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ORIGINAL PAPER

Magnetic Resonance Imaging Evaluation of Lumbar Multifidus Muscle in Early Degenerative Changes of Lumbar Spine: a Cross-Sectional Study

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ABSTRACT

Background: *Low back pain (LBP) is a leading global cause of disability, with lumbar paraspinal muscle degeneration playing a key pathophysiological role. Lumbar multifidus muscle (LMM) atrophy, detectable on magnetic resonance imaging (MRI) as fatty infiltration, is closely associated with degenerative lumbar pathology. However, the relationship between LMM fat infiltration and co-existing degenerative changes – disc herniation, intervertebral disc degeneration (IVDD) and facet joint degeneration (FJD) – requires further characterisation.*

Methods: *This hospital-based cross-sectional study was conducted from March 2023 to February 2024. Eighty-six patients (38 males, 48 females; age 20–60 years) with clinically diagnosed LBP of ≥ three month-duration underwent 1.5 Tesla MRI lumbar spine in Assam Medical College and Hospital (AMCH), Dibrugarh, India. Lumbar multifidus muscle fat infiltration at the L4/L5 mid-disc level was graded using Goutallier's classification (Grades 0–4). Intervertebral disc degeneration was graded using Pfirrmann's system and facet joint changes by Pathria's grading. Statistical analysis was performed using Fisher's exact test.*

Results: *The majority of patients had Grade 2 LMM fat infiltration (45.34%), followed by Grade 3 (23.26%), Grade 1 (18.61%), Grade 4 (8.14%) and Grade 0 (4.66%). Disc herniation was present in 67.44% of patients, with Grade 3 being the most frequently seen (36.04%). A progressive increase in disc herniation grade was*

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observed with increasing LMM atrophy grade. Pfirrmann Grade 3 IVDD was most prevalent (27.90%). Grade 1 facet joint degeneration predominated (50.0%). Higher grades of LMM fat infiltration correlated significantly with higher grades of IVDD and FJD ($p < 0.05$).

Conclusion: *MRI-based qualitative assessment of LMM fat infiltration using Goutallier's grading is a reliable, clinically practical method that should be incorporated into routine lumbar spine reporting. Increasing LMM atrophy correlates significantly with progressive degenerative changes including disc herniation, IVDD and FJD. Targeted lumbar muscle rehabilitation should be considered as an integral component of LBP management.*

Keywords: lumbar multifidus muscle, low back pain, MRI, Goutallier classification, intervertebral disc degeneration, lumbar spine.

ABBREVIATIONS

LMM: lumbar multifidus muscle
MRI: magnetic resonance imaging
LBP: low back pain
IVDD: intervertebral disc degeneration
FJD: facet joint degeneration
CSA: cross-sectional area
DDD: degenerative disc disease
STIR: short tau inversion recovery
SD: standard deviation
SPSS: Statistical Package for the Social Sciences

INTRODUCTION

Low back pain (LBP) represents one of the foremost causes of global disability, with lifetime prevalence being estimated at 65–85% of the population (1). It ranks consistently as the leading contributor to years lived with disability (YLDs) worldwide, imposing a substantial burden on healthcare systems and socioeconomic productivity (2). Among its many determinants, paraspinal muscle degeneration – particularly atrophy of the lumbar multifidus muscle (LMM) – has attracted increasing scientific attention.

The LMM is the most medial component of the lumbar paraspinal musculature, which is unisegmentally innervated by the medial branch of the dorsal ramus of the corresponding segmental nerve (3, 4). Its segmental anatomy, intrinsic architecture, and central role in lumbar stabilisation have been characterised in detail in dedicated anatomical and rehabilitation reviews (5, 6). This unique innervation pattern renders the LMM highly susceptible to localised level-specific and side-specific atrophy in the presence of disc pathology. Experimental and biomechanical studies have demonstrated that paraspinal muscle dysfunction directly compromises segmental stiffness, alters intradiscal pressure distribution and increases load on the passive spinal elements (7-9). Atrophy of the LMM thus precipitates a pain–inhibition–atrophy cycle, and perpetuates LBP through an inhibitory feedback mechanism originating at the intervertebral discs or zygapophyseal joints (10).

