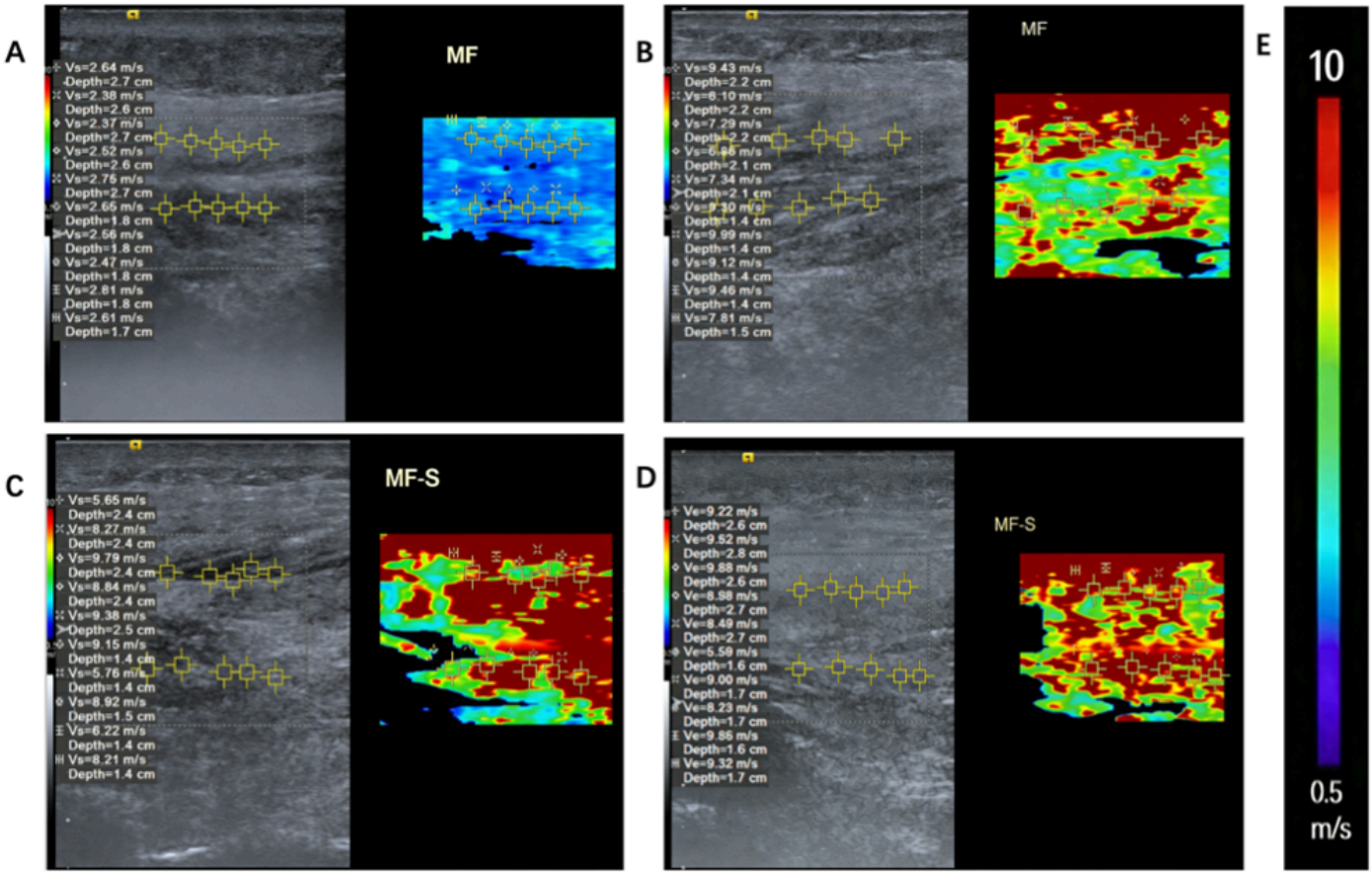


Figure 1

Shear wave elastography image of the lumbar multifidus muscle

Caption: Figure A shows the elastic ultrasound measurement of the resting state (MF) of the lumbar multifidus muscle in the healthy group; B shows the elastic ultrasound measurement of the resting state (MF) of the lumbar multifidus muscle in the LDH group; C shows the elastic ultrasound measurement of the contracted state (MF-S) of the lumbar multifidus muscle in the control group; D shows the elastic ultrasound measurement of the contracted state (MF-S) of the lumbar multifidus muscle in the LDH group; E shows the color scale beside the tissue elasticity map.

