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Psoas Major Volume Asymmetry, Not Attachment Site Asymmetry, is Associated with Chronic Low Back Pain Status

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Research Article

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Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11159258/v1

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Additional Declarations: No competing interests reported.

Psoas Major Volume Asymmetry, Not Attachment Site Asymmetry, is Associated with Chronic Low Back Pain Status

ABSTRACT

Purpose: To determine whether psoas major muscle (PMM) volume and attachment-site asymmetry are associated with chronic low back pain (CLBP). Exploratory analyses examined associations between PMM volume asymmetry and disability, physical activity, and age.

Methods: This retrospective secondary analysis included adults aged 35–65 years with and without CLBP from the NIH-sponsored BACPAC imaging cohort. Participants were propensity score matched on age, BMI, and sex. Automated segmentation (MuscleMap) was used to quantify bilateral PMM volumes, and volume asymmetry was calculated as the percent difference between left and right volumes. Attachment-site asymmetry was assessed using axial and coronal MRI classifications. Binary logistic regression evaluated associations between PMM volume and attachment-site asymmetry and CLBP status. Exploratory multiple linear regression evaluated associations between PMM volume asymmetry and disability, physical activity, age, and CLBP status.

Results: Greater PMM volume asymmetry was associated with higher odds of CLBP (OR = 1.08 per 1% increase, 95% CI 1.02–1.14, $p = .007$). Neither axial nor coronal attachment-site asymmetry was significantly associated with CLBP. The exploratory model was not statistically significant ($F(4,172) = 2.01$, $p = .095$), and disability, physical activity, age, and CLBP status were not individually significantly associated with PMM volume asymmetry.

Conclusion: Greater PMM volume asymmetry was associated with CLBP, whereas attachment-site asymmetry was not. These findings support further investigation of PMM volume asymmetry as a morphological feature associated with CLBP.

Keywords: automated segmentation, MuscleMap, muscle morphology, volumetric analyses, spinal stabilizers

Classifications: Observational Study

Introduction

Chronic low back pain (CLBP), defined as pain located below the costal margin and above the inferior gluteal folds persisting for ≥12 weeks, is the leading global cause of years lived with disability and imposes substantial socioeconomic burden worldwide [1-3]. Musculoskeletal and neuromuscular factors, including muscle dysfunction and asymmetry, have increasingly been implicated in CLBP pathophysiology [4].

The psoas major muscle (PMM) originates from the lumbar spine (T12–L5) and converges with the iliacus to insert on the lesser trochanter. Although primarily associated with hip flexion and external rotation, the PMM is the only lower-extremity muscle with direct lumbar attachments and therefore contributes to lumbar mechanics and spinal stability [5, 6]. Its morphology has been hypothesized to influence CLBP and lumbar instability [7, 8]. The PMM typically lacks direct attachment at L5-S1, where mechanical forces are greatest and may therefore be less effectively distributed [6, 9, 10].

Despite its importance, PMM morphology, particularly vertebral and discal attachments, remains inconsistently described [5, 6, 11, 12]. Prior studies have also reported PMM asymmetry or atrophy in individuals with CLBP, but findings are inconsistent [13-15]. The direction of this relationship remains unclear: asymmetry may contribute to altered spinal mechanics, result from pain-related changes in loading, or reflect pre-existing differences in habitual loading.

Most research on spinal stabilizers has focused on the multifidus, with less attention given to the PMM [16, 17]. Further investigation of PMM asymmetry may clarify its relationship with CLBP.

The purpose of this study was to examine whether PMM volume and attachment-site asymmetry are associated with CLBP. We hypothesized that (1) greater PMM volume asymmetry and (2) greater attachment-site asymmetry would be associated with a higher likelihood of being in the CLBP group. Exploratory analyses examined associations between PMM volume asymmetry and disability, physical activity, and age.

Methods

Hypotheses

The primary hypotheses were that (1) greater PMM volume asymmetry and (2) greater PMM attachment-site asymmetry would be associated with a higher likelihood of CLBP.

Study Design and Data Source

This retrospective secondary analysis used lumbar spine MRI scans from the NIH-sponsored Back Pain Consortium (BACPAC) imaging cohort. Deidentified imaging data were accessed for secondary PMM morphological analysis.

Participants, Matching, and Analytic Cohorts

Participants were adults aged 35–65 years, ambulatory without assistive devices, and eligible for MRI. The CLBP group included individuals reporting axial (non-radiating) low back pain lasting ≥3 months; controls reported no history of CLBP or scoliosis. Individuals with prior hip or knee surgery were excluded. Pain status was confirmed using standardized BACPAC self-report measures [18], and participants with inconsistent pain reports were excluded.

To balance age, BMI, and biological sex, 1:1 nearest-neighbor propensity score matching was performed without replacement. Propensity scores were estimated using age and BMI, with exact matching on biological sex and a caliper of 0.25. Matching was applied to the full cohort (n=252), yielding 202 participants (101 with CLBP ;101 controls), for the primary PMM volume analysis.

