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ORIGINAL ARTICLE

Correlation between lower lumbar multifidus muscles fatty atrophy and corresponding level degenerative diseases in patients with low back pain using MRI

Jiufa Cui[1] · Ruizhi Zhou[1] · Na Tian[1] · Xueqing Sui[1] · Mingqian Huang[2] · Dapeng Hao[1] · Wenjian Xu[1]

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Abstract

Purpose To investigate the potential correlation between multifidus muscles (MM) fatty atrophy and MR signs of lumbar spine degeneration in patients with low back pain (LBP).

Methods Following IRB approval, lumbar spine MRI of 518 patients (278 females and 240 males; age, 10–92 years) with LBP were retrospectively reviewed by two experienced musculoskeletal radiologists. MM fatty atrophy was graded at L4–5 and L5–S1 levels per modified Goutallier classification. Disc degeneration, herniation was graded according to Pfirrmann classification, and facet joint osteoarthritis was graded according to Fujiwara classification. Gender, age and body mass index (BMI) were recorded as well. Mann–Whitney *U* test was used to determine whether there was a difference in fatty atrophy between woman and man. Kendall's tau-*b* coefficient and ordinal multiple logistic regression were used to evaluate relationship between MM fatty atrophy and signs of lumbar spine degeneration. Intra-observer agreement was tested using weighted Kappa.

Results There was significant difference among the grades of fatty atrophy between woman and man. Both at L4–L5 and L5–S1 levels, correlation between MM fatty atrophy with age, disc degeneration, facet joint osteoarthritis was significant ($p < 0.001$). No correlation was found between MM fatty atrophy with BMI, disc herniation at L4–5 ($p = 0.187$, 0.307) and L5–S1 ($p = 0.307$, 0.927). Among the independent variables included in the logistic regression model, gender, age and facet joint osteoarthritis at L4–5 level were statistically significant. Older people (OR = 1.11 at L4–5 level; OR = 1.08 at L5–S1 level), women (OR = 5.88 at L4–5 level; OR = 7.46 at L5–S1 level) with higher-grade facet joint osteoarthritis at L4–5 level (OR = 0.14, 0.26, 0.34; Grade 4 as reference) are more prone to MM fat degeneration than younger people, man and lower-grade facet joint osteoarthritis ($p < 0.001$). Intra-observer agreement was good with Kappa value range from 0.79 to 0.98.

Conclusion In patients with low back pain, MM fatty atrophy in the lower lumbar spine was related to age, gender, facet joint osteoarthritis at L4–5 levels.

Keywords Lumbar vertebrae · Paraspinal muscles · Atrophy · Magnetic resonance imaging · Low back pain

Introduction

Low back pain (LBP) is one of the most common reason for seeking medical help in the world [1]. Degenerative diseases of the lumbar spine are the leading cause of LBP and radiculopathy [2]. There are several interrelated processes, such as disc herniation, disc degeneration and facet joint osteoarthritis, that are considered under the heading of spinal degeneration [3]. Para-spinal muscle abnormalities, including decrease in size of the muscles (atrophy) and/or replacement of muscle fibres by fat (fatty degeneration) [4], are common in patients with LBP [5]. Several studies have demonstrated that selected ipsilateral atrophy of para-spinal

✉ Wenjian Xu
13963952822@163.com

[1] Department of Radiology, The Affiliated Hospital of Qingdao University, 16 Jiangsu Road, Qingdao 266003, Shandong, People's Republic of China

[2] Department of Radiology, Stony Brook University Hospital, Stony Brook, NY, USA

muscles tend to occur on the symptomatic side in patients with unilateral LBP [6, 7].

Among the para-spinal muscles, the multifidus muscle (MM) has some primacy due to its large contribution to lumbar spine segmental stability [8]. It seems that MM is an early marker of spinal degenerative changes [9–11], with several studies showing a relationship with disc degeneration [12, 13], as well as disc herniations [13–16]. However, these studies have conflicting results.