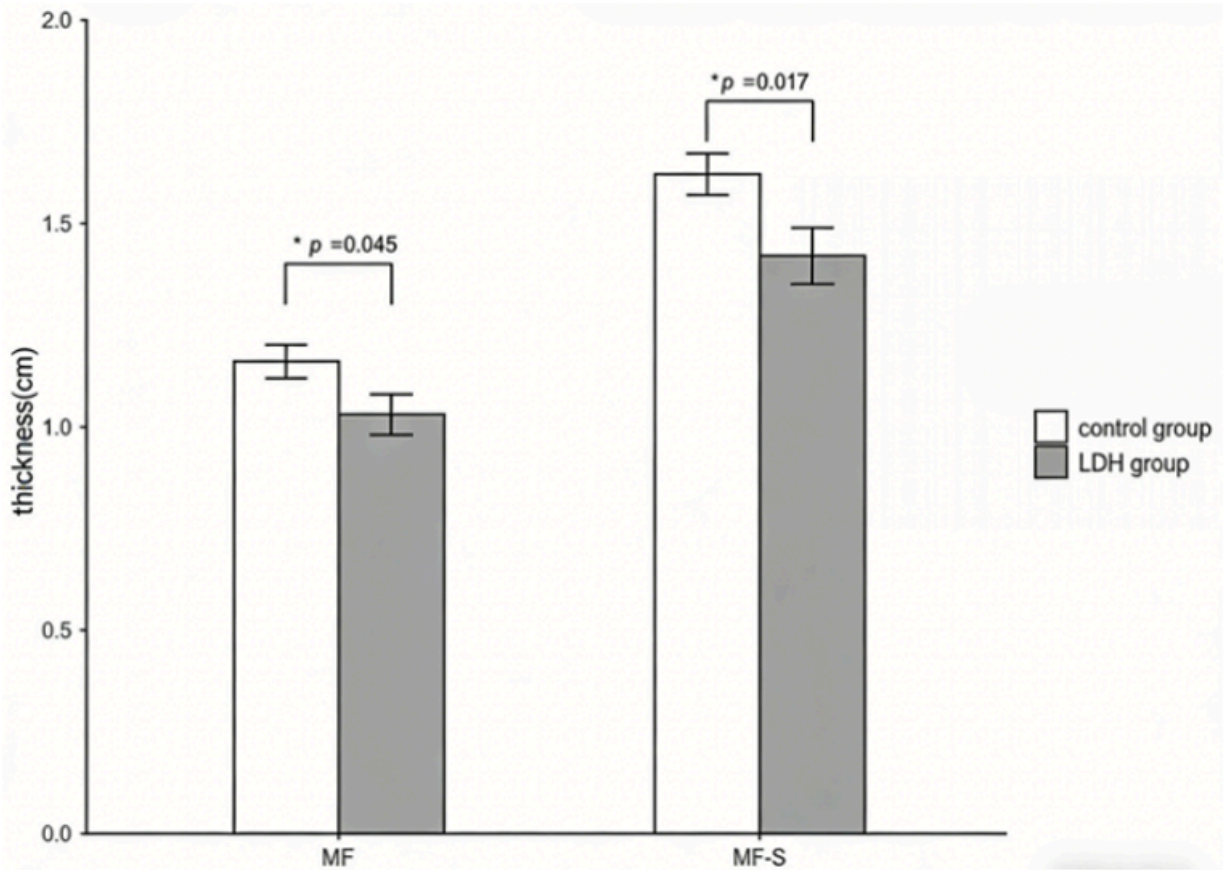


Figure 2

Comparison of resting-state and contracted-state thickness of the multifidus muscles between the LDH group and the control group

Caption: MF represents the resting-state multifidus muscle, P<0.05; MF-S represents the contracted-state multifidus muscle, P<0.05.

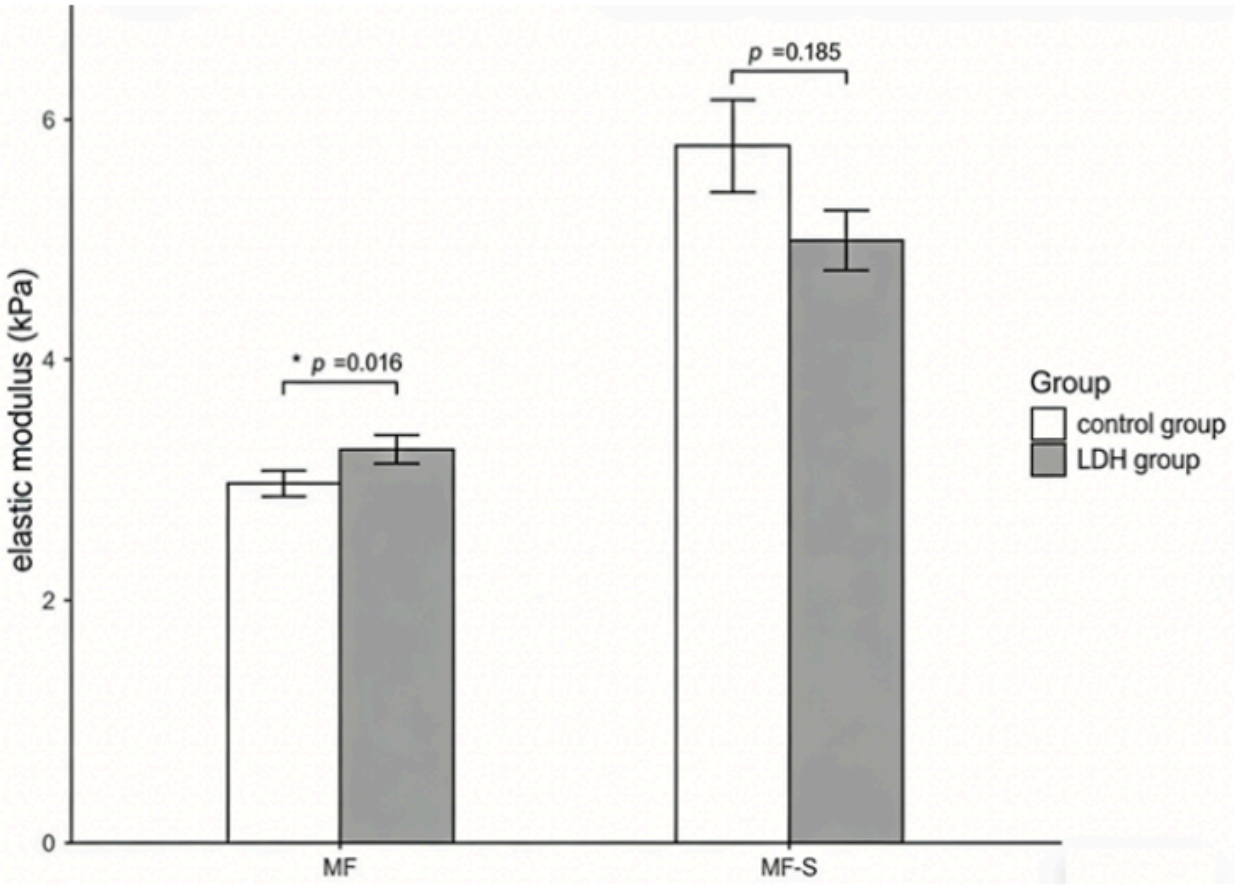


Figure 3

Comparison of resting-state and contracted-state elastic modulus of the multifidus muscles between the LDH group and the control group

Caption: MF represents the resting-state multifidus muscle, P<0.05; MF-S represents the contracted-state multifidus muscle, P>0.05.

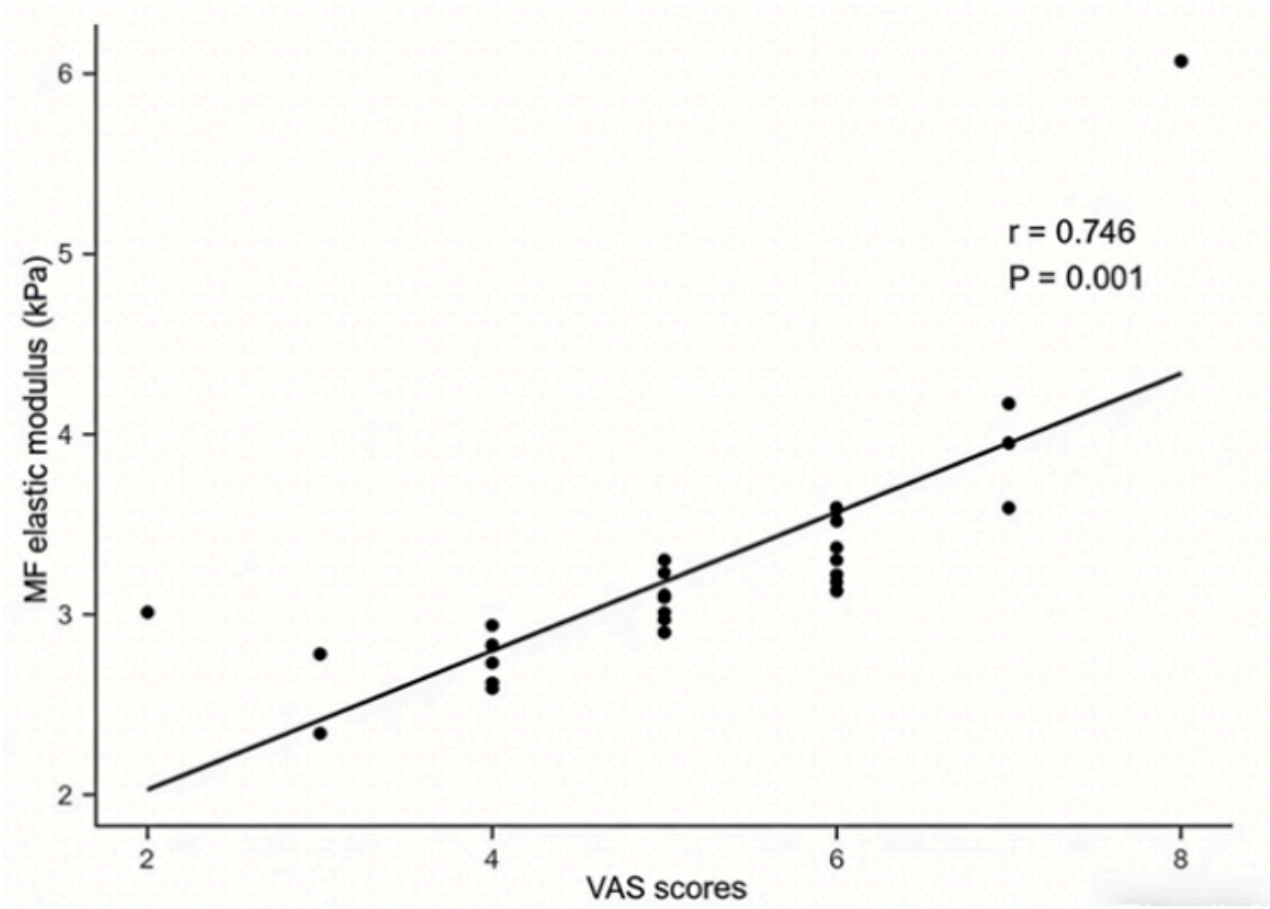


Figure 4

Relationship between VAS scores and resting-state multifidus muscle elastic modulus in the LDH group

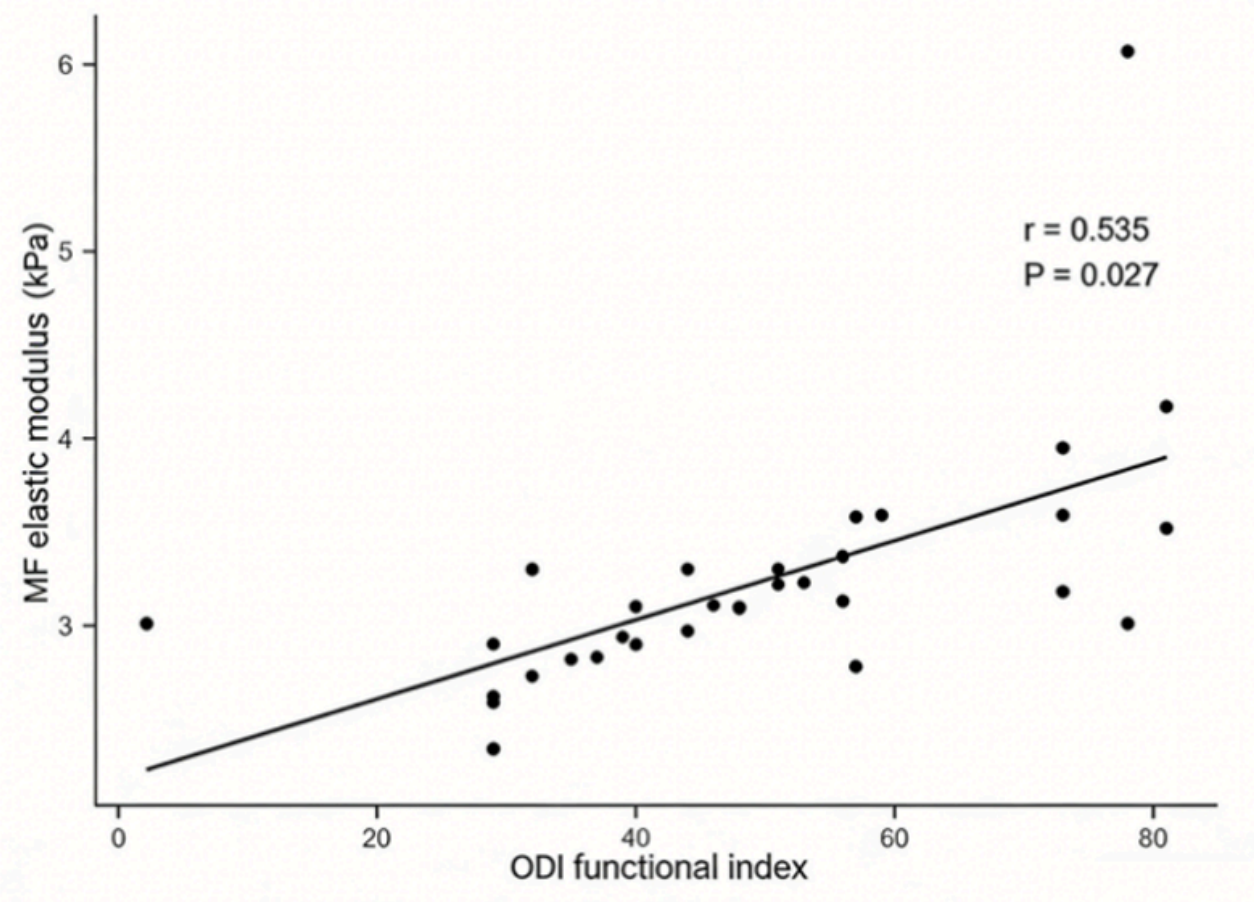


Figure 5

Figure 4: Relationship between ODI functional index and resting-state multifidus muscle elastic modulus in the LDH group

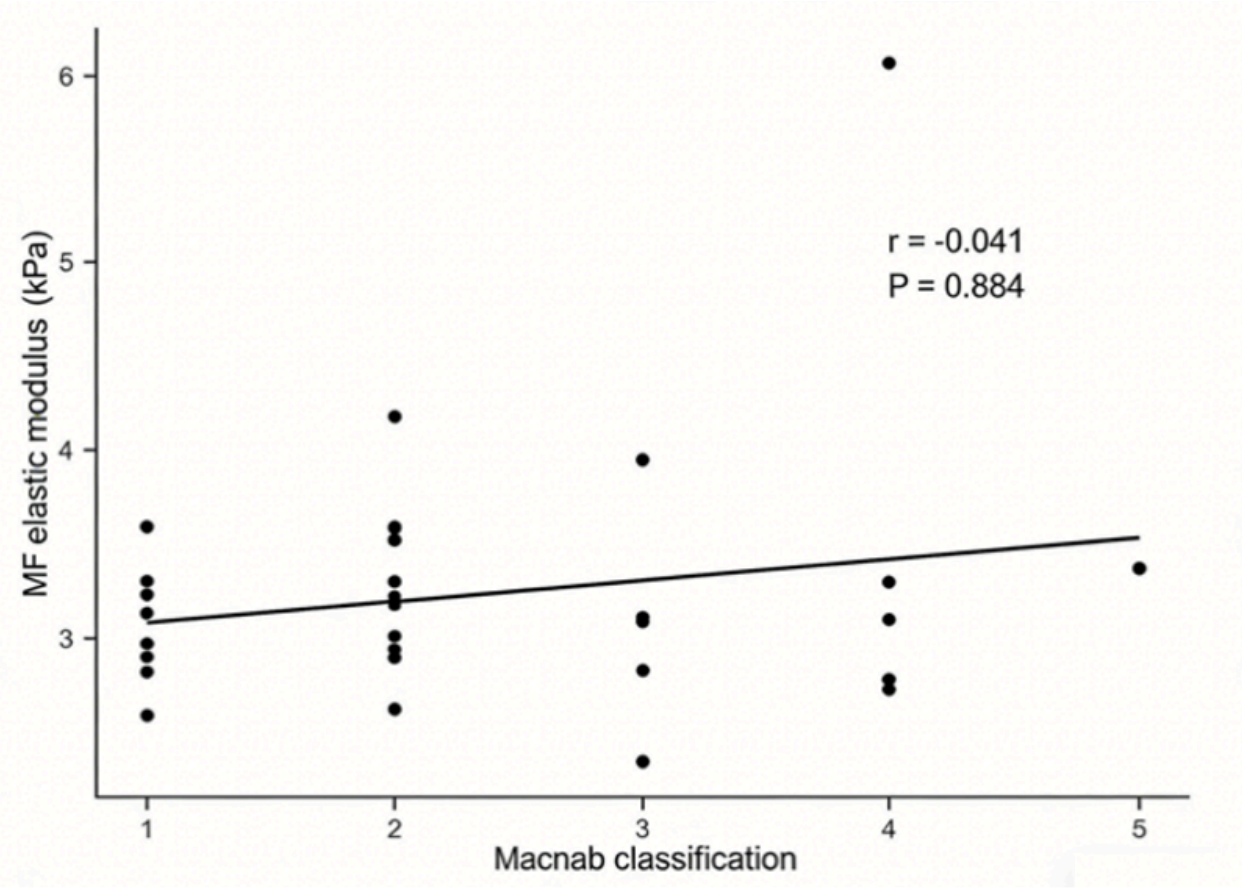


Figure 6

Figure 5: Relationship between Macnab classification and resting-state multifidus muscle elastic modulus in the LDH group