For the exploratory analysis of PMM volume asymmetry and ODI, physical activity, age, and CLBP status, participants with available IPAQ data were restricted to 179 participants and rematched using age, BMI, and biological sex, yielding 178 participants.

For attachment-site analysis, the primary matched cohort (n=202) was restricted to participants with required axial and coronal images and complete CLBP status data (n=181), then rematched using age and BMI, exact matching on biological sex, and a caliper of 0.25, yielding 150 participants. See *Figure 1* for the participant flow diagram and sample characteristics.

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ), reported as MET-min/week across activity domains [19]. Functional disability was measured using the Oswestry Disability Index (ODI; 0-100 scale, higher scores indicating greater disability) [20].

MRI Acquisition

MRI examinations were performed using a 3.0-T MAGNETOM Vida system (Siemens Healthineers, Erlangen, Germany). Participants were positioned head-first in the supine position during image acquisition.

The present analysis utilized T2-weighted axial sequences and T1-weighted coronal sequences spanning from the T12 vertebral body through the L5–S1 intervertebral disc level [18]. Axial T2-weighted images were acquired with a field of view (FOV) of approximately 18 cm, slice thickness of 4.0 mm, and 1 mm interslice spacing, using an acquisition matrix of 288 × 192, repetition time (TR) of approximately 7,858 ms, and echo time (TE) of 60 ms. Coronal T1-weighted images were obtained with a 30 cm FOV, 4.0 mm slice thickness, and 1 mm slice spacing, using a matrix of 384 × 224, TR of approximately 595 ms, and TE of 14.1 ms.

MRI parameters followed the parent BACPAC imaging protocol and were not specifically optimized for PMM morphology, resulting in variability in field of view, slice coverage, and image contrast across participants [21].

Image Processing and Segmentation

Manual muscle segmentation reliability was first evaluated in a pilot subset using OsiriX software (14.1.1 Geneva, Switzerland) [22]. PMM was manually traced on approximately 22 axial slices per participant bilaterally from T12–L1 to the inguinal ligament. Three participants were remeasured by the same researcher after ≥5 days, yielding excellent intra-rater reliability (ICC[2,1] = 0.99) [23].

For the full dataset, automated segmentation and volumetric computation were performed using MuscleMap, an open-source machine learning-based toolbox designed for whole-body muscle MRI segmentation [24]. MuscleMap was validated against manual OsiriX segmentation in 20 randomly selected participants from a larger cohort (n=314), processing approximately 484 MRI slices. Agreement was assessed using ICC and Bland–Altman analysis for individual slices and total left and right PMM volumes. MuscleMap and OsiriX segmentations are shown in *Figure 2*.

MuscleMap demonstrated good-to-excellent agreement with manual segmentation: ICCs were 0.87 and 0.85 for left and right individual slices, and 0.84 and 0.90 for total Left and right volumes. Bland–Altman analysis showed minimal mean bias, with narrow 95% limits of agreement. MuscleMap reduced manual (OsiriX) processing time from approximately 20 hours to 15–20 minutes, representing approximately a 60-fold efficiency gain without substantial loss of accuracy.

When left- and right-side segmentation produced different slice counts, counts were harmonized and total volumes recalculated using matched anatomical slice levels.

Morphological Variables

Muscle Volume Asymmetry

Percent volume difference between left and right PMM was calculated as:

$$\text{Volume Percent Difference} = |\text{Left} - \text{Right}| / \text{Mean} \times 100$$

Transverse Attachment Classification

A single trained evaluator performed all quadrant segmentation and attachment scoring.

Axial images were evaluated at each vertebral level (T12–L1 through L5–S1) using a four-quadrant model, as illustrated in *Figure 3.* This classification was adapted from a previously reported method of determining attachment site [25].

To divide each disc into quadrants, image processing and annotation were performed using Python (Python software Foundation, Wilmington, DE, USA; version 3.10) Vertical and horizontal reference lines were manually drawn to segment each disc, and image brightness and contrast were adjusted as needed to optimize visualization of PMM attachment.

The vertical reference line was aligned within the medial-lateral bounds of the spinous process and adjusted as needed to maintain alignment. A horizontal reference line was then drawn perpendicular to the vertical line, dividing the disc into superior and inferior halves as evenly as possible.

Attachment configurations were scored using a 0-15 ordinal classification system listed in *Table 1*. For statistical modeling, these classifications were collapsed into two categories to enhance model stability:

- 0 = no asymmetry
- 1 = any asymmetry at any disc level

The simplified ordinal variable was used in regression analyses.