MRI grades have been used as reference standards for muscle atrophy as well as disc degeneration [17–20]. Hence, we sought to study the correlation between MM fatty atrophy in lower lumbar spine with disc degeneration, herniation and facet osteoarthritis through MRI.

Patients and methods

Patients

This retrospective study was approved by the institutional review board of our hospital, with a waiver of informed consent. Patients, who had self-reported LBP and an MRI of lumbar spine between June 2017 and July 2018 were first selected for this study. Any patients with spondylolysis and spondylolisthesis of the lumbar spine or with history of previous lumbar spine surgery were excluded. Gender, Age, and BMI were also recorded.

In total, lumbar spine MRI of 518 patients (278 females and 240 males; age, 10–92 years; mean, 49.99 ± 17.596 years) with LBP were included in the study. Among these patients, 18 had acute LBP, 117 had subacute LBP, and 383 had chronic low back pain. The duration of symptoms ranged from 6 days to 7 months. At the time of visit, 397 had nonspecific LBP, and 121 had LBP associated with radiculopathy. LBP severity was evaluated by Japanese Orthopaedic Association (JOA) scores ranging from 2 to 28.

MR procedure

MRI were performed on either 1.5T or 3.0T MR scanner with body spine surface coil. MR protocols included T2-weighted spin-echo sagittal (TR/TE 3000–4000/100–120 ms, Slice 4 mm, matrix 320×320, FOV 350 mm), T2 STIR (Short Tau Inversion Recovery) sagittal (TR/TE 4000–5000/110 ms, Slice 4 mm, matrix 320×320, FOV 350 mm), T2-weighted spin-echo axial (TR/TE 3000–4000/100–120 ms, Slice 4 mm, matrix 256×256, FOV 250–290 mm), T1-weighted spin-echo sagittal (TR/TE 400–600/15–25 ms, Slice 4 mm, matrix 256×256, FOV 350 mm). The axial sequences were acquired along the plane of each disc.

Imaging analysis

All available images were retrospectively reviewed twice by two musculoskeletal radiologists (with 9 years and 20 years of experience) to determine interobserver agreement. Discrepancies were subsequently resolved by consensus. MM fatty atrophy, disc degeneration, disc herniation and facet joint osteoarthritis were graded twice at L4–L5 and L5–S1 levels. The multifidus muscle has the largest diameter at L4–L5 and L5–S1 levels, allowing for a better evaluation [21].

MM fatty atrophy was graded on T2-weighted, without fat-suppressed, axial MR images [17]: grade 0 for normal muscle, grade 1 for fatty streaks within the muscle (Fig. 1a), grade 2 for fat less than muscle (Fig. 1b), grade 3 for fat equal to muscle (Fig. 1c), grade 4 for fat greater than muscle (Fig. 1d).

Disc degeneration was graded on T2-weighted sagittal MR images [18]. If the signal of the disc is homogeneous, with bright hyper-intense signal and without loos of disc height, then Grade 1. If there is inhomogeneous signal in the disc, with a hyper-intense signal and distinction between nucleus and anulus is clear, and the disc height is normal, with or without horizontal grey bands, then Grade 2. If the signal of the disc is inhomogeneous, with intermediate grey signal and distinction between nucleus and anulus is unclear, and with preserved or mild loss of disc height, then Grade 3. If the signal of the disc is inhomogeneous with hypo-intense dark grey signal and distinction between nucleus and anulus is lost, and the disc height is normal or moderately decreased, then Grade 4. If the signal of the disc is inhomogeneous, with hypo-intense black signal and distinction between nucleus and anulus is lost, with collapsed disc height, then Grade 5.

Disc herniations were visually graded on T2-weighted axial and sagittal MR images [19]: no compromise of the nerve root is seen. There is no evident contact of disc material with the nerve root, and the epidural fat layer between the nerve root and the disc material is preserved (Grade 0, normal). There is visible contact of disc material with the nerve root, and the normal epidural fat layer between the two is not evident. The nerve root has a normal position, and there is no dorsal deviation (Grade 1, contact). The nerve root is displaced dorsally by disc material (Grade 2, deviation). The nerve root is compressed between disc material and the wall of the spinal canal; it may appear flattened or be indistinguishable from disc material (Grade 3, compression).

Facet joint osteoarthritis was graded on T2-weighted axial MR images [20]: grade 1, normal (Fig. 2a); grade 2, joint space narrowing or mild osteophyte (Fig. 2b); grade 3, sclerosis or moderate osteophyte (Fig. 2c); and grade 4, marked osteophyte (Fig. 2d).

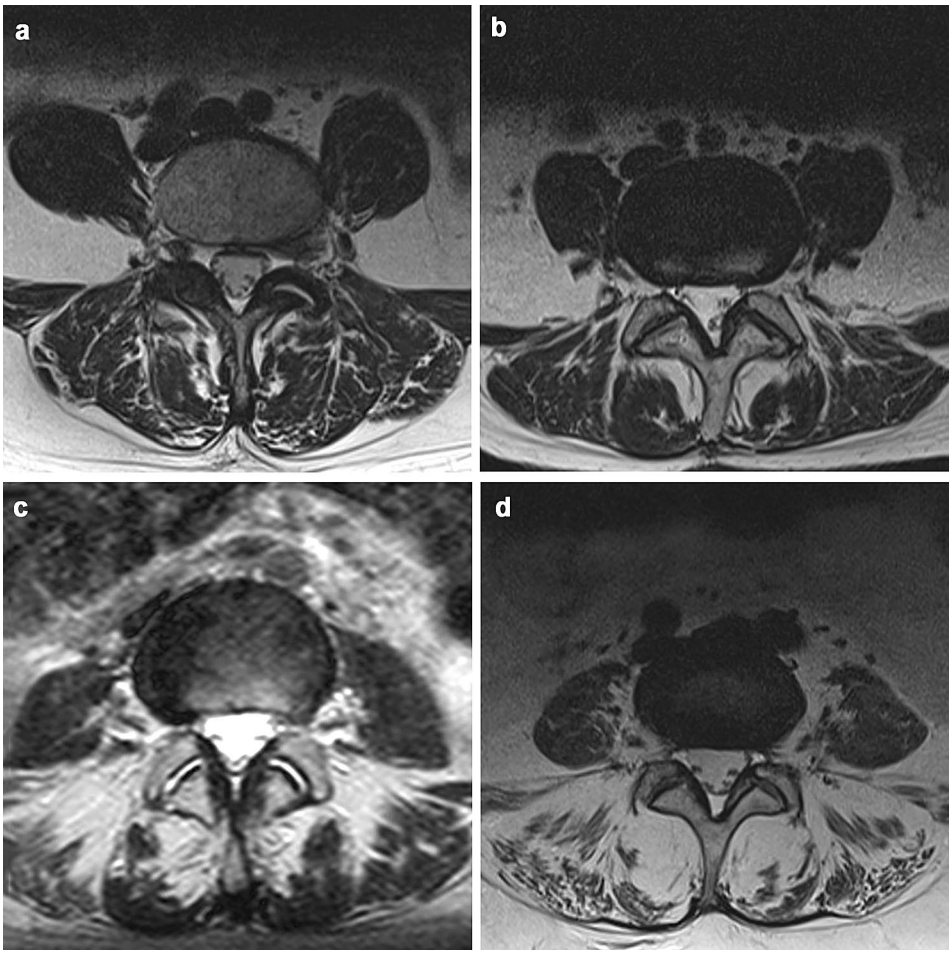

Fig. 1 **a** Axial T2-weighted MR image at L4–L5 level demonstrates fatty streaks within the muscle (Goutallier grade 1); **b** Axial T2-weighted MR image at L4–L5 level demonstrates fat is less than muscle (Goutallier grade 2); **c** Axial T2-weighted MR image at L4–L5 level demonstrates fat and muscle are equal (Goutallier grade 3); **d** Axial T2-weighted MR image at L4–L5 level demonstrates fat is greater than equal (Goutallier grade 4)

Statistical analysis

SPSS software was used for all the statistical analyses (IBM SPSS statistics 26). The significance level was set at $p < 0.05$. Mann–Whitney U test was used to determine whether there was a difference in fatty atrophy between woman and man. First, Kendall's tau-b coefficient was used to evaluate relationship between MM fatty atrophy with age, BMI and signs of lumbar spine degeneration, such as grades of disc degeneration, disc herniation and facet joint osteoarthritis. The variables with statistical significance were included in the ordinal multiple logistic regression model as a forward stepwise method. The odds ratio was used as a measure of the relative magnitude of an association between the variables and high-grade MM fatty atrophy. The interobserver agreement was tested using the weighted Kappa coefficient. Kappa of 0.41–0.60 was interpreted as fair agreement, 0.61–0.80 as good agreement, and 0.81–0.99 as excellent agreement [22].

Results

Tables 1, 2 summarised statistic results about the correlation between MM fatty atrophy with gender, age, BMI and MR signs of lumbar spine degeneration in patients with LBP.

Mann–Whitney U test showed that there was significant difference in the grades of MM fatty atrophy at L4–5 level ($U = 24{,}374.500$, $p < 0.001$) and L5–S1 level ($U = 19{,}564.500$, $p < 0.001$) between men and women. At both L4–L5 and L5–S1 levels, a significant correlation was demonstrated between MM fatty atrophy with age ($p < 0.001$). Kendall's tau-b correlation coefficients were 0.533 at L4–L5 level and 0.430 at L5–S1 level, respectively.

At the L4–L5 level, significant correlations were demonstrated between MM fatty atrophy with disc degeneration (Kendall's tau-$b = 0.379$, $p < 0.001$) and facet joint osteoarthritis (Kendall's tau-$b = 0.452$, $p < 0.001$). At the L5–S1 level, correlation between MM fatty atrophy with disc degeneration (Kendall's tau-$b = 0.301$, $p < 0.001$) and facet joint osteoarthritis (Kendall's tau-$b = 0.315$, $p < 0.001$)

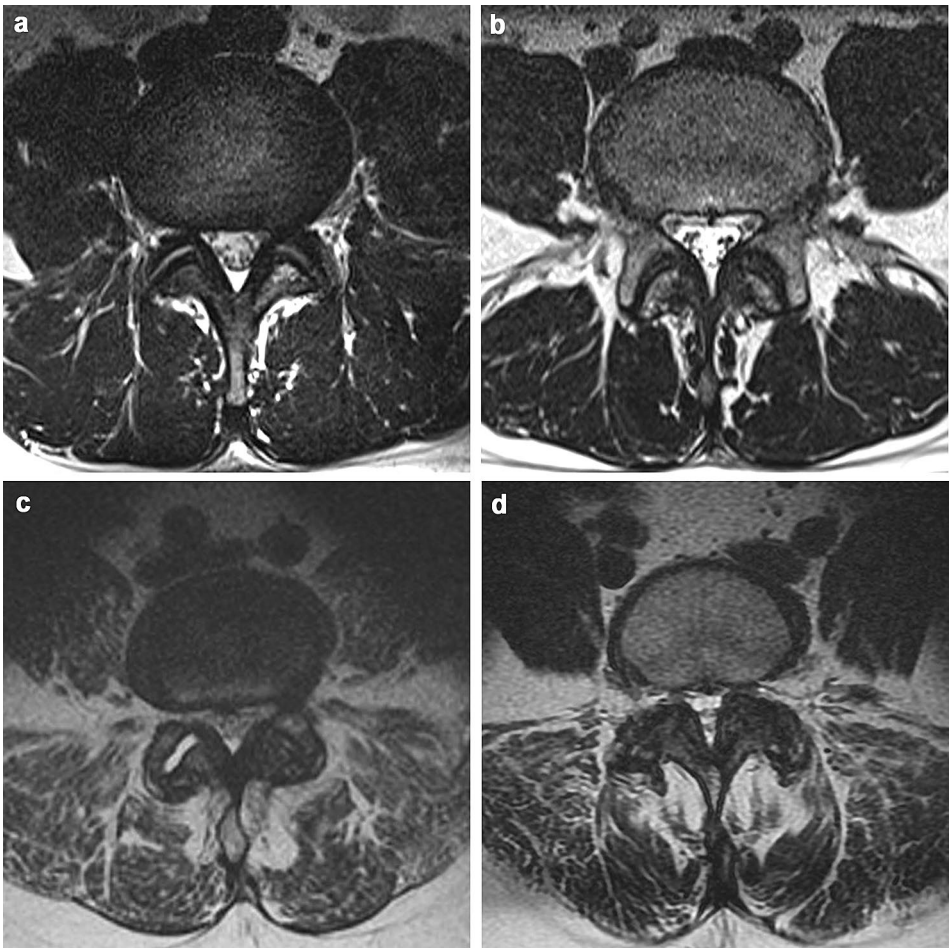

Fig. 2 **a** Axial T2-weighted MR image at L4–L5 level shows normal facet joint (Fujiwara grade 1); **b** Axial T2-weighted MR image at L4–L5 level shows narrow facet joint space without distinct osteophyte (Fujiwara grade 2); **c** Axial T2-weighted MR image at L4–L5 level shows sclerosis facet joint with moderate osteophyte (Fujiwara grade 3); **d** Axial T2-weighted MR image at L4–L5 level shows obscure facet joint with marked osteophyte (Fujiwara grade 4)

Table 1 Nonparametric tests of MM fatty atrophy at L4–L5 and L5–S1 levels

	L4–5	L5–S1
Gender[a]	$U = 24{,}374.500$, $p < 0.001$	$U = 19{,}564.500$, $p < 0.001$
Age[b]	0.533, $p < 0.001$	0.430, $p < 0.001$
BMI[b]	0.051, $p = 0.187$	0.026, $p = 0.487$
Disc degeneration[b]	0.379, $p < 0.001$	0.301, $p < 0.001$
Disc Herniation[b]	− 0.041, $p = 0.307$	− 0.004, $p = 0.927$
Facet joint osteoarthritis[b]	0.452, $p < 0.001$	0.315, $p < 0.001$

MM multifidus muscles

[a]Mann–Whitney *U* tests

[b]Kendall's tau-*b*

was significant. There was no correlation between MM fatty atrophy and BMI, at L4–L5 level (Kendall's tau-$b = 0.051$, $p = 0.187$) and L5–S1 level (Kendall's tau-$b = 0.026$, $p = 0.307$). There was also no correlation between MM fatty atrophy and disc herniation, at either L4–L5 level (Kendall's tau-$b = -0.041$) or L5–S1 level (Kendall's tau-$b = -0.004$) with p values at 0.307 and 0.927, respectively.

Of the variables studied in the ordinal multiple logistic regression model, women have an increased risk of MM fat atrophy compared with men at L4–5 level (odds ratio of 5.88; 95% confidence interval 3.86–9.01; $p < 0.001$) and L5–S1 level (odds ratio (OR) of 7.46; 95% confidence interval (CI) 5.08–10.87; $p < 0.001$). At L4–5 level, the risk of MM fat atrophy increased by 1.11 times (95% CI 1.09–1.13) with the increase of age ($p < 0.001$). At L5–S1 level, the risk of MM fat atrophy increased by 1.08 times (95% CI 1.06–1.09) with the increase of age ($p < 0.001$). Compared with grade 5 group of disc degeneration at L4–5 level, there was no statistical difference in grade 1 group (OR 0.37; 95% CI 0.12–1.15; $p = 0.37$), grade

Table 2 Results of final multivariate regression model

	L4–5		L5–S1	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Gender				
Female	5.88 (3.86–9.01)	< 0.001	7.46 (5.08–10.87)	< 0.001
Male	1		1	
Age	1.11 (1.09–1.13)	< 0.001	1.08 (1.06–1.09)	< 0.001
Disc degeneration				
Grade 1	0.37 (0.12–1.15)	0.085	0.30 (0.13–0.68)	0.004
Grade 2	0.80 (0.39–1.65)	0.549	0.62 (0.33–1.15)	0.129
Grade 3	0.85 (0.45–1.60)	0.614	0.80 (0.44–1.44)	0.452
Grade 4	0.75 (0.43–1.32)	0.321	0.74 (0.43–1.26)	0.260
Grade 5	1		1	
Facet joint osteoarthritis				
Grade 1	0.14 (0.06–0.33)	< 0.001	0.24 (0.08–0.71)	0.010
Grade 2	0.26 (0.11–0.62)	0.002	0.39 (0.13–1.19)	0.096
Grade 3	0.34 (0.14–0.86)	0.022	0.43 (0.12–1.48)	0.178
Grade 4	1		1	

OR odds ratio, *CI* confidence interval

2 group (OR 0.80; 95% CI 0.39–1.65; $p = 0.549$), grade 3 group (OR 0.85; 95% CI 0.45–1.60; $p = 0.614$), and grade 4 group (OR 0.75; 95% CI 0.43–1.32; $p = 0.321$). Compared with grade 5 group of disc degeneration at L5–S1 level, grade 1 group was 0.30 (95% CI 0.13–0.68; $p = 0.004$) times more likely to have advanced MM fatty atrophy grade. There was no statistical difference in grade 2 group (OR 0.62; 95% CI 0.33–1.15; $p = 0.129$), grade 3 group (OR 0.80; 95% CI 0.44–1.44; $p = 0.452$), and grade 4 group (OR 0.74; 95% CI 0.43–1.26; $p = 0.260$), compared with grade 5 group. Compared with grade 4 group of facet joint osteoarthritis at L4–5 level, grade 1 group, grade 2 group, and grade 3 group were 0.14 (95% CI 0.06–0.33; $p < 0.001$), 0.26 (95% CI 0.11–0.62; $p = 0.002$) and 0.34 (95% CI 0.14–0.86; $p = 0.022$) times more likely to have advanced MM fatty atrophy grade. Compared with grade 4 group of facet joint osteoarthritis at L5–S1 level, grade 1 group were 0.24 (95% CI 0.08–0.71; $p = 0.010$) times more likely to have advanced MM fatty atrophy grade. There was no statistical difference in grade 2 group (OR 0.39; 95% CI 0.13–1.19; $p = 0.096$), grade 3 group (OR 0.43; 95% CI 0.12–1.48; $p = 0.178$), compared with grade 4 group.

The interobserver agreements in the classification were as follows: MM fatty atrophy (Kappa value = 0.90, 0.89), disc degeneration (Kappa value = 0.87, 0.89), disc herniation (Kappa value = 0.98, 0.97), and facet joint osteoarthritis (Kappa value = 0.81, 0.79) at the L4–5, L5–S1 levels, respectively. There was good to excellent interobserver agreement (Kappa value, 0.79–0.98).

Discussion

MRI offers us the ability to evaluate many components of the lower lumbar spine stability simultaneously. Combined with additional information of patient's general health condition of age, gender, BMI, we could study the potential correlation of MM fatty atrophy with lumbar spine degenerative process at L4–5 and L5–S1 levels. The study shows that women are more prone to MM fat atrophy than men, the risk of MM fat atrophy increased with age, and high-grade facet joint osteoarthritis were more likely to have advanced MM fatty atrophy grade at L4–5 level. This would hopefully shed light into understanding and further exploration of the pathophysiology and epidemiology of lumbar spine degenerative process.

CT, MRI, and ultrasound (US) have all been used for assessing structural changes of the para-spinal muscles in patients with LBP [13, 23–27]. These assessments can be semi-quantitative and quantitative. The former includes histograms and visual grading method for muscle atrophy. The latter includes proton MR spectroscopy (MRS) [28, 29] and chemical shift MRI [30] for evaluation of fatty degeneration. There are advantages and disadvantages of each method, without a clear gold standard. We employed the semi-quantitative visual grading method in this study, because of its ease of implementation and good reproducibility [31].

Several previous studies had demonstrated that MM fatty atrophy is more common in woman, and can increase

with advanced age [21, 23, 32, 33]. Nakagaki et al. [34] reported that body mass index (BMI, weight in kilograms divided by the square of the height in metres) does not appear to reflect muscular fat content. Our results confirmed these findings that significant correlation exists between MM fatty atrophy and age, gender, but not with BMI.

Anatomically, ventral spinal elements (disc/annulus) are innervated separately from posterior spinal elements (facet joints, posterior muscles) [35, 36]. The facet joints and MM are both supplied by the median branch of dorsal ramus which supplies the posterior innervation. This pattern of spinal innervation may explain the correlation between MM fatty atrophy and facet joint osteoarthritis as well as the lack of correlation between disc degeneration with MM fatty atrophy. Additionally, an electromyographic study on porcine MM has shown that stimulation of the facet joint capsule will produce contraction in MM, suggesting that there may be interactive responses between them [11]. Multiple studies have pointed out that disc degeneration precedes facet joint osteoarthritis [37, 38]. And facet joint osteoarthritis is usually associated with advanced disc degeneration, and it may take many years to develop facet joint osteoarthritis following onset of disc degeneration [20]. Thus, it is reasonable to postulate that MM fatty atrophy occurs many years after onset of disc degeneration with additional influence from facet joint osteoarthritis and explaining our results of the significant correlation existed between MM fatty atrophy with facet joint osteoarthritis and advanced age at both levels, but no strong relationship with disc degeneration.

Histological studies have shown a change in distribution of muscle fibre types and a reduction of muscle size in patients with intervertebral disc herniations [39, 40]. However, imaging studies about the relationship between MM fatty atrophy and herniation are inconsistent. Kader et al. [13] demonstrated that the relationships between muscle atrophy and herniated nucleus pulposus was statistically not significant. In contrast, Fortin et al. [16] found greater fatty infiltration on the side of herniation, although the association is likely too weak. Our result showed no significant correlation between MM fatty atrophy and herniation at both levels. We think that the difference of the results may be partially explained by different measuring methods. T2-weighted MR images were used to evaluate multifidus signal intensity in Fortin et al.'s study, while semi-quantitative grading system was used in Kader et al.'s and our study. After all, no significant difference between herniation and muscle size was found in Fortin et al.'s study. In addition, lack of muscle atrophy in acute disc hernia may be explained by the longer time period required for fat replacement [21].

This study has some limitations to be acknowledged. First, semi-quantitative visual grading method is not rigorous enough to distinguish between the small differences in muscle composition. The side of MM fatty atrophy was not scored independently. However, it is widely agreed that muscle atrophy was usually bilateral [13]. Second, MRI is less sensitive in depicting the bony cortex margin as compared with CT. So, it tends to underestimate the severity of facet joint osteoarthritis. Nevertheless, many studies reported that MR accuracy in evaluating facet joint osteoarthritis was more than 93% [20, 41]. And MRI can be a substitute for CT in assessing facet joint osteoarthritis [20].

In conclusion, the relationship between MM fatty atrophy and degenerative diseases of lower lumbar spine is complicated. However, our large series study indicates that MM fatty atrophy positively correlates with advanced age, female gender and facet osteoarthritis at L4–5 level, in the lower lumbar spine, but not with BMI and disc herniation in patients with LBP. These data have potential at guiding clinical treatment in certain disease population. Therefore, further study will be required to elucidate the role of MM fatty degeneration in degenerative process of lumbar spine.

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Compliance with ethical standards

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

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