



Research Article

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Differences of Deep and Superficial Lumbar Multifidus Regional Composition between Young Males with Nonspecific Chronic Low Back Pain and Healthy Individuals

Ardo Okilanda¹ , Rahmat Adnan^{2*} , Rina Mayangsari¹ , Nurul Athilah Muhammad Nasir² , Ahmad Rafshan Hazim Ahmad Risham² , Siti Nuradriana Syafira Mohd Rizal² , Nur Syafiqah Elyssa Amirudin² , Nuramnani Suffiya Rohim² , Dzulhafiz Zikrie Dzolkapli² , Siti Nurul Ezzah Che Man² , Sarah Syafieqah Anuwar² , Hashbullah Ismail² , Norasrudin Sulaiman² , Mazuin Mohd Razalli³ , Shariman Ismadi Ismail²

¹Department of Coaching and Sports, Universitas Negeri Padang, Padang, West Sumatra, Indonesia; ²Faculty of Sports Science and Recreation, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia; ³Faculty of Medicine, Universiti Teknologi MARA (UiTM), Al-Sultan Abdullah Hospital (HASA UiTM), Malaysia

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Abstract

Background: Chronic low back pain (CLBP) is increasingly prevalent among young adults, yet paraspinal muscle imaging research has focused predominantly on middle-aged and older populations, leaving the multifidus (LM) morphological profile in young CLBP poorly characterized. **Objective:** To examine bilateral deep and superficial LM cross-sectional area percentage (CSA%), fat percentage (Fat CSA%), and muscle-fat index percentage (MFI%) at L4 between young adults with CLBP and healthy controls (HC). **Methods:** A 1.5T MRI T2-weighted Dixon compared bilateral deep and superficial LM morphology at L4 between young male adults with CLBP (n=10; mean age 23.5±1.08 years) and age-matched HCs (n=10; mean age 24.4±1.9 years). The Roland Morris Disability Questionnaire (RMDQ) was used to examine whether functional disability moderated compartment-specific group differences. **Results:** No significant differences between groups were found for any variable in either compartment (all $p>0.05$). A highly significant within-subjects muscle main effect was observed ($p<0.001$, partial $\eta^2=0.557$), confirming the morphological distinction between the deep and superficial compartments. The muscle and group interaction was non-significant ($p=0.079$), indicating the deep-to-superficial composition pattern did not differ between groups. **Conclusions:** Gross morphological degeneration of deep or superficial LM at L4 may not yet be detectable at this early stage of chronicity in young adults. Adequately powered, multi-level MRI studies targeting young CLBP populations are warranted.

Keywords: Chronic low back pain, Fat infiltration; Multifidus; Magnetic resonance imaging; Muscle composition.

اختلافات التركيب لعضلة الظهر القطني العميق والسطحي بين الذكور الشباب الذين يعانون من آلام أسفل الظهر المزمن غير المحددة والأفراد الأصحاء

الخلاصة

الخلفية: آلام أسفل الظهر المزمنة (CLBP) تزداد انتشاراً بين الشباب، ومع ذلك ركزت أبحاث تصوير عضلات العمود الفقري بشكل أساسي على الفئات في منتصف العمر وكبار السن، مما ترك الملف الشكلي لمتعددات الظهر (LM) في CLBP الشباب غير محدد بشكل جيد. **الهدف:** فحص نسبة مساحة المقطع العرضي للكتلة العميقة والسطحية (%CSA)، ونسبة الدهون (%CSA)، ونسبة مؤشر الدهون العضلية (%MFI) عند الفقرة الرابعة بين الشباب المصابين ب CLBP والأشخاص الأصحاء (HC). **الطرائق:** قارن تصوير الرنين المغناطيسي 1.5T موزون بوزن T2 ديكسون بين شكل ال LM العميق والسطحي الثنائي في الفقرة الرابعة بين الذكور الشباب المصابين ب CLBP (n=10؛ متوسط العمر 23.5±1.08 سنة) و HCs المطابقة للعمر (n=10؛ متوسط العمر 24.4±1.9 سنة). تم استخدام استبيان Roland Morris لإعاقاة الإعاقة (RMDQ) لفحص ما إذا كانت الإعاقة الوظيفية تخفف من فروق المجموعة الخاصة بكل قسم. **النتائج:** لم يتم العثور على فروق ذات دلالة إحصائية بين المجموعات لأي متغير في أي من الأقسام (جميعها $p>0.05$). لوحظ تأثير رئيسي ذو دلالة عالية داخل العضلات ($p<0.001$ ، $\eta^2=0.557$)، مما أكد التمييز الشافي بين الأقسام العميقة والسطحية. كان التفاعل بين العضلات والمجموعة غير ذو دلالة إحصائية ($p=0.079$)، مما يشير إلى أن نمط التركيب العميق إلى السطحي لم يختلف بين المجموعات. **الاستنتاجات:** قد لا يكون التنكس الشكلي السطحي للنمو العميق أو السطحي عند الفقرة الرابعة قد لا يكون قابلاً للكشف بعد في هذه المرحلة المبكرة من المزملة لدى الشباب. من الضروري إجراء دراسات رنين مغناطيسي متعددة المستويات ذات الطاقة الكافية التي تستهدف مجموعات CLBP الشابة.

*Corresponding author: Rahmat Adnan. Faculty of Sports Science and Recreation, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia; Email: rahmatadnan@uitm.edu.my

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INTRODUCTION

Chronic low back pain (CLBP) is among the most prevalent and burdensome musculoskeletal conditions worldwide, ranking as the leading cause of years lived with disability globally [1]. Among the paraspinal muscles, the lumbar multifidus (LM) has received

considerable research attention owing to its fundamental role in segmental spinal stabilization and its well-documented susceptibility to atrophy, fatty infiltration, and neuromuscular inhibition in individuals with CLBP [2-4]. Recent reviews have reinforced that non-specific CLBP is consistently associated with LM atrophy, fatty infiltration, and abnormal muscle function, underscoring

the importance of characterizing these morphological changes with precision [5,6]. The LM is not a morphologically homogeneous structure. Anatomically, it comprises distinct deep and superficial fibers with divergent functional roles: the deep fibers, attaching directly to the vertebral laminae and spinous processes, are primarily responsible for intersegmental control and stiffness, whereas the superficial fibers contribute to global lumbar movement and load transfer [7,8]. This architectural distinction has led to the investigation into whether pathological changes associated with CLBP preferentially affect one compartment relative to the other. Emerging studies have provided compelling evidence that fat infiltration in the deep LM, particularly in the region closest to the disc center of rotation at L4-L5, is more strongly associated with pain and adjacent disc degeneration than superficial fat infiltration [9,10]. Prior MRI studies have demonstrated significant fatty infiltration and CSA reduction in the LM in CLBP populations [11,12]. However, most investigations characterize the muscle as a single entity, failing to account for potentially divergent responses of deep and superficial compartments to pain-related disuse, neurogenic inhibition, and altered motor control strategies [13,14]. The few compartment-specific analyses that exist have produced inconsistent results, likely attributable to small sample sizes, heterogeneous patient populations, and variable imaging protocols [15]. A recent large-scale cross-sectional cohort study of LBP patients confirmed that lower pure LM CSA is associated with multiple degenerative lumbar pathologies, further substantiating the need for precise compartment-level morphological assessment [16]. Additionally, Naghdi *et al.* (2025) demonstrated a positive association between LM fat infiltration and shear-wave elastography stiffness measures at L4-L5 and L5-S1, suggesting that altered muscle composition functionally impacts LM performance in CLBP [17]. Beyond morphology alone, the degree of functional disability as quantified by the Roland Morris Disability Questionnaire (RMDQ) may moderate the relationship between group membership and muscle composition. Individuals with greater disability may exhibit more pronounced muscle degeneration due to prolonged inactivity and altered neuromuscular drive [18]. Importantly, Cooley *et al.* (2023) demonstrated in a secondary care cohort that reduced LM muscle quality is significantly associated with longer pain duration and greater self-reported disability, providing direct empirical support for the hypothesis that disability level modulates the degree of compartment-specific LM degeneration. Furthermore, psychosocial factors, including kinesiophobia and pain-related fear, have been identified as potential exacerbators of dysfunction in the motor control of paraspinal muscles in CLBP, warranting their inclusion as covariates in morphological studies. Despite the growing body of evidence characterizing LM pathology in CLBP, the

vast majority of imaging studies have been conducted in middle-aged and older adult populations, where age-related muscle degeneration may independently confound group differences. Research specifically targeting young adults with CLBP remains critically limited. Early population-based work noted that while increased fat content of the lumbar muscles has been observed in adults with CLBP, there is limited knowledge of this association in younger populations [11,19]. More recently, Luo *et al.* (2024) conducted one of the few quantitative MRI studies of paraspinal muscles specifically in young adults with non-specific CLBP, demonstrating measurable morphological changes in this cohort, yet compartment-specific deep versus superficial LM analysis in young CLBP patients remains entirely absent from the literature [19]. Given that CLBP onset in young adulthood may represent a distinct pathophysiological trajectory with less accumulated degenerative change yet potentially greater neuromuscular inhibition and fear-avoidance behavior, dedicated investigation in this age group is essential to understanding early-stage muscle degeneration and guiding timely therapeutic intervention. Therefore, the aims of this study were twofold: 1) to compare deep and superficial LM CSA%, Fat CSA%, and MFI% at L4 between young adults with CLBP and HC bilaterally using 1.5T MRI; and 2) to determine whether RMDQ score moderates the group-by-muscle-profile relationship. It was hypothesized that individuals with CLBP would demonstrate significantly greater fat infiltration and reduced CSA% muscle, particularly in the deep compartment, and that this pattern would be more pronounced in individuals with higher disability scores.

METHODS

Study design

A cross-sectional, observational design was employed. The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the UiTM Research Ethic Committee (REC/02/2026(ST/MR/43)). All participants provided written informed consent prior to enrollment.

Sample selection

Twenty male participants were enrolled and allocated into two groups: CLBP (n= 10) and HC (n= 10). Inclusion criteria for the CLBP group were low back pain persisting for more than 12 weeks, pain intensity of at least 3/10 on the Numerical Rating Scale, and age between 20 and 30 years. Inclusion criteria for the HC group were no history of low back pain in the preceding 12 months, no chronic musculoskeletal condition, and age-matched to the CLBP group. Exclusion criteria for

both groups included prior lumbar surgery, spinal deformity, active infection, malignancy, and contraindications to MRI.

Baseline clinical measurements

Clinical measures were recorded for all participants before imaging. Pain intensity was rated on a visual analogue scale (VAS). The scale ranged from 0 to 10. A score of 0 denoted no pain, and 10 the worst pain imaginable. Current pain and worst pain over the preceding week were recorded separately. Symptom duration was documented in months. Kinesiophobia was assessed using the Tampa Scale for Kinesiophobia (TSK). Scores range from 17 to 68, with higher values indicating greater fear of movement. Disability was assessed using RMDQ. Scores range from 0 to 24, with higher values indicating greater disability [20,21].

T2-weighted Dixon MRI

A lumbar spine MRI was performed using a 1.5 Tesla scanner (Siemens, Erlangen, Germany). Participants were scanned in the supine position with standardized positioning. Axial T2-weighted-Dixon sequences were acquired at the L4 vertebral level, providing optimal muscle-to-fat contrast for segmentation [22, 23]. Slice thickness, field of view, repetition time, and echo time were standardized across all scans [24].

Image segmentation and outcome variables

A sample CSA of the bilateral LM at L4 was performed by a single trained rater, blinded to group allocation, using Image J (Java-based version of public domain National Institute of Health Image Software; Research Service Branch). Intra-rater reliability was assessed by repeat measurement. The same rater repeated the measurements after a washout period of ten days. A two-way mixed-effects model with absolute agreement was applied, based on single measurements. The intraclass correlation coefficient was 0.91, indicating excellent agreement. Deep and superficial muscle fibers were defined based on established anatomical landmarks [25-27]. Three outcome variables were computed per compartment per side, including muscle CSA%, the proportion of contractile muscle tissue within the total sample; fat CSA%, the proportion of adipose tissue within total compartment area; and MFI%, the ratio of muscle to total tissue expressed as a percentage, reflecting overall muscle quality [28]. A representative axial T2-weighted Dixon MRI image illustrating the sample of deep fibers (adjacent to lamina) and sample fibers of superficial (superficial and anterior border of the muscle) LM compartments bilaterally at the L4 level is shown in Figure 1.

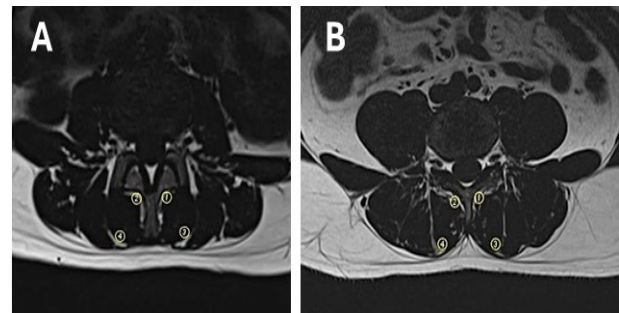


Figure 1: Deep and Superficial Sample of Lumbar Multifidus between HC and CLBP. Representative axial T2-Weighted Dixon at the L4 vertebral level demonstrating bilateral LM segmentation. Yellow sample indicate regions of interest for the deep (1 and 2) and superficial (3 and 4) LM compartments on both the right and left sides. A) MRI image of Lumbar Multifidus refers as Healthy Control, and B) Right MRI image refers as Chronic Low Back Pain Patient.

Statistical analysis

Data were analyzed using IBM SPSS Statistics Version 31. Normality was assessed using the Shapiro-Wilk test. A repeated measures MANOVA was conducted with the eight muscle outcome variables (deep and superficial CSA%, Fat CSA%, and MFI% for right and left sides) as within-subjects factors, group (CLBP vs HC) as the between-subjects factor, and RMDQ score included in the model. Multivariate test statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) were examined. Mauchly's test of sphericity was assessed for all within-subjects effects; Greenhouse-Geisser (GG) correction was applied where sphericity was violated. Huynh-Feldt's corrected results are reported additionally for borderline effects. Effect sizes are reported as partial eta-squared (η^2). Statistical significance was set at $p < 0.05$.

RESULTS

Twenty participants completed the study (CLBP: $n = 10$; HC: $n = 10$). Demographic and clinical characteristics are presented in Table 1. The mean age of the HC group was 24.4 ± 1.9 years, and of the CLBP group was 23.5 ± 1.08 years, with no significant between-group difference. BMI was comparable between groups (HC: 25.09 ± 5.88 kg/m²; CLBP: 24.43 ± 4.59 kg/m²). As expected, the CLBP group reported significantly higher current VAS (3.7 ± 2.0) and worst VAS (6.5 ± 0.71) compared to the HC group (current VAS: 0; worst VAS: 0). Mean symptom duration in the CLBP group was 23 ± 14.85 months. The CLBP group demonstrated markedly higher scores on both the Tampa Scale of Kinesiophobia (TSK= 42.0 ± 5.46) and the Roland Morris Disability Questionnaire (RMDQ= 9.0 ± 6.39) relative to HC (TSK= 29.5 ± 13.08 ; RMDQ= 1.2 ± 1.99). Results of the multivariate tests are presented in Table 2.

Table 1: Demographic and clinical characteristics of study participants (n=10 in each group)

Variable	Total	HC	CLBP	p-value
Age (year)	23.95±1.57	24.4±1.9	23.5±1.08	0.213
BMI (kg/m ²)	24.76±5.15	25.09±5.88	24.43±4.59	0.784
Current VAS (0-10)	1.85±2.35	0.00±0.0	3.7±2.0	<0.001
Worst VAS (0-10)	3.25±3.37	0.00±0.0	6.5±0.71	<0.001
Symptom duration (month)	11.5±15.61	0.00±0.0	23±14.85	<0.001
TSK score (17-68)	35.75±11.67	29.5±13.08	42±5.46	0.016
RMDQ score (0-24)	5.1±6.1	1.2±1.99	9.0±6.39	0.004

Values are presented as mean±SD. HC: Healthy Controls; CLBP: Chronic Low Back Pain; BMI: Body Mass Index; VAS: Visual Analogue Scale; TSK: Tampa Scale of Kinesiophobia; RMDQ: Roland Morris Disability Questionnaire. HC group reported zero pain on all VAS items and zero symptom duration by inclusion criteria.

Table 2: Multivariate tests (MANOVA) — within-subjects effects

Effect/Statistics	Value	p-value	Partial eta ²	Noncent	Power
<i>Muscle</i>					
Pillai's Trace	1.0	<0.001	1.0	4,101, 046.9	1.0
Wilks' Lambda	0.0	<0.001	1.0	4,101, 046.9	1.0
Hotelling's Trace	455, 671.88	<0.001	1.0	4,101, 046.9	1.0
Roy's Largest Root	455, 671.88	<0.001	1.0	4,101, 046.9	1.0
<i>Muscle * Group * RMDQ</i>					
Pillai's Trace	0.737	0.736	0.369	11.683	0.305
Wilks' Lambda	0.377	0.755	0.386	11.304	0.281
Hotelling's Trace	1.346	0.781	0.402	10.77	0.254
Roy's Largest Root	1.059	0.332	0.514	10.591	0.335
<i>Muscle * Group</i>					
Pillai's Trace	0.223	0.937	0.223	2.584	0.101
Wilks' Lambda	0.777	0.937	0.223	2.584	0.101
Hotelling's Trace	0.287	0.937	0.223	2.584	0.101
Roy's Largest Root	0.287	0.937	0.223	2.584	0.101

Note. b = Exact statistics. c = Upper-bound statistics yielding a lower-bound significance level. eta² = partial eta-squared. Power computed using alpha < 0.05.

The muscle main effect was highly significant across all four multivariate criteria (Pillai's Trace= 1.0, $p < 0.001$, partial eta²= 1.0, observed power= 1.0), confirming substantial systematic variation across the eight muscle outcome variables. The muscle and group interaction was non-significant across all criteria (Pillai's Trace= 0.22, $p = 0.937$, partial eta²= 0.22), indicating that the overall LM composition profile did not differ significantly between CLBP and HC. The three-way (Muscle x Group x RMDQ) interaction was also non-significant in the multivariate tests (Pillai's Trace= 0.74, $p = 0.736$, partial eta²= 0.37). Between-group comparisons of compartment-specific LM composition at the upper and lower L4 levels revealed no statistically significant differences between CLBP and HC for any variable on either side (all $p > 0.05$), as presented in **Table 3**. Although the CLBP group demonstrated consistently higher fat CSA percentages and MFI% values across most compartments, these differences were small in magnitude and did not reach statistical significance. The largest absolute mean differences were observed for deep MFI% (MD= -3.53, 95% CI: -14.37 to 7.31) and superficial MFI% (MD= -3.23, 95% CI: -14.26 to 7.81) on the left upper L4, with both favoring greater fat infiltration in the CLBP group. However, the wide confidence intervals observed across all MFI% variables reflect substantial within-group variability and are consistent with the limited statistical power afforded by the current sample size, precluding definitive conclusions from the null findings.

DISCUSSION

The present study is among the first to examine LM composition in a young adult CLBP population, distinguishing between deep and superficial regions. The absence between-group differences do not necessarily indicate a true biological equivalence between CLBP and HC. Rather, it reflects the challenge of detecting early-stage morphological changes in a young adult's cohort where gross structural degeneration may not yet have accumulated to a detectable threshold. This interpretation is supported by Luo *et al.* (2024), whose quantitative MRI study of young adults with non-specific CLBP demonstrated that measurable paraspinal changes are present but subtle in this demographic, a pattern that standard T1-weighted sequences at 1.5T may lack the sensitivity to resolve at small sample sizes [19]. The consistent directional trend observed across the data with the CLBP group showing higher fat percentages and MFI% values in the deep regions at the left upper L4 is clinically meaningful despite not reaching statistical significance [29]. The deep LM is functionally distinct from its superficial counterpart, bearing primary responsibility for intersegmental stabilization at the L4 vertebral level [7]. Spatial fat-mapping research has established that this deep compartment is disproportionately vulnerable to fat infiltration in CLBP, with fat accumulation proximal to the disc center of rotation demonstrating stronger associations with pain and disc degeneration than

superficial fat infiltration [9,10]. The directional pattern observed here is therefore anatomically and functionally

coherent and warrants investigation in adequately powered future studies.

Table 3: Difference of deep and superficial multifidus compartments between CLBP and HC at the L4 upper (ULL4) and lower (LLL4) levels (n=10 in each group)

Variable	HC (mean±SD)	CLBP (mean±SD)	p-value	Mean diff.±SE	95% CI
<i>ULL4 Right side</i>					
Deep Muscle CSA%	30.16±3.5	29.35±5.11	0.684	0.81±1.96	-3.31 to 4.93
Superficial Muscle CSA%	30.63±3.58	29.88±4.88	0.699	0.75±1.91	-3.27 to 4.77
Deep Fat CSA%	8.64±3.5	9.45±5.11	0.684	-0.81±1.96	-4.93 to 3.31
Superficial Fat CSA%	8.17±3.58	8.92±4.88	0.699	-0.75±1.91	-4.77 to 3.27
Deep MFI%	22.3±9.03	24.37±13.18	0.687	-2.07±5.05	-12.68 to 8.55
Superficial MFI%	21.04±9.25	23±12.56	0.697	-1.95±4.93	-12.32 to 8.41
<i>ULL4 Left side</i>					
Deep Muscle CSA%	29.66±4.13	28.34±4.85	0.52	1.32±2.01	-2.91 to 5.55
Superficial Muscle CSA%	30.26±4.07	29.02±5.01	0.551	1.24±2.04	-3.05 to 5.53
Deep Fat CSA%	9.14±4.13	10.46±4.85	0.52	-1.32±2.01	-5.55 to 2.91
Superficial Fat CSA%	8.54±4.07	9.78±5.01	0.551	-1.24±2.04	-5.53 to 3.05
Deep MFI%	23.52±10.62	27.05±12.39	0.503	-3.53±5.16	-14.37 to 7.31
Superficial MFI%	22.01±10.48	25.24±12.89	0.547	-3.23±5.25	-14.26 to 7.81
<i>LLL4 Right side</i>					
Deep Muscle CSA%	30.12±2.75	29.54±3.41	0.68	0.58±1.39	-2.33 to 3.49
Superficial Muscle CSA%	31.84±3.44	30.43±4.81	0.461	1.41±1.87	-2.52 to 5.34
Deep Fat CSA%	6.96±3.44	8.37±4.81	0.461	-1.41±1.87	-5.34 to 2.52
Superficial Fat CSA%	7.74±3.69	8.94±4.99	0.548	-1.2±1.96	-5.32 to 2.92
Deep MFI%	22.33±7.09	23.93±8.78	0.661	-1.59±3.57	-9.09 to 5.91
Superficial MFI%	17.96±8.81	21.58±12.43	0.462	-3.62±4.82	-13.75 to 6.5
<i>LLL4 Left side</i>					
Deep Muscle CSA%	29.60±4.0	30.19±4.97	0.773	-0.59±2.02	-4.83 to 3.65
Superficial Muscle CSA%	31.06 ±3.69	29.86±4.99	0.548	1.2±1.96	-2.92 to 5.32
Deep Fat CSA%	9.2±4.0	9.11±4.2	0.961	0.09±1.83	-3.76 to 3.94
Superficial Fat CSA%	7.74±3.69	8.94±4.99	0.548	-1.2±1.96	-5.32 to 2.92
Deep MFI%	23.72±10.27	23.49±10.83	0.961	0.24±4.72	-9.68 to 10.15
Superficial MFI%	20.02±9.48	23.04±12.86	0.557	-3.02±5.05	-13.64 to 7.59