Coronal Attachment Assessment

Coronal images were evaluated for proximal and distal asymmetry and dichotomized as:

- 0 = no asymmetry
- 1 = any asymmetry at proximal or distal levels

Statistical Analyses

All analyses were conducted in R Studio 2024.02.2 (Posit Software, Boston USA). The 202-participant matched cohort was used to test hypothesis 1, and the 150-participant sample was used to test hypothesis 2. The 178-participant matched cohort was used exploratory analyses. Missing attachment-site values were treated as missing for the corresponding predictor.

We performed a binary logistic regression with CLBP status (0 = control, 1 = CLBP) as the outcome and volume percent difference (Vol_Perc_Diff) as the predictor for hypothesis 1. Odds ratios and 95% confidence intervals were calculated to quantify the association.

The second hypothesis was examined using a second binary logistic regression. CLBP status remained the outcome, with coronal asymmetry (0 = no asymmetry, 1 = any asymmetry), axial/transverse attachment categories at each disc level (0 = no asymmetry, 1 = any asymmetry), and volume percent difference as predictors. Odds ratios and 95% confidence intervals were calculated for each fixed effect.

The exploratory analysis used multiple linear regression. PMM volume percent difference served as the continuous outcome, with ODI, IPAQ physical activity score, age, and CLBP status as predictors. Model assumptions, including linearity, homoscedasticity, and normality of residuals, were assessed using diagnostic plots, and variance inflation factors were calculated to evaluate multicollinearity.

Statistical significance was set at $\alpha = 0.05$. Model fit was evaluated using Nagelkerke's R^2 for logistic models and adjusted R^2 for linear models.

Results

Association Between PMM Volume Asymmetry and CLBP

The logistic regression model was statistically significant, with greater PMM volume asymmetry associated with CLBP status ($p = .007$). For every 1% increase in PMM volume asymmetry, the odds of a participant having CLBP increased by 7.6% (OR = 1.08, 95% CI [1.02, 1.14]). The model explained approximately 5.3% (Nagelkerke's R^2) of the variance in CLBP status. PMM volume asymmetry results displayed in *Figure 4.*

Association Between PMM Attachment-Site Asymmetry and CLBP

Neither axial asymmetry (OR = 0.67, 95% CI [0.30, 1.47], $p = 0.322$) nor coronal asymmetry (OR = 1.31, 95% CI [0.50, 3.49], $p = 0.581$) were significantly associated with CLBP.

Exploratory Associations Between PMM Volume Asymmetry, CLBP, Disability, and Age

Demographic and clinical characteristics of the matched samples are shown in *Table 2*.

The exploratory multiple linear regression model was not statistically significant, $F(4,172) = 2.01$, $p = 0.095$, and explained 4.5% of variance in PMM volume percent difference ($R^2 = 0.045$; adjusted $R^2 = 0.022$). CLBP status was positively associated with PMM volume asymmetry, although the association was not statistically significant ($\beta = 2.02$, $p = 0.097$). ODI, IPAQ score, and age were also not significantly associated with PMM volume percent difference (*Table 3, Figure 5*).

Discussion

Interpretation of Key Findings

This study evaluated whether PMM volume and attachment-site asymmetry were associated with CLBP using matched cohorts and automated segmentation, with exploratory analyses examining clinical and demographic factors associated with PMM volume asymmetry.

PMM Volume Asymmetry Predicting CLBP

The primary finding of this study supported Hypothesis 1, demonstrating a statistically significant association between greater right-to-left percent volume asymmetry in the PMM and increased odds of CLBP. Specifically, each 1% increase in volume asymmetry was associated with approximately 8% higher odds of CLBP. These results align with prior evidence of PMM asymmetry in LBP populations, which has reported ipsilateral atrophy or reduced cross-sectional area on the symptomatic side in unilateral cases [13, 14]. Such findings have been hypothesized to reflect altered spinal mechanics, although the directionality of the relationship between muscle

morphology and pain remains uncertain. Because asymmetry was quantified as the percent difference between right and left PMM volumes rather than absolute volume, these findings suggest that bilateral imbalance may be relevant to CLBP.

PMM Attachment Site Asymmetry

Hypothesis 2 was not supported. Neither coronal nor axial attachment-site asymmetry were significantly associated with CLBP. Descriptive analyses showed similar distributions of attachment asymmetry across groups, with low category frequencies supporting the decision to collapse classifications (*Table 4*).

Although such anatomical variation could theoretically alter localized segmental mechanics, our data indicate that variations in attachment symmetry were not associated with CLBP status. One possible explanation is that preserved or complete attachments at proximal and distal spinal levels may compensate for asymmetries occurring at intermediate segments, thereby maintaining overall functional stability of the muscle-tendon unit. This compensatory effect could reduce the clinical impact of isolated asymmetries and help explain the similar prevalence observed between groups.

However, there exist methodological challenges that could call into question the reliability of classifying attachments using standard MRI sequences. Proximal asymmetries in coronal views were uncommon and difficult to confirm with confidence, as scrolling through adjacent slices frequently revealed eventual bilateral attachment unless one side showed complete absence. In

some cases, interpretation was further complicated by participant positioning or fascial contact that could mimic true muscular attachment [26].

Functional Disability and Physical Activity

Exploratory analyses found no significant associations between PMM volume asymmetry and CLBP status, ODI score, IPAQ score, or age. This suggests that, within this cohort, PMM volume asymmetry was not strongly associated with measures of functional disability, physical activity, or age. The lack of a significant associations may reflect the fact that the ODI and IPAQ capture broader, whole-body functional impacts (such as walking, lifting, and work demands [19, 20]) that are influenced by multiple muscle groups, rather than reflecting PMM-specific mechanical contributions.

Furthermore, while age is a known factor in sarcopenic muscle changes typically seen beyond age 70 (e.g., fat infiltration and dorsal retraction)[27], our focused 35–65 age range may have limited the influence of age-related muscle changes and may partly explain the absence of association between age and PMM asymmetry.

Automated Muscle Segmentation Enables Efficient PMM Quantification

Automated segmentation enabled efficient bilateral PMM quantification across the cohort while demonstrating good-to-excellent agreement with manual segmentation. Although this approach facilitates larger-scale muscle morphology studies, the primary significance of the present study is the association between PMM volume asymmetry and CLBP.

Historically, assessment of whole-muscle volume has relied on manual segmentation, requiring slice-by-slice tracing of regions of interest across numerous axial images. This approach is labor-intensive and can limit the feasibility of large-scale muscle morphology studies. MuscleMap [24], a free, open-source automated segmentation tool, substantially reduced the time required to quantify PMM volume while demonstrating good-to-excellent agreement with manual OsiriX segmentation [22]. Manual segmentation of the validation dataset required approximately 20 hours, whereas automated segmentation required approximately 15–20 minutes, representing an approximately 60-fold reduction in processing time.

These findings demonstrate the feasibility of automated segmentation for large-scale investigations of bilateral muscle morphology. Efficient quantification of both right and left PMM volumes facilitated the within-participant asymmetry analysis used here. However, automated segmentation does not eliminate the need for validation or quality control. Future studies should evaluate MuscleMap across additional spinal and paraspinal muscles, MRI acquisition protocols, and patient populations.

Clinical Implications

These findings position PMM volume asymmetry as a potentially relevant morphological feature in CLBP pathophysiology. Whether PMM volume asymmetry has sufficient discriminatory value to serve as a clinical imaging marker remains unknown and was not evaluated in the present study. Future studies using larger, prospectively collected cohorts should determine whether the magnitude of PMM asymmetry improves identification or characterization of individuals with CLBP beyond established clinical and imaging measures.

The findings also raise the possibility that PMM volume asymmetry could be modifiable through rehabilitation, although this has not been established. Future intervention and longitudinal studies should determine whether changes in PMM morphology accompany changes in pain and function. The lack of robust attachment findings also supports refinement of attachment assessment using higher-resolution imaging or biomechanical modeling.

Whether pain changes the muscle or the muscle changes the pain remains uncertain; the present findings establish an association within this cohort.

Qualitative Observations and Future Directions

Qualitative inspection also revealed anatomical features warranting future investigation. Most notably, variations in the diaphragmatic crus and its fascial blending with the proximal PMM at the T12/L1 junction were frequently observed. Because the PMM and diaphragm share a fascial connection through the medial arcuate ligament [28], crus variation could theoretically influence proximal PMM tension. Future studies could quantify crus thickness and fascial integrity alongside PMM morphology.

Limitations

While this study benefited from a relatively large initial cohort (n = 252) drawn from the well-characterized NIH-sponsored BACPAC imaging dataset [21] and employed rigorous nearest-neighbor matching to balance key demographics (age, BMI, sex), several limitations must be acknowledged.

The analytic samples were substantially reduced to 202 for volume asymmetry analyses and 150 for combined morphological logistic models due to complete-case requirements and matching. This reduction stemmed primarily from imaging constraints inherent to the retrospective, secondary-use design rather than participant dropout or measurement error. The parent BACPAC MRI protocol was not optimized for detailed PMM assessment, leading to variable field-of-view (often truncating proximal or distal muscle), inconsistent slice coverage, and occasional poor contrast/quality that precluded reliable boundary delineation or attachment evaluation in some cases. Missing data were thus likely systematic (e.g., inferior attachments outside FOV, proximal origins incompletely visualized), potentially biasing results toward participants with more complete/robust imaging and limiting external generalizability to broader CLBP populations. The BACPAC dataset also did not provide sufficiently detailed information regarding prior abdominal or spinal surgical history to determine whether these factors influenced PMM morphology.

Attachment classifications, particularly in coronal views, were prone to interpretive challenges: proximal asymmetries were rare and hard to confirm without full bilateral visualization, and subtle differences (e.g., "touching" vs. true attachment) could not be resolved reliably. The collapsed ordinal categories improved model stability but may have masked nuanced variants. Although MuscleMap [24] demonstrated strong agreement with manual OsiriX [22] segmentation (good-to-excellent ICCs, minimal bias), any residual discrepancies could propagate in large-scale analyses.

Despite these constraints, the consistent volume asymmetry findings across levels provide a solid foundation for future prospective, protocol-optimized studies.

Conclusion

This study found that greater right-to-left PMM volume asymmetry was associated with CLBP, whereas PMM attachment-site asymmetry was not. Physical activity, functional disability, and age were not significantly associated with PMM volume asymmetry in exploratory analyses. Automated segmentation demonstrated the feasibility of efficiently quantifying bilateral PMM volume in large MRI datasets. Although the cross-sectional design precludes determination of causality, these findings support further prospective investigation of whether PMM volume asymmetry precedes CLBP, develops in response to pain or altered loading, or is modifiable through rehabilitation.

Funding

<…>

Conflict of Interest

There are no competing interests to report.

Ethics approval

The parent study was approved by the Institutional Review Board (IRB# 2021-027) at <anonymous>.

Consent

All participants provided written informed consent.

Data and/or code availability

Data will be shared upon reasonable request.

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Figure Captions

Figure 1: Participant Flow: Dataset Breakdown and Matching for Analyses

Figure 2: MuscleMap vs OsiriX Segmentation

Figure 3: MRI Scans of Types of Asymmetries

Figure 4: Predictors of Chronic Low Back Pain Status: Volume Asymmetry

Figure 5: Exploratory Associations with PMM Volume Percent Difference: ODI, IPAQ, Age, Pain Status

1

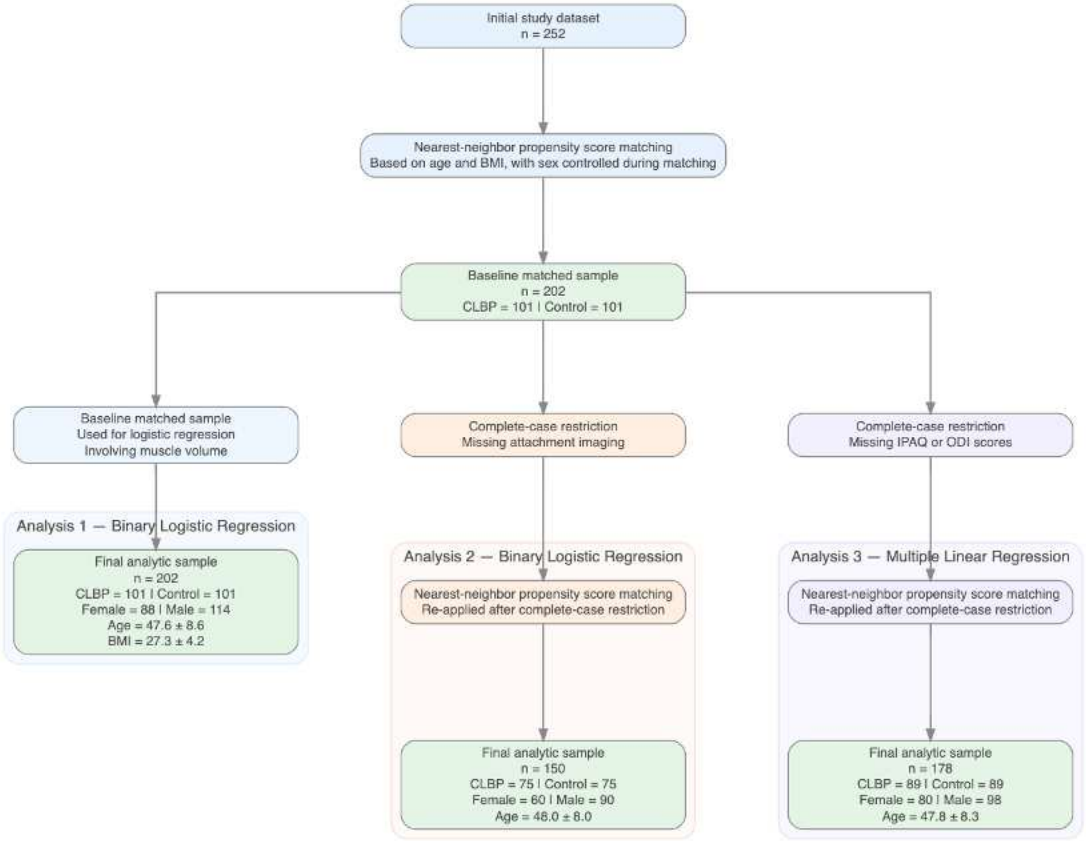


Figure 1: Participant flow chart starting with initial sample, then breaking down into samples used for binary logistic regression, multiple linear regression and generalized linear mixed-effects logistic regression.



Figure 2: Left: MuscleMap segmentation of left (light purple) and right (light blue) PMM; Middle: manual segmentation of left PMM using OsiriX; Right: manual segmentation of right PMM using OsiriX. The participant and MRI slice number is consistent across each image.

1

2

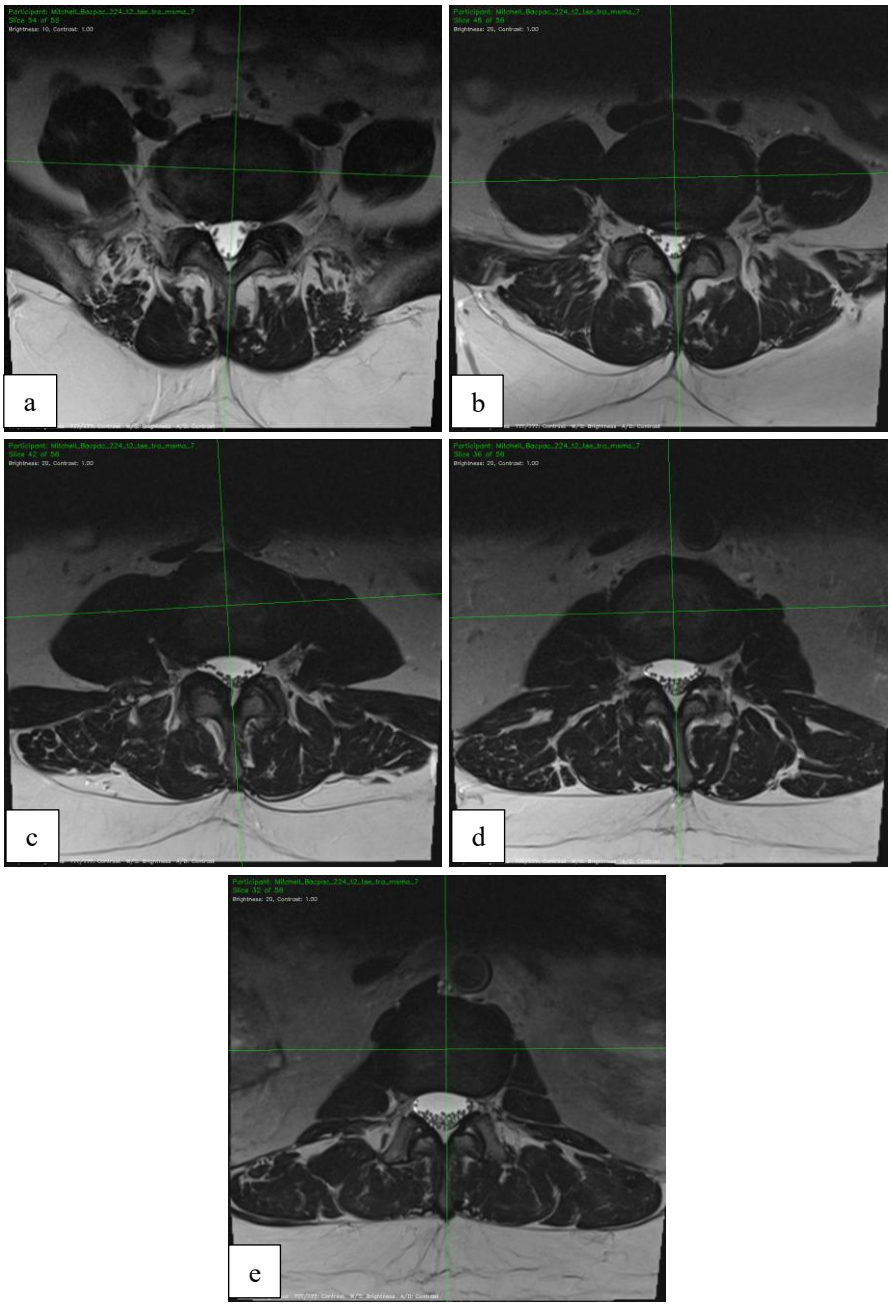


Figure 3: Axial MRI scans from a single participant showing different lumbar and lower thoracic disc levels. (a) L5–S1, score 0, no PMM attachment; (b) L4–L5, score 2, lateral asymmetry; (c) L3–L4, score 1, complete attachment; (d) L2–L3, score 1, complete attachment; (e) T12-L1, score 3, rotary asymmetry.

1

1

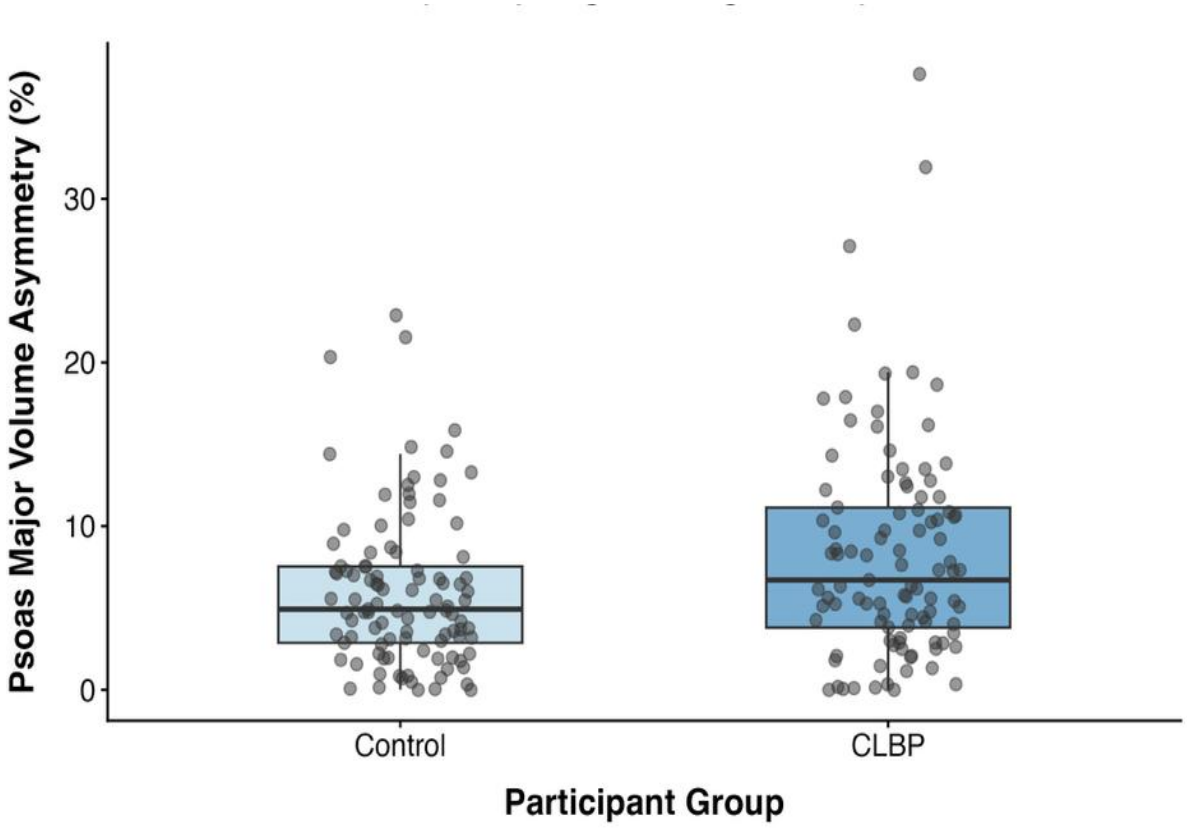


Figure 4: Psoas major muscle volume asymmetry (%) in control (n=101) and CLBP (n=101) participants. Individual points are overlaid on boxplots. Greater asymmetry was associated with the presence of CLBP in a binary logistic regression.

