Investigation of the Relationship Between Sagittal Curvature and Lumbar Extensor Muscle Volume in Patients with Lower Back Pain

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Research

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Abstract

Objective: 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 with 87 being female and 63 male who presented to our hospital with the complaint of lower back pain and were referred to our radiology clinic were included in this study. 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 as 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 mm$^3$, while the mean left lumbar extensor volume was calculated as 2286.5±1452.8 mm$^3$.

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 provide contribution to the management of patients with lower back pain and will be helpful in determining whether these patients would benefit from intensive treatment.

Introduction

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 present in humans expanding from the neck to the pelvis, and these curvatures distribute body load evenly during walking or working (2). It is important to maintain a normal curvature in order to protect the spinal cord against extensive movements. A balanced spinal alignment optimizes muscle energy expenditure and joint stress, where the gravity center is in a physiological position and maintains the static and dynamic postures.

Deterioration of muscle composition may cause the occurrence of prolonged lower back pain and its recurrence (3). Extensor muscles of the lumbar spine are found posterior to the vertebral bodies, and play a critical role in the control of movements and providing mechanical balance (4). These muscles consist of two main groups as transversospinalis and erector spinae muscles.

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 as ‘follower loads’ (6). In a recent modelling study, how the forces required
to generate follower loads are influenced by the difference of curvature magnitude was investigated (7). The range of lumbar sagittal curvature is wide in the normal population (8).

In general, it is known that muscle strength is proportional to the 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 a great variability, especially in the lower lumbar regions (12). In a modelling study by Meakin et al., it was proposed that individuals with a greater 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 majority of them being modelling 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.

**Material & Methods**

A total of 150 patients with 87 being female and 63 male who presented to our hospital with the complaint of 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 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. All angulation and volumetric measurements were obtained through magnetic resonance imaging (MRI) method in all patients. The images were acquired using Siemens 1.5 T (Siemens Healthcare GmbH, Erlangen, Germany) brand MRI device.

BMI was calculated by dividing body weight in Kg by square of height by meter (Kg/m$^2$). Lumbar angle was measured as the angle between L1 and S1. Lumbosacral angle was measured between L3 and S1 vertebrae. Wedge angle was considered as the angle between L4 and L5 vertebrae. Sacral horizontal angle was taken as the angle between the upper level of S1 and the horizontal axis. Right and weight 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 echo time of 1.9 ms with gradient echo sequence. Depending on the size of the patient, an in-plane resolution between 1.76 and 1.95 mm/pixel was used. ROIs included the iliocostalis, multifidus and longissimus muscles. Patients with fat infiltration detected in ROI were excluded from the study.

The status of lower back pain was confirmed with the answer given to the questions that 'Do you have or had you lower back pain in the past, which was questioned through a survey form.
Ethics Considerations

Before the beginning of the study, the necessary approval was received from the local ethics committee of our hospital. All patients were informed about the objectives of the study and gave verbal and written consent. Patients who rejected participation were excluded from the study. This study was conducted in the ethical principles of the Declaration of Helsinki.

Statistical Analysis

Data obtained in the study were analyzed using SPSS version 23.0 (Statistical Package for Windows (SPSS), IBM Inc., Chicago, IL, USA). Normality of the data was evaluated using Kolmogorov-Smirnov test. Variance analysis was used for the evaluation of the differences between the groups, and Bonferroni correction was used for the multiple comparisons as the post hoc test. The strength between the correlations between the variables was determined using Pearson’s correlation analysis. A linear regression analysis was performed in order to determine the best model predicting muscle volume using 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 < 0.05 values were considered statistically significant.

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 found as 57.3 ± 14.2 years. The mean age was found as 55.8 ± 14.2 years in male patients and 58.0 ± 12.7 years in female patients. The mean height of all patients was found as 164.1 ± 8.7 cm. The mean height was measured as 175.3 ± 8.7 in male patients and 158.9 ± 8.4 cm in female patients. The mean body weight of all patients included in the study was found as 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 BMI values of all enrolled patients were examined; the mean BMI value was found as 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 morbid obese. Demographic data of the patients included in the study are given in Table 1.
<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Number</td>
<td>87</td>
<td>58</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>mean ± SD</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
</tr>
<tr>
<td>Age (years)</td>
<td>58.0 ± 12.7</td>
<td>55.8 ± 14.2</td>
<td>57.3 ± 14.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158.9 ± 8.4</td>
<td>175.3 ± 8.7</td>
<td>164.1 ± 8.7</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>73.1 ± 8.2</td>
<td>75.7 ± 7.9</td>
<td>73.9 ± 7.9</td>
</tr>
<tr>
<td>Body Mass Index (Kg/m²)</td>
<td>29.05 ± 4.27</td>
<td>24.5 ± 4.24</td>
<td>27.8 ± 4.24</td>
</tr>
</tbody>
</table>

When lumbosacral angulation measurements carried out with MRI were evaluated; the mean lumbar angle was found as 44.2 ± 10.6 degrees, and the mean lumbosacral angle was measured as 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.