Legend: CSA% = cross-sectional area percentage; Fat CSA% = fat percentage within CSA; MFI% = muscle-fat index percentage; MD = mean difference; SE = standard error; CI = confidence interval. All p-values two-sided. No variables reached statistical significance (alpha < 0.05).

The borderline moderating effect, medium-to-large by conventional benchmarks, of disability on the compartment-specific group pattern is perhaps the most clinically important finding. The magnitude of this effect, medium-to-large by conventional benchmarks, suggests that functional disability may amplify the degree to which CLBP-related neuromuscular inhibition translates into detectable muscle compositional differences [30]. This finding is consistent with the fear-avoidance model, suggesting individuals with greater disability and kinesiophobia adopt movement restriction strategies that promote progressive disuse and muscular deconditioning [31-33]. The elevated TSK scores in the CLBP group (mean= 42.0) indicate a clinically relevant degree of kinesiophobia that may have already initiated this trajectory yet without producing overt structural changes detectable at this sample size and imaging resolution (34). Cooley *et al.* (2023) demonstrated in a large secondary care cohort that poorer LM quality is significantly linked to greater disability and longer pain duration, implying that the disability-muscle degeneration relationship becomes more pronounced as chronicity advances [16]. An important strength of the study is the confirmation that deep and superficial LM compartments represent genuinely distinct morphological constructs. This finding carries a methodological implication: the study characterizes the

LM as a single whole-muscle entity and may risk masking compartment-specific patterns of degeneration that are functionally and clinically meaningful. Future research should adopt improved MRI segmentation protocols to fully capture the heterogeneous nature of LM composition across compartments, levels, and sides in large groups of both CLBP and HC.

Study Limitations

This study has limitations common to preliminary investigations. The sample was modest, with ten participants per group, in keeping with its exploration scope [35]. Larger cohorts would help confirm the directional trends observed here. Assessment focused on the L4 level, given its clinical relevance for CLBP. Extension to additional lumbar levels would broaden the compositional picture [36]. A single trained and blinded rater undertook segmentation. Multi-rater reliability assessment in future work would further strengthen measurement confidence. Cross-sectional design captures associations at a single time point, while longitudinal studies are suited to clarifying temporal relationships. A focus on young males enhanced homogeneity and reduced age- and sex-related

confounding, while broader sampling would extend generalisability.

Conclusion

This study found no statistically significant differences in deep and superficial LM morphology composition at L4 between CLBP and HC. The compartment-specific, multi-metric MRI framework employed here provides a methodologically rigorous foundation for future research. Adequately powered studies with comprehensive clinical phenotyping, multi-level assessment, and standardized segmentation protocols are required to definitively characterize LM pathology in CLBP.

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Conflict of interests

The authors declared no conflict of interest.

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Data sharing statement

The data that supports the findings of this study are available from the corresponding author upon a reasonable request.

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