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1

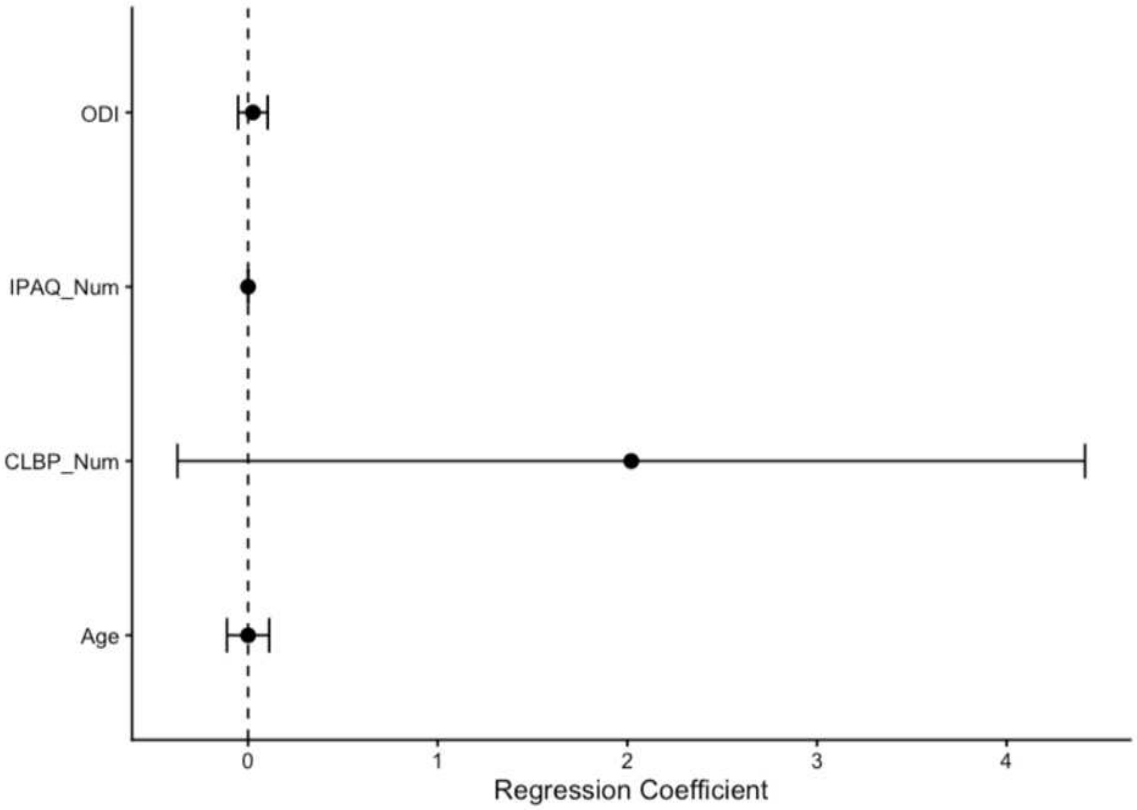


Figure 5 Exploratory associations between clinical and demographic variables and PMM volume percent difference. Points represent regression coefficients and horizontal bars represent 95% confidence intervals from a multiple linear regression model including ODI, IPAQ physical activity score, age, and CLBP status. The vertical dashed line represents a coefficient of zero.

1

Attachment Configurations					
Code	**Description**	**Attachment Type**	**Category Type**	**Simplified**	**Category Type**
0	No attachment	0	No attachment in any quadrant	0	No asymmetry
1	Complete attachment	1	Attachment in all 4 quadrants	0	No asymmetry
2	L/R anterior attached; L/R posterior NOT attached	2	Lateral asymmetry	1	Any asymmetry at any disc level
3	L/R anterior NOT attached; L/R posterior attached	2	Lateral asymmetry	1	Any asymmetry at any disc level
4	L anterior/posterior attached; R anterior/posterior NOT attached	2	Lateral asymmetry	1	Any asymmetry at any disc level
5	L anterior/posterior NOT attached; R anterior/posterior attached	2	Lateral asymmetry	1	Any asymmetry at any disc level
6	L anterior attached; R anterior NOT attached; L/R posterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
7	R anterior attached; L anterior NOT attached; L/R posterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
8	L posterior attached; R posterior NOT attached; L/R anterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
9	R posterior attached; L posterior NOT attached; L/R anterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
10	L/R anterior, R posterior attached; L posterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
11	L/R anterior, L posterior attached; R posterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
12	L/R posterior, R anterior attached; L anterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
13	L/R posterior, L anterior attached; R anterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
14	L anterior R posterior attached; R anterior L posterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level
15	R anterior L posterior attached; L anterior R posterior NOT attached	3	Rotary asymmetry	1	Any asymmetry at any disc level

Table 1: Attachment configurations using 0-15 ordinal classification system translated to an attachment 0-3 classification by asymmetry type; then simplified to a 0 or 1 binary classification to determine whether no asymmetry exists or asymmetry at any level exists.

1

Characteristics of Matched Sample for CLBP, Disability, and Physical Activity Predicting Asymmetry

	Age (years)	ODI (%)	IPAQ (METmin/week)	Volume Difference (%)
CLBP	48.3±8.7	25.5±15.2	5907.6±8455.8	8.7±7.0
Control	47.2±7.8	5.3±6.9	7581.9±11087.3	6.2±4.9
p-value	0.400	<0.001	0.259	0.007

Table 2: Characteristics of matched sample for hypothesis 3.

2

Multiple Linear Regression Results

Predictor	Estimate (β)	Std. Error	t value	p value
Intercept	5.811	2.764	2.103	0.037
ODI	0.025	0.040	0.639	0.524
IPAQ	0.000032	0.000047	0.669	0.505
Age	0.00023	0.056	0.004	0.997
CLBP Status	2.021	1.212	1.667	0.097

Table 3: Multiple linear regression analysis examining the associations between disability (ODI), physical activity level (IPAQ), age, CLBP status, and psoas muscle volume asymmetry.

Occurrence of Asymmetry Type

	CLBP						Control					
Type	**T12 L1**	**L1 L2**	**L2 L3**	**L3 L4**	**L4 L5**	**L5 S1**	**T12 L1**	**L1 L2**	**L2 L3**	**L3 L4**	**L4 L5**	**L5 S1**
0	9	0	0	0	8	71	6	3	1	0	9	70
7	6	65	75	73	48	0	1	59	74	73	48	0
2	1	3	0	0	13	0	1	9	0	1	11	3
3	0	7	0	2	7	0	0	4	0	1	7	0

Table 4: Axial view: 0 = no attachment; 1 = complete attachment; 2 = lateral asymmetry; 3 = rotary asymmetry.