When volumes of the muscles in the lower lumbar region were examined; the mean right PSOAS muscle volume was found as 885.9 ± 358.7 mm³, while the mean left PSOAS muscle volume was found as 890.9 ± 346.1 mm³. No statistically significant difference was found between the PSOAS angles in both sides (p = 0.790). 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 both muscle volumes (p = 0.870). Data regarding sagittal curvature and extensor muscle volumes are given in Table 2.
Table 2
Sagittal curvature and extensor muscle volume values

<table>
<thead>
<tr>
<th>CURVATURE ANGLES</th>
<th>MIN</th>
<th>MAX</th>
<th>MEAN</th>
<th>SD (±)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar Angle (degrees)</td>
<td>20.0</td>
<td>82.0</td>
<td>44.2</td>
<td>10.6</td>
</tr>
<tr>
<td>Lumbosacral Angle (degrees)</td>
<td>29.0</td>
<td>87.0</td>
<td>56.7</td>
<td>10.9</td>
</tr>
<tr>
<td>Wedge Angle (degrees)</td>
<td>1.0</td>
<td>40.0</td>
<td>9.3</td>
<td>9.0</td>
</tr>
<tr>
<td>Sacral Horizontal Angle (degrees)</td>
<td>20.0</td>
<td>63.0</td>
<td>33.6</td>
<td>7.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXTENSOR MUSCLE VOLUMES</th>
<th>MIN</th>
<th>MAX</th>
<th>MEAN</th>
<th>SD (±)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right PSOAS muscle volume (mm3)</td>
<td>55.0</td>
<td>2027.0</td>
<td>885.9</td>
<td>358.7</td>
</tr>
<tr>
<td>Left PSOAS muscle volume (mm3)</td>
<td>261.0</td>
<td>1891.0</td>
<td>890.9</td>
<td>346.1</td>
</tr>
<tr>
<td>Right Lumbar Extensor Muscle Volume (mm3)</td>
<td>972.0</td>
<td>3998.0</td>
<td>2169.0</td>
<td>489.6</td>
</tr>
<tr>
<td>Left Lumbar Extensor Muscle Volume (mm3)</td>
<td>969.0</td>
<td>18930.0</td>
<td>2286.5</td>
<td>1452.8</td>
</tr>
</tbody>
</table>

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 = 0.030) and a positive correlation was found between lumbosacral angle and muscle volume (r = .58, p < 0.001). However, these two parameters were not correlated with the volume of PSOAS muscles. No significant correlation was found between height, weight and BMI parameters that were subjected to the linear regression analysis and extensor muscle volume.

An example of the measurement of sagittal curvature angles is given in Fig. 1. Figure 2 shows the measurement of lower lumbar extensor muscle volumes in the same patients 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. Lumbar spina facilitates flexion and extension, and is helpful in resisting against torsion and shear load (13, 14). In a previous hypothesis proposed by Meakin et al., the effect of the shape of lumbar spine on the forces required for the stabilization of follower loads was investigated, and a relationship between them was confirmed (7). A greater muscle strength is needed to provide stability of lumbar vertebrae with a greater curvature, and force-generating capacity of a muscle is associated with the physical size of the muscle. This suggests
variations in the size of the extensor muscle (15, 16). This variation has been reported to be associated with the variation in lumbar curvature (17).

In a study by Meakin et al. in 2013, greater extensor muscles caudal to L3/L4 were found to be associated with a greater lumbar curvature degree 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. In order to avoid confounding factors, all patients were positioned in the same posture during MRI examinations. We measured volume instead of area to determine the size of 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 carried out in the supine position in all patients, it has been reported that results 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 correlation found significant in our study between lower lumbar muscle volume and age is consistent with the other studies in the literature. Previous studies have reported that ageing is related to the reduction in the amount of muscles in the body depending on the various molecular and cellular alterations (20, 21). The effect of age on this relationship is associated with age-related muscle loss, and reduction in the strength of the spinal muscles lead to a decrease in lumbar curvature. This association may also be explained by other age-related alterations in the height of spinous process in the spine (22) or disc highness and decreases in the anterior wedging (23).

In the present study; no significant correlation was found between the lower lumbar muscle volume and height, weight and BMI. However, there are studies reporting that muscle mass is greater in taller and heavier persons (24) and that there is a positive correlation between lumbar muscles and physical size (25). This difference might be a result of the relatively small number of our patients. Furthermore, in the present study although there was a significance between height and muscle volume, this significance did not reach statistical significance (p = 0.055).

Studies in the literature have reported that the shape of the spine of an individual is an intrinsic property (7) and this is caused by vertebral morphology. Vertebral morphology is changed by the size and shape of vertebral bodies and size and angulation of posterior elements. However, since the relation of vertebral morphology with the 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 to explain the relationship between sagittal curvature and lower lumbar muscle volume is that this association may be affected by body size, gender and lifestyle. Because vertebral morphology may affect the action mechanism of extensor muscles, modifying the forces applied on the spine, this issue is of paramount importance. However, there is still no study on this issue in the literature,
and further studies are urgently needed to investigate the relationship between vertebral morphology and above mentioned factors.

There are studies in the literature arguing that the reduction in lumbar curvature is correlated with lower back pain (26). Although studies in the literature have reported that 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 the 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.

**Study 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 health 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 extensor muscles in the lower half of the 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 provide contribution to the management of patients with lower back pain and will be helpful in determining whether these patients would benefit from intensive treatment.

**Declarations**

**Ethical Approval and Consent to Participate:**

Yes

**Consent for Publication:**

Informed consent form was obtained from the patient for this manuscript.

**Availