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Investigation of the relationship between sagittal curvature and lumbar extensor muscle volume in patients with lower back pain

Sagittal curvature and lumbar muscle volume

Isil Yurdaisik[1], Süleyman Hilmi Aksoy[2]

[1]Department of Radiology, Medical Park Gaziosmanpasa Hospital, Faculty of Medicine, İstinye University, İstanbul, Türkiye.
[2]Department of Radiology, Hisar Intercontinental Hospital, Faculty of Medicine, Galata University, İstanbul, Türkiye.

Abstract

Aim: The objective of this study was to investigate the relationship between spinal curvature and extensor muscle volume in patients who presented to our hospital with lower back pain and were referred to our radiology clinic for imaging investigations.

Methods: A total of 150 patients, 87 female and 63 male, who presented to our hospital with lower back pain and were referred to our radiology clinic, were included in this study. The lumbar angle, lumbosacral angle, wedge angle, sacral horizontal angle, the volume of the right and left psoas muscles, and the volume of the right and left extensor muscles were calculated and analyzed.

Results: A total of 150 patients with lower back pain were included in the study. The mean lumbar angle was found as 44.2 ± 10.6 degrees, and the mean lumbosacral angle was 56.7 ± 10.9 degrees. The mean wedge angle of all patients included in the study was measured as 9.3 ± 3.7 degrees. The mean sacral horizontal angle was found as 33.6 ± 7.1 degrees. The mean right lumbar extensor muscle volume was measured as 2169.6 ± 489.6 mm3, while the mean left lumbar extensor volume was calculated as 2286.5 ± 1452.8 mm3.

Conclusion: Our findings indicate a significant positive correlation between the volume of extensor muscles in the lower half of the lumbar spine and sagittal curvature in the same region. Clarifying the relationship between sagittal curvature and lower lumbar muscle size will contribute to the management of patients with lower back pain and help determine whether these patients would benefit from intensive treatment.

Keywords

sagittal curvature, lumbosacral angle, lumbar extensor muscles, muscle volume, lower back pain

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Corresponding Author: Isil Yurdaisik, Department of Radiology, Medical Park Gaziosmanpasa Hospital, Faculty of Medicine, İstinye University, İstanbul, Türkiye.
E-mail: mdisilyurdaisik@gmail.com **P.:** +90 212 979 30 00
Corresponding Author ORCID ID: https://orcid.org/0000-0001-8316-1229
Other Authors ORCID ID: Süleyman Hilmi Aksoy, https://orcid.org/0000-0002-2356-0268

Introduction

The vertebral column is a complex anatomic structure consisting of vertebrae and intervertebral discs, it has a wide range of motion and provides a load-bearing capacity supporting physical movements during daily life activities.[1] Vertebral curvatures in humans extend from the neck to the pelvis, distributing body load evenly during walking or working.[2] It is important to maintain a normal curvature to protect the spinal cord from excessive movement. A balanced spinal alignment optimizes muscle energy expenditure and joint stress, with the gravity center in a physiological position and the ability to maintain static and dynamic postures.

Deterioration in muscle composition may lead to prolonged lower back pain and its recurrence.[3] The extensor muscles of the lumbar spine are located posterior to the vertebral bodies and play a critical role in controlling movement and providing mechanical balance.[4] These muscles consist of two main groups: the transversospinalis and the erector spinae.

The mechanical stability of the lumbar spine is achieved when the forces occurring in the spine travel to the sagittal spinal curvature.[5] These forces enable the lumbar spine to support the weight of the upper body. These forces are termed 'follower loads'.[6] In a recent modeling study, the influence of curvature magnitude differences on the forces required to generate follower loads was investigated.[7] The range of lumbar sagittal curvature is wide in the normal population.[8]

In general, muscle strength is proportional to muscle size.[9] Studies have reported that muscle size is closely associated with the ability to apply follower loads.[10-11]

The measurement of extensor muscles shows great variability, especially in the lower lumbar regions.[12] In a modeling study by Meakin et al., it was proposed that individuals with a great lumbar lordosis have more muscles, particularly in the lower half.[13] However, studies in the literature evaluating the association between sagittal curvature of the lumbar spine and extensor muscle volume are very limited, with most being modeling studies.[7]

The objective of this study was to investigate the relationship between spinal curvature and extensor muscle volume in patients who presented to our hospital with lower back pain and were referred to our radiology clinic for imaging investigations.

Materials and Methods

A total of 150 patients, 87 female and 63 male, who presented to our hospital with lower back pain and were referred to our radiology clinic between 01/05/2020 and 01/07/2020, were included in this study.

Patients' demographic data, such as age and gender, height, weight, and body mass index (BMI), were measured and recorded. In addition, in all patients, the lumbar angle, lumbosacral angle, wedge angle, sacral horizontal angle, and the volumes of the right and left psoas and extensor muscles were calculated and analyzed. All angulation and volumetric measurements were obtained using magnetic resonance imaging (MRI) in all patients. The images were acquired using a Siemens 1.5 Tesla MRI device (Siemens Healthcare GmbH, Erlangen, Germany).

BMI was calculated by dividing body weight in Kg by the square of height in meters (Kg/m2). The lumbar angle was measured as the angle between L1 and S1. The lumbosacral angle was measured between the L3 and S1 vertebrae. The wedge angle was considered the angle between the L4 and L5 vertebrae. The sacral horizontal angle was taken as the angle between the upper level of S1 and the horizontal axis. Right and left psoas muscle volumes and right and left extensor muscle volumes were measured on T2-weighted axial plane images. These images were acquired using a repetition time of 55 ms and an echo time of 1.9 ms with a gradient echo sequence. Depending on the patient's size, an in-plane resolution of 1.76-1.95 mm/pixel was used. ROIs included the iliocostalis, multifidus, and longissimus muscles. Patients with fat infiltration detected in the ROI were excluded from the study.

The status of lower back pain was confirmed by the answer to the question 'Do you have or have you had lower back pain in the past?'in a survey form.

Ethical Approval

This study was approved by the Ethics Committee of Istinye University (Date: 02.07.2020, Decision No: 2/2020.K-047).

Statistical Analysis

Data obtained in the study were analyzed using SPSS version 23.0 (Statistical Package for Windows (SPSS), IBM Inc., Chicago, IL, USA). The normality of the data was evaluated using the Kolmogorov-Smirnov test. Variance analysis was used to evaluate differences between the groups, and the Bonferroni correction was used for multiple comparisons as the post hoc test. The strength of the correlations between the variables was determined using Pearson's correlation analysis. A linear regression analysis was performed to determine the best model for predicting muscle volume from age, height, weight, BMI, and L3-S1 angle. Continuous variables are expressed as mean ± standard deviation, while categorical variables are given as frequency and percentage. $P < .05$ values were considered statistically significant.

Reporting Guidelines

This study was conducted and reported in accordance with the STROBE guidelines.

Results

A total of 150 patients with lower back pain were included in the study. Of all patients, 63 (42%) were male, and 87 (58%) were female. The mean age of all patients was 57.3 ± 14.2 years. The mean age was 55.8 ± 14.2 years in male patients and 58.0 ± 12.7 years in female patients. The mean height of all patients was 164.1 ± 8.7 cm. The mean height was 175.3 ± 8.7 cm in male patients and 158.9 ± 8.4 cm in female patients. The mean body weight of all patients included in the study was 73.9 ± 7.9 Kg. The mean weight was measured as 75.7 ± 7.9 Kg in male patients and 73.1 ± 8.2 Kg in female patients. When the BMI values of all enrolled patients were examined, the mean BMI was 29.05 ± 4.27 Kg/m2. Accordingly, 12 (31.6%) patients were within the normal range, 13 (34.2%) were overweight, 11 (28.9%) were obese, and 2 (5.3%) were morbidly obese. Demographic data of the patients included in the study are given in Table 1. When lumbosacral angulation measurements carried out with MRI were evaluated, the mean lumbar angle was found to be 44.2 ± 10.6 degrees, and the mean lumbosacral angle was measured as 56.7 ± 10.9 degrees. The mean wedge angle for all patients included in the study was 9.3 ± 3.7 degrees. The mean sacral horizontal angle was found to be 33.6 ± 7.1 degrees.

Table 1. *Demographic features of the patients*

	Female		Male		Total	
Number	n	%	n	%	n	%
	87	58	63	42	150	100
	mean ± SD		mean ± SD		mean ± SD	
Age (years)	58.0 ± 12.7		55.8 ± 14.2		57.3 ± 14.2	
Height (cm)	158.9 ± 8.4		175.3 ± 8.7		164.1 ± 8.7	
Weight (Kg)	73.1 ± 8.2		75.7 ± 7.9		73.9 ± 7.9	
Body Mass Index (Kg/m²)	29.05 ± 4.27		24.5 ± 4.24		27.8 ± 4.24	

When volumes of the muscles in the lower lumbar region were examined, the mean right psoas muscle volume was found to be 885.9 ± 358.7 mm3, while the mean left psoas muscle volume was found to be 890.9 ± 346.1 mm3. No statistically significant difference was found between the psoas angles on both sides (P = .790). The mean right lumbar extensor muscle volume was measured as 2169.6 ± 489.6 mm3, while the mean left lumbar extensor volume was calculated as 2286.5 ± 1452.8 mm3. There was no statistically significant difference between the two muscle volumes (P = .870). Data regarding sagittal curvature and extensor muscle volumes are given in Table 2.

In the linear regression analysis, the correlations between age, height, weight, BMI, lumbar angle, lumbosacral angle, wedge angle, and sacral horizontal angle were evaluated. Accordingly, a negative correlation was found between age and muscle volume (r = -.38, P = .030), and a positive correlation was found between lumbosacral angle and muscle volume (r = .58, P < .001). However, these two parameters were not correlated with psoas muscle volume. No significant correlation was found between the height, weight, and BMI parameters subjected to linear regression analysis and extensor muscle volume.

An example of measuring sagittal curvature angles is shown in Figure 1. Figure 2 shows measurements of lower lumbar extensor muscle volumes in the same patients obtained on MRI.

Discussion

The aim of this study was to investigate whether there was an association between the magnitude of extensor muscles and sagittal curvature of the lumbar spine. The lumbar spine facilitates flexion and extension and helps resist torsion and shear loads.[13-14] In a previous hypothesis proposed by Meakin et al., the effect of the shape of the lumbar spine on the forces required for the stabilization of follower loads was investigated, and a relationship between them was confirmed.[7] Greater muscle strength is needed to provide stability to the lumbar vertebrae with greater curvature, and a muscle's force-generating capacity is associated with its physical size. This suggests variations in extensor muscle size.[15-16] This variation has been reported to be associated with the variation in lumbar curvature.[17]

Table 2. *Sagittal curvature and extensor muscle volume values*

CURVATURE ANGLES				
	MIN	**MAX**	**MEAN**	**SD (±)**
Lumbar Angle (degrees)	20.0	82.0	44.2	10.6
Lumbosacral Angle (degrees)	29.0	87.0	56.7	10.9
Wedge Angle (degrees)	1.0	40.0	9.3	9.0
Sacral Horizontal Angle (degrees)	20.0	63.0	33.6	7.1
EXTENSOR MUSCLE VOLUMES				
	MIN	**MAX**	**MEAN**	**SD (±)**
Right PSOAS muscle volume (mm^3)	55.0	2027.0	885.9	358.7
Left PSOAS muscle volume (mm^3)	261.0	1891.0	890.9	346.1
Right Lumbar Extensor Muscle Volume (mm^3)	972.0	3998.0	2169.0	489.6
Left Lumbar Extensor Muscle Volume (mm^3)	969.0	18930.0	2286.5	1452.8

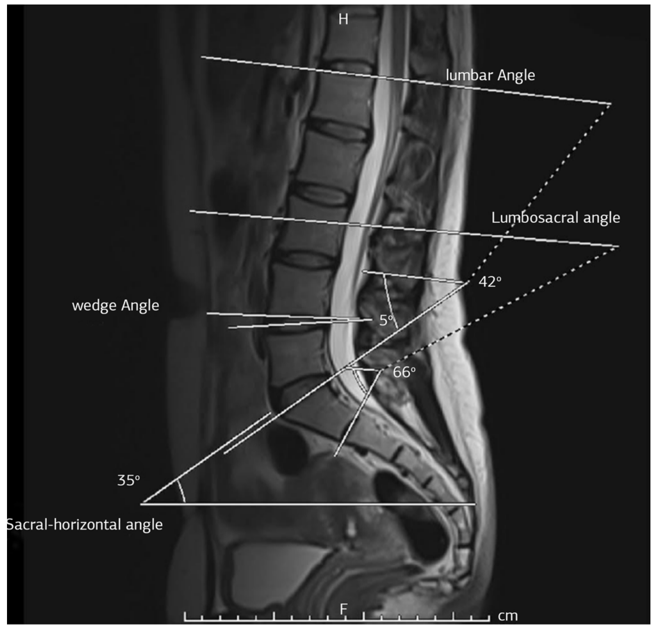

Figure 1. *Measurements of lumbar angle, lumbosacral angle, wedge angle, and sacral horizontal angle of a patient MRI images*

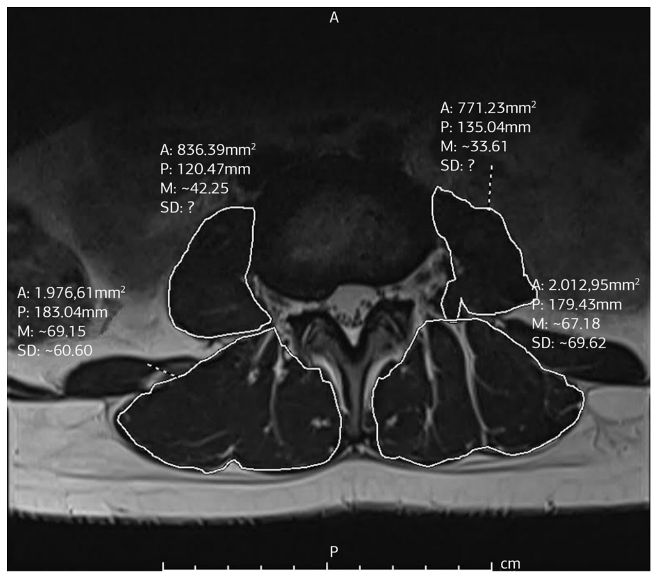

Figure 2. *Measurements of the right and left PSOAS muscle volumes and the right and left lumbar extensor muscles of a patient on T2 weighted axial plane MRI*