Historically, cross-sectional area (CSA) measurement of paraspinal muscles using magnetic resonance imaging (MRI) or computed tomography (CT) was used to quantify atrophy (11, 12). Multiple studies using CSA-based methods have demonstrated significant multifidus and psoas atrophy in patients with unilateral sciatica, chronic LBP, and lumbar radiculopathy, with measurable asymmetry between the symptomatic and asymptomatic sides (13–18). However, qualitative assessment of MRI signal intensity – specifically Goutallier's grading of fat infiltration – has been demonstrated to be a more sensitive and reproducible method for detecting LMM atrophy compared to CSA measurement alone (4, 19) and correlates with histopathological evidence of muscle degeneration in chronic degenerative lumbar disease (20). This grading system, originally described for rotator cuff muscles, assigns scores from Grade 0 (normal muscle) to Grade 4 (predominantly fatty muscle).

Despite the extensive literature linking LMM atrophy to lumbar disc herniation, a paucity of data characterises the simultaneous evaluation of LMM fat infiltration alongside intervertebral disc degeneration (IVDD) and facet joint degeneration (FJD) (21), particularly in the Indian subcontinent population, where age- and sex-stratified data on LMM atrophy and combined MRI-based evaluation remain limited (22, 23). The present study was designed to address this gap. The primary aim was to assess LMM atrophy using Goutallier's grading at the L4/L5 level in patients with early lumbar degenerative changes, with secondary objectives to evaluate its association with disc herniation grade, Pfirrmann IVDD grade and Pathria facet joint degeneration grade.

MATERIALS AND METHODS

Study design and setting

A hospital-based cross-sectional observational study was conducted in the Department of Radiodiagnosis, Assam Medical College and Hospital (AMCH), Dibrugarh, Assam, India, over one year (March 2023 to February 2024). Ethical clearance was obtained from the Institutional Human Ethics Committee, AMCH (No. AMC/EC/PG, Dibrugarh, 2023). Written informed consent was obtained from all participants. The study adhered to the principles of the Declaration of Helsinki.

Study population and sample size

Patients clinically diagnosed with LBP presenting for MRI evaluation of the lumbar spine constituted the study population. The sample size was calculated assuming a visual grading proportion of 33% (Grade 4 infiltration) with a 10% margin of error and 95% confidence interval (CI), yielding a minimum of n=86 (4).

Inclusion criteria comprised age 20–60 years; LBP duration ≥ three months; and clinical indication for MRI lumbar spine. Exclusion criteria were prior spinal surgery; acute spinal trauma; known malignancy; and contraindications to MRI.

Magnetic resonance imaging protocol

All examinations were performed on a Siemens Magnetom Avanto-fit Tim+ Dot 1.5 Tesla whole-body MRI system (Siemens Healthineers, Erlangen, Germany). The standard lumbar spine protocol included: T2-weighted sagittal and axial sequences; T2 fat-saturated sagittal sequence (T2FS); T1-weighted sagittal and axial sequences; and STIR sequence. Images were acquired with the patient in the supine position after appropriate ferromagnetic screening.

Image assessment and grading

Lumbar multifidus muscle fat infiltration was assessed on axial T2-weighted images at the L4/L5 mid-disc level using Goutallier's grading system (Grades 0–4). Disc herniation was graded on sagittal T2 sequences *per* the severity of neural compression (Grades 1–3), in accordance with the standardised lumbar disc nomenclature (24), and IVDD was graded using Pfirrmann's five-grade classification on sagittal T2 images, alongside conventional assessment of disc desiccation, height loss, and Modic-type end-plate changes as described in established imaging frameworks for lumbar degenerative disk disease (25-27). Facet joint degeneration was evaluated on axial T2 images using Pathria's four-grade classification.

Statistical analysis

Data were entered into Microsoft Excel and analysed using SPSS version 29 (IBM Corp., Armonk, NY, USA). Categorical variables are expressed as frequency and percentage. Association between ordinal variables was tested using Fisher's exact test. A p-value <0.05 was considered statistically significant.

RESULTS

Demographic profile

The present study included 86 patients, of whom 38 (44.18%) were males and 48 (55.81%) females. Participants' age range was 20–60 years (mean±SD: 37.82±12.13 years). The majority of subjects belonged to the 21–30-year age group (34.88%), followed by 31–40 years (31.40%), 51–60 years (17.44%) and 41–50 years (16.28%). Symptom duration ranged from three to 24 months (mean±SD: 8.3±4.45 months); 83.72% of patients had a symptom duration of 3–12 months. Demographic data are summarised in Table 1.

Lumbar multifidus muscle fat infiltration

Goutallier's grading of LMM fat infiltration revealed Grade 2 infiltration as the most prevalent finding (n=39, 45.34%), followed by Grade 3 (n=20, 23.26%), Grade 1 (n=16, 18.61%), Grade 4 (n=7, 8.14%) and Grade 0 (n=4, 4.66%). Only 4.66% of patients had entirely normal LMM morphology on MRI. The distribution by sex is shown in Table 2 and Figure 1.

Disc herniation

Disc herniation was identified in 58 patients (67.44%); 28 patients (32.55%) had no disc herniation. Among those with herniation, Grade 3 (severe neural compression) was most frequent: 31 patients (36.04%) comprising 12 males (13.95%) and 19 females (22.09%). Grade 2 herniation was present in 14 patients (16.27%) and Grade 1 in 13 patients (15.12%). A progressive

Variable	Male (n=38)	Female (n=48)	Total (n=86)	P-value
Mean age (years±SD)	40.6±13.2	35.6±11.1	37.82±12.13	0.042
Age 21–30 years	11 (12.79%)	19 (22.09%)	30 (34.88%)	—
Age 31–40 years	10 (11.62%)	17 (19.76%)	27 (31.40%)	—
Age 41–50 years	5 (5.81%)	9 (10.46%)	14 (16.28%)	—
Age 51–60 years	12 (13.95%)	3 (3.48%)	15 (17.44%)	—
Mean symptom duration (months±SD)	—	—	8.3 ± 4.45	—
Duration 3–12 months	34 (39.53%)	38 (44.18%)	72 (83.72%)	—
Duration >12 months	4 (4.65%)	10 (11.63%)	14 (16.28%)	—

SD: standard deviation

TABLE 1. Demographic and clinical profile of study participants

Goutallier grade	Description	Male	Female	Total	%
Grade 0	Normal muscle — no fat	2	2	4	4.66
Grade 1	Some fatty streaks	9	7	16	18.61
Grade 2	Fat < muscle	15	24	39	45.34
Grade 3	Fat = muscle	9	11	20	23.26
Grade 4	Fat > muscle	3	4	7	8.14
Total		**38**	**48**	**86**	**100**

TABLE 2. Distribution of lumbar multifidus muscle fat infiltration grades by sex

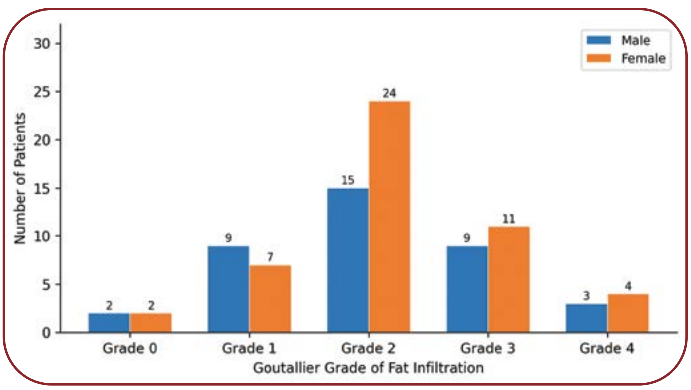

FIGURE 1. Distribution of Goutallier's grades of lumbar multifidus muscle (LMM) fat infiltration by sex (n = 86), with grouped bar chart showing the number of male and female patients across five grades (0–4). Grade 2 (fat < muscle) was the most prevalent infiltration grade overall (45.34%) and Grade 3 (fat = muscle) the second most frequent (23.26%). Female patients outnumbered males across Grades 1–4, which was consistent with the overall female predominance (55.81%) in the cohort.

LMM grade	DH cases (n)	DH grade 3 (%)	IVDD cases (n)	IVDD grade ≥3 (%)	FJD cases (n)	FJD grade ≥2 (%)
Grade 0	4	25.0	9	55.6	4	50.0
Grade 1	9	11.1	13	53.8	15	13.3
Grade 2	24	50.0	38	60.5	35	22.9
Grade 3	14	64.3	18	72.2	26	61.5
Grade 4	7	71.4	8	62.5	6	50.0

DH: disc herniation; IVDD: intervertebral disc degeneration; FJD: facet joint degeneration; LMM: lumbar multifidus muscle

TABLE 3. Cross-correlation of lumbar multifidus muscle fat infiltration grade with disc herniation, intervertebral disc degeneration and facet joint degeneration

increase in disc herniation grade was observed with ascending LMM fat infiltration grade ($p < 0.05$ by Fisher's exact test): among patients with Grade 4 LMM infiltration, 71.4% had Grade 3 disc herniation *versus* 25.0% among Grade 0 LMM.

Intervertebral disc degeneration

Pfirrmann grading demonstrated Grade 3 IVDD as the most frequent finding (n=24, 27.90%), followed by Grade 2 (25.58%), Grade 4 (22.09%), Grade 1 (12.79%) and Grade 5 (11.62%). There

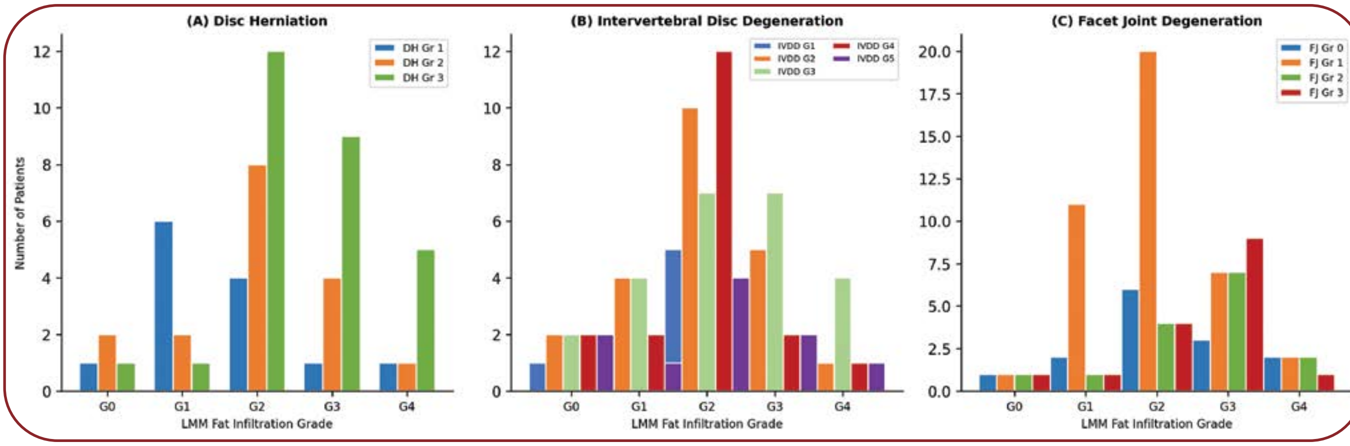

FIGURE 2. Correlation of LMM fat infiltration grades (Goutallier) with degenerative lumbar findings: (A) cross-tabulation of LMM fat infiltration grade with disc herniation grade: a progressive increase in Grade 3 disc herniation proportion was observed from Grade 0 LMM (25.0%) to Grade 4 LMM (71.4%); (B) cross-tabulation of LMM fat infiltration grade with Pfirrmann IVDD grade: higher LMM grades were associated with higher proportions of Grades 3–5 IVDD; and (C) cross-tabulation of LMM fat infiltration grade with Pathria facet joint degeneration grade, with higher LMM grades showing increasing proportions of Grade 2–3 facet degeneration. All associations were statistically significant ($p < 0.05$, Fisher's exact test). DH: disc herniation; IVDD: intervertebral disc degeneration; FJD: facet joint degeneration; LMM: lumbar multifidus muscle.

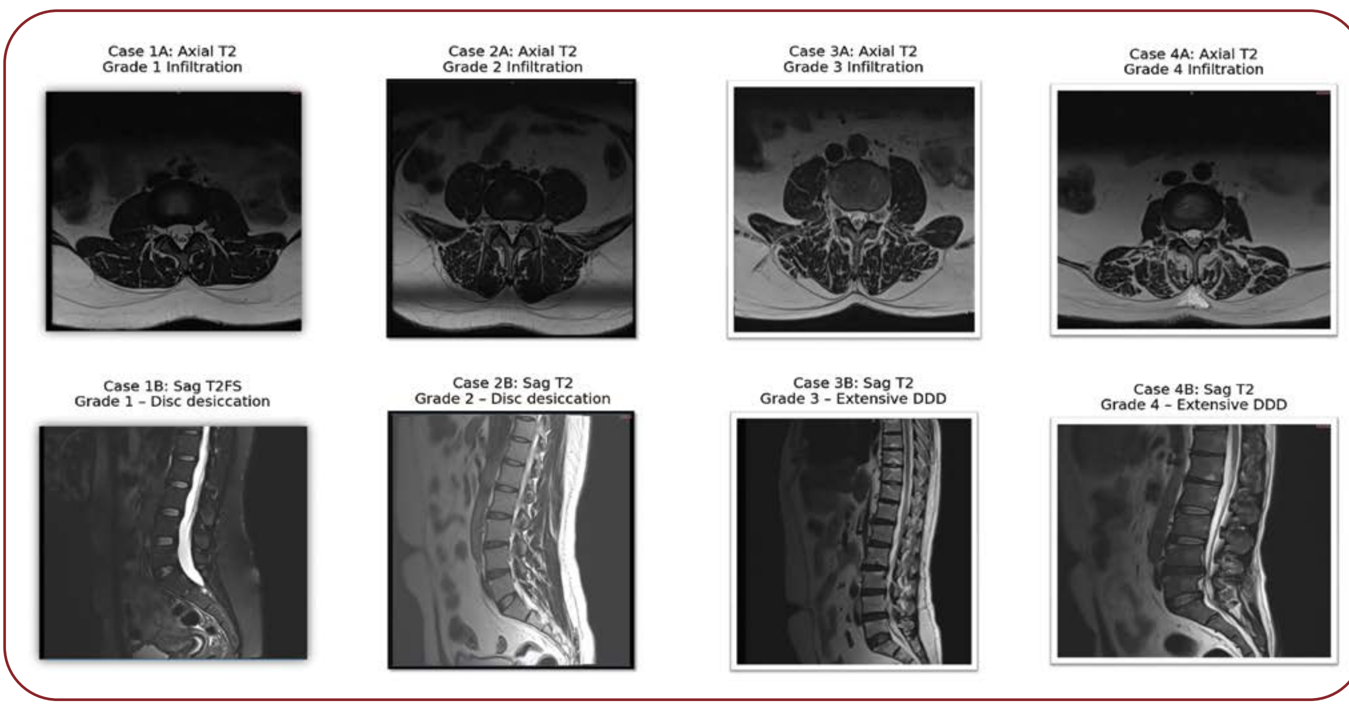

FIGURE 3. Representative magnetic resonance imaging cases illustrating the spectrum of Goutallier LMM fat infiltration grades with corresponding degenerative findings. Top row (axial T2-weighted images at L4/L5 level): Grade 1 — subtle fatty streaks within the multifidus; Grade 2 — fat less than muscle tissue; Grade 3 — fat approximately equal to muscle tissue; and Grade 4 — predominantly fatty muscle with minimal residual muscle fibres. Bottom row (sagittal T2/T2FS images);
Case 1 (Grade 1 LMM): mild disc desiccation at L5/S1 only; Case 2 (Grade 2 LMM): multi-level disc desiccation with loss of disc height; Case 3 (Grade 3 LMM): extensive disc degeneration with Modic changes and Schmorl's nodes; and
Case 4 (Grade 4 LMM): advanced multilevel DDD with disc herniation and end-plate irregularity. LMM: lumbar multifidus muscle; DDD: degenerative disc disease; T2FS: T2 fat-saturated sequence.

was a consistent trend of increasing IVDD severity with increasing LMM fat infiltration grade. Among patients with Grade 2 LMM infiltration, 38 cases of IVDD were recorded; 12 of these (13.95% of total) had Grade 4 IVDD – the highest co-occurrence.

Facet joint degeneration

Pathria's grading of facet joints showed Grade 1 degeneration in 43 patients (50.0%) — the predominant grade — followed by Grade 2 (n = 16, 18.60%), Grade 0 (n = 15, 17.44%), and Grade 3 (n = 12, 13.95%). Grade 2 LMM fat infiltration was associated with the highest number of facet joint changes (35 cases; 40.67% of total) and higher LMM grades (Grades 3–4) showed increasing proportions of Grade 2–3 FJD. Cross-correlation data for all three degenerative parameters against LMM grades are presented in Table 3 and Figure 2.

Representative cases

Representative axial T2-weighted and sagittal T2/T2FS MRI images illustrating the spectrum of Goutallier grades 1–4 LMM fat infiltration with corresponding degenerative findings are presented in Figure 3.

DISCUSSION

This study systematically evaluated LMM fat infiltration by MRI in 86 patients with LBP and correlated it with co-existing degenerative lumbar pathology. The preponderance of Grade 2 LMM infiltration (45.34%) mirrors the findings of Colakoglu and Alis (4), who described Grade 1–2 fat infiltration as the most frequent finding in patients with lumbar disc herniation. The observation that only 4.66% of patients had entirely normal LMM (Grade 0) underscores the near-universal presence of some degree of muscle degeneration in symptomatic LBP patients.

The female predominance (55.81%) in our study corroborates the globally reported higher LBP prevalence among women (1). The mean age of 37.82 years is consistent with the peak working-age burden of LBP and is somewhat lower than the mean of 44.88 years reported by Colakoglu *et al* (4), potentially reflecting the younger demographic profile of Northeast India.

In our study, disc herniation was present in 67.44% of patients, with Grade 3 herniation (severe neural compression) predominating (36.04%). The progressive increase in disc herniation severity with ascending LMM fat infiltration grade (Grade 4 LMM having 71.4% Grade 3 disc herniation) aligns with prior work by Liu *et al* in 2021, who demonstrated a bidirectional relationship between multifidus muscle degeneration and lumbar disc herniation (28). The unisegmental innervation of the LMM by the medial branch of the dorsal ramus at each level provides the neuroanatomical basis for this relationship: disc herniation causing radiculopathy leads to denervation-induced muscle atrophy, which in turn reduces spinal stability and predisposes to further disc injury – perpetuating the degenerative cascade (10).

The predominance of Pfirrmann Grade 3 IVDD (27.90%) with progressive correlation with LMM fat infiltration grades replicates the findings of Sun *et al*, who demonstrated a positive correlation between disc degeneration and LMM atrophy at the L3/L4 level (29). This correlation likely reflects shared degenerative mechanisms – proteoglycan loss, reduced intradiscal pressure and altered spinal biomechanics – that create a pro-atrophic milieu for the paraspinal musculature and contribute mechanistically to chronic low back pain (30).

Facet joint changes, graded by Pathria's system, were present in 82.55% of patients (Grade 1 or higher). Higher grades of LMM fat infiltration – particularly Grades 3 and 4 – showed increasing proportions of Grade 2–3 facet degeneration. This interdependence reflects the well-established concept that the functional spinal unit (vertebral body–IVD–facet joint complex) degenerates as a whole: disc height loss shifts axial load to facet joints, while paraspinal muscle atrophy reduces dynamic stabilisation, culminating in accelerated facet osteoarthritis (31, 32).

The practical implication of our findings is significant. Visual qualitative grading of LMM fat infiltration on routine MRI sequences does not require additional time, cost, or software – yet provides actionable information for the clinician and surgeon. Pre-surgical knowledge of the degree of LMM dysfunction is particularly valuable in planning lumbar decompression or fusion surgeries, given the established negative impact of LMM atrophy on post-surgical rehabilitation outcomes (4). Furthermore, our data support the integration of structured lumbar muscle strengthening programmes into the non-operative management of LBP, in line with evidence that active rehabilitation improves outcomes in chronic LBP (33) and that sagittal alignment and paraspinal muscle morphology are inter-related determinants of clinical outcome in degenerative lumbar disease (34).

CONCLUSIONS

Magnetic resonance imaging-based qualitative assessment of lumbar multifidus muscle fat infiltration using Goutallier's grading system is a simple, reliable and clinically actionable tool that should be incorporated into routine lumbar spine MRI reporting protocols. In the present study, Grade 2 fat infiltration was the most prevalent finding, with the majority of symptomatic LBP patients demonstrating at least Grade 1 LMM atrophy. Higher grades of LMM fat infiltration correlated significantly with increasing severity of disc herniation, IVDD and facet joint degeneration, confirming the integral role of LMM dysfunction in the degenerative lumbar spine cascade. These findings advocate for the routine assessment of LMM morphology in surgical planning and highlight the importance of targeted lumbar muscle rehabilitation as a therapeutic strategy in the management of low back pain. ❑

Conflicts of interest: none declared.

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References

1. **Hoy D, Bain C, Williams G, et al.** A systematic review of the global prevalence of low back pain. *Arthritis Rheum* 2012;64:2028-2037.
2. **Wu A, Dong W, Liu S, et al.** The prevalence and years lived with disability caused by low back pain in China, 1990 to 2016. *Pain* 2019;160:237.
3 **Battié MC, Niemelainen R, Gibbons LE, Dhillon S.** Is level- and side-specific multifidus asymmetry a marker for lumbar disc pathology? *Spine J* 2012;12:932-939.
4. **Colakoglu B, Alis D.** Evaluation of lumbar multifidus muscle in patients with lumbar disc herniation. *J Int Med Res* 2019;47:3590-3600.
5. **Danneels L, Dickx N, Cagnie B.** The lumbar multifidus: from anatomy to rehabilitation. 7th Interdisciplinary World Congress on Low Back and Pelvic Pain. 2010.
6. **MacDonald DA, Moseley GL, Hodges PW.** The lumbar multifidus: does the evidence support clinical beliefs? *Man Ther* 2006;11:254-263.
7. **Kong WZ, Goel VK, Gilbertson LG, Weinstein JN.** Effects of muscle dysfunction on lumbar spine mechanics. *Spine* 1996;21:2197.
8. **Wilke HJ, Wolf S, Claes LE, et al.** Influence of varying muscle forces on lumbar intradiscal pressure. *J Biomech* 1996;29:549-555.
9. **Oxland TR.** Fundamental biomechanics of the spine. *J Biomech* 2016;49:817-832.
10. **Freeman MD, Woodham MA, Woodham AW.** The role of the lumbar multifidus in chronic low back pain: a review. *PM&R* 2010;2:142-146.
11. **Lee HJ, Lim WH, Park JW, et al.** The relationship between cross sectional area and strength of back muscles in patients with chronic low back pain. *Ann Rehabil Med* 2012;36:173.
12. **Danneels LA, Vanderstraeten GG, Cambier DC, et al.** CT imaging of trunk muscles in chronic low back pain patients. *Eur Spine J* 2000;9:266-272.
13. **Kim WH, Lee SH, Lee DY.** Changes in the cross-sectional area of multifidus and psoas in unilateral sciatica caused by lumbar disc herniation. *J Korean Neurosurg Soc* 2011;50:201.
14. **Dangaria TR, Naesh O.** Changes in cross-sectional area of psoas major muscle in unilateral sciatica caused by disc herniation. *Spine* 1998;23:928-931.
15. **Lee HI, Song J, Lee HS, et al.** Association between cross-sectional areas of lumbar muscles on MRI and chronicity of low back pain. *Ann Rehabil Med* 2011;35:852-859.
16. **Chon J, Kim HS, Lee JH, et al.** Asymmetric atrophy of paraspinal muscles in patients with chronic unilateral lumbar radiculopathy. *Ann Rehabil Med* 2017;41:801-807.
17. **Hyun JK, Lee JY, Lee SJ, Jeon JY.** Asymmetric atrophy of multifidus muscle in patients with unilateral lumbosacral radiculopathy. *Spine* 2007;32:E598-E602.
18. **Kader DF, Wardlaw D, Smith FW.** Correlation between the MRI changes in the lumbar multifidus muscles and leg pain. *Clin Radiol* 2000;55:145-149.
19. **Hildebrandt M, Fankhauser G, Meichtry A, Luomajoki H.** Correlation between lumbar dysfunction and fat infiltration in lumbar multifidus muscles. *BMC Musculoskelet Disord* 2017;18:12.
20. **Shahidi B, Hubbard JC, Gibbons MC, et al.** Lumbar multifidus muscle degenerates in individuals with chronic degenerative lumbar spine pathology. *J Orthop Res* 2017;35:2700-2706.
21. **van der Graaf JW, Kroeze RJ, Buckens CFM, et al.** MRI image features with an evident relation to low back pain. *Eur Spine J* 2023;32:1830-1841.
22. **Ekin EE, Yıldız HK, Mutlu H.** Age and sex-based distribution of lumbar multifidus muscle atrophy. *Diagn Interv Radiol* 2016;22:273.
23. **Vohra P, Kasana VP, Arya RK.** Role of

