

Lumbar Muscle Morphology and Composition in Adolescent Idiopathic Scoliosis: A Magnetic Resonance Study

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Introduction

Adolescent idiopathic scoliosis (AIS) is a heterogeneous three-dimensional spinal deformity associated with neuromuscular imbalance and chronic asymmetric loading, which may induce adaptive changes in lumbar paraspinal and trunk muscles. Magnetic resonance imaging allows in vivo assessment of muscle morphology, most studies have focused on muscle size, with limited evaluation of muscle composition and few analyses across Lenke curve types. This study aimed to characterize lumbar muscle morphology and composition in AIS and to assess curve-type-specific and concave-convex asymmetry patterns.

Materials and Methods

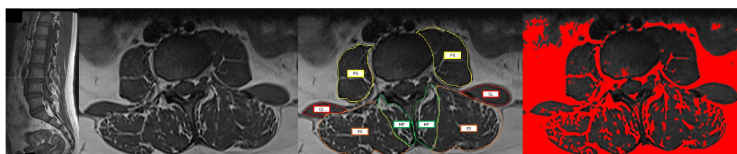
This retrospective cohort study included AIS patients undergoing posterior spinal fusion between January 2019 and December 2023 with available preoperative T1-weighted axial MRI. Lumbar muscle morphology of the psoas, paraspinal (erector spinae and multifidus), and quadratus lumborum muscles was assessed bilaterally at the inferior endplate of L3. Patients were stratified by Lenke classification into non-structural lumbar curves (Group 1, Lenke 1–2) and structural lumbar curves (Group 2, Lenke 3–6) and compared with age-matched controls (Group 3). Muscle size and composition were quantified using threshold-based methods, with measurements independently performed by two pediatric radiologists and interobserver reliability assessed using intraclass correlation coefficients. Non-parametric analyses were performed using Wilcoxon tests for group comparisons and univariate Spearman correlations for associations between lumbar muscle metrics and radiographic parameters, with statistical significance set at $p < 0.05$.

Results

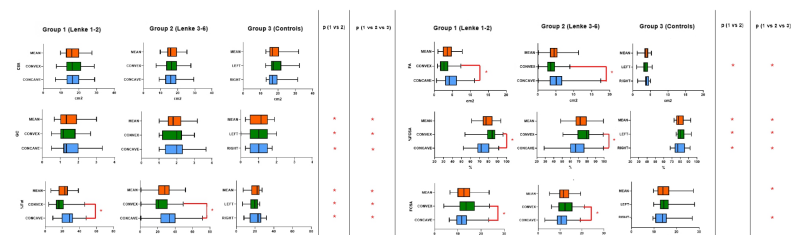
Eighty-three AIS patients (Group 1, $n = 31$; Group 2, $n = 52$) and 20 controls were included. Demographic characteristics were comparable between groups. Lumbar muscle bulk was largely preserved across AIS subtypes and controls, with minimal cross-sectional area asymmetry. In contrast, muscle composition showed distinct curve-type-specific patterns. Group 1 demonstrated marked concave-sided fatty infiltration of the psoas muscle, whereas Group 2 exhibited greater degeneration of paraspinal muscles, particularly the multifidus ($p > 0.05$). Controls showed lower fatty infiltration and no side-to-side asymmetry. Quadratus lumborum morphology was relatively preserved, with modest concave-sided alterations in AIS. Associations between AIS muscle parameters, curve severity, flexibility, and spinal alignment were weak and not statistically significant after correction ($p > 0.05$).

Conclusion

Lumbar muscle alterations in AIS predominantly involve muscle composition rather than muscle bulk and follow curve-type-specific patterns consistent with localized adaptations to asymmetric loading. These findings support further longitudinal and multimodal studies to clarify the role of muscle composition in the pathophysiology and progression of spinal deformity.



Example of lumbar muscle segmentation and quantitative analysis on T1-weighted MRI at the level of L3. From left to right: (1) sagittal T1-weighted image centered on the L3 vertebral body, indicating the axial slice level; (2) native axial T1-weighted image at the inferior endplate of L3; (3) manual region-of-interest (ROI) segmentation of lumbar muscles performed using ImageJ, including bilateral psoas (PS), erector spinae (ES), multifidus (MF), and quadratus lumborum (QL); (4) threshold-based segmentation map highlighting fatty infiltration (FI) signal, used to calculate fat percentage (%Fat) and derive quantitative parameters such as fat area (FA) and functional cross-sectional area (FCSA).



Lumbar paraspinal muscle morphology and composition across Lenke scoliosis subtypes and controls. "*" indicate statistically significant differences. Between-group comparisons were performed using the Wilcoxon rank-sum test, and within-group concave-convex comparisons using the Wilcoxon signed-rank test. CSA = cross-sectional area; GC = Goutallier classification; FA = fat area; %FA = percentage fat area; FCSA = functional cross-sectional area; %FCSA = percentage functional cross-sectional area.