In a 2013 study by Meakin et al., greater extensor muscle activity caudal to L3/L4 was associated with a greater degree of lumbar curvature between L4 and S1.7 Similarly, in our study, the degree of lumbar curvature between L3 and S1 was greater in patients with greater extensor muscles caudal to L4/l5. In our study, lumbar muscle volume was measured from T2-weighted axial plane images. To avoid confounding factors, all patients were positioned in the same posture during MRI examinations. We measured volume rather than area to assess the size of the lumbar muscles. Because we aimed to minimize passive elongation.[18] Passive elongation is expected to reduce the area, while this factor does not change the volume.

Although in our study MRI examinations were performed in the supine position for all patients, it has been reported that results obtained in the supine position are highly correlated with those in the standing position.[7] Andreasen et al. showed that changes between the supine and standing positions at the levels of lumbar curvature are only a few degrees.[19] The significant correlation between lower lumbar muscle volume and age found in our study is consistent with other studies in the literature. Previous studies have reported that aging is associated with a reduction in body muscle mass, driven by various molecular and cellular alterations.[20] The effect of age on this relationship is associated with age-related muscle loss, and a reduction in spinal muscle strength leads to a decrease in lumbar curvature. This association may also be explained by other age-related alterations in spinous process height[21] or disc height, and by decreases in anterior wedging.[22]

In the present study, no significant correlation was found between the lower lumbar muscle volume and height, weight, and BMI. However, studies report greater muscle mass in taller and heavier individuals[23] and a positive correlation between lumbar muscle mass and physical size.[24] This difference might be due to the relatively small number of our patients. Furthermore, in the present study, although there was a significant association between height and muscle volume, it did not reach statistical significance (P = .055).

Studies in the literature have reported that an individual's spinal shape is an intrinsic property,[7] attributable to vertebral morphology. Vertebral morphology is changed by the size and shape of vertebral bodies and the size and angulation of posterior elements. However, because the relationship between vertebral morphology and spinal curvature has not been adequately evaluated in the literature, the main objective of the present study is to investigate this association.

An alternative mechanism for explaining the relationship between sagittal curvature and lower lumbar muscle volume is that this association may be influenced by body size, gender, and lifestyle. Because vertebral morphology may affect the action mechanism of the extensor muscles and modify the forces applied to the spine, this issue is of paramount importance. However, there is still no study on this issue in the literature, and further research is urgently needed to investigate the relationship between vertebral morphology and the aforementioned factors.

Studies in the literature argue that reduced lumbar curvature is correlated with lower back pain.[25] Although studies in the literature have reported that the extensor muscles of patients with lower back pain are smaller compared to those of healthy volunteers,[12,16] in the present study all participants were patients with lower back pains, and when sagittal curvature angles and lower lumbar extensor muscle volumes were evaluated between these patients themselves, as is expected muscle volumes were greater in the patients with a larger curvature.

Limitations

This study has some limitations. First, the number of our patients is relatively small for such an analysis. Second, sagittal curvature angles and lower lumbar region extensor muscle volumes could not be compared with a healthy control group. However, given the lack of studies in the literature on this issue, we believe that our results would provide a significant contribution.

Conclusion

Our findings indicate a significant positive correlation between the volume of the extensor muscles in the lower lumbar spine and sagittal curvature in the same region. However, our results should be supported with further comprehensive studies, including a larger number of patients. We think that clarifying the relationship between sagittal curvature and lower lumbar muscle size will contribute to the management of patients with lower back pain and help determine whether these patients would benefit from intensive treatment.

Declarations

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments, or comparable ethical standards.

Informed Consent

Written informed consent was waived due to the retrospective design of the study.

Data Availability

The datasets used and/or analyzed during the current study are not publicly available due to patient privacy reasons but are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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None.

Author Contributions (CRediT Taxonomy)

Conceptualization: I.Y.
Methodology: I.Y., S.H.A.
Investigation: I.Y.
Data curation: I.Y.
Formal analysis: I.Y.
Writing – original draft: I.Y.
Writing – review & editing: S.H.A.
Supervision: S.H.A.

AI Usage Disclosure

The authors declare that no AI-assisted technologies were used.

Abbreviations

BMI: Body Mass Index
MRI: Magnetic Resonance Imaging
ROI: Region of Interest
SPSS: Statistical Package for the Social Sciences

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