MRI and ultrasonography in evaluation of multifidus muscle in chronic low back pain patients.
Int J Res Med Sci 2016;4:5302-5309.
24. **Fardon DF, Williams AL, Dohring EJ, et al.** Lumbar disc nomenclature: version 2.0.
Spine 2014;39:E1448-E1465.
25. **Modic MT, Masaryk TJ, Ross JS, Carter JR.** Imaging of degenerative disk disease.
Radiology 1988;168:177-186.
26. **Emch TM, Modic MT.** Imaging of lumbar degenerative disk disease.
Skeletal Radiol 2011;40:1175-1189.
27. **Roudsari B, Jarvik JG.** Lumbar spine MRI for low back pain.
AJR Am J Roentgenol 2010;195:550-559.
28. **Liu C, Xue J, Liu J, et al.** Is there a correlation between upper lumbar disc herniation and multifidus muscle degeneration?
BMC Musculoskelet Disord 2021;22:92.
29. **Sun D, Liu P, Cheng J, et al.** Correlation between intervertebral disc degeneration, paraspinal muscle atrophy, and lumbar facet joints degeneration in patients with lumbar disc herniation.
BMC Musculoskelet Disord 2017;18:167.
30. **Diwan AD, Melrose J.** Intervertebral disc degeneration and how it leads to low back pain.
JOR Spine 2023;6:e1231.
31. **Bogduk N.** Degenerative joint disease of the spine.
Radiol Clin North Am 2012;50:613-628.
32. **Adams MA, Roughley PJ.** What is intervertebral disc degeneration, and what causes it?
Spine 2006;31:2151-2161.
33. **Käser L, Mannion AF, Rhyner A, et al.** Active therapy for chronic low back pain.
Spine 2001;26:909.
34. **Hiyama A, Katoh H, Sakai D, et al.** The correlation analysis between sagittal alignment and cross-sectional area of paraspinal muscle in patients with lumbar spinal stenosis.
BMC Musculoskelet Disord 2019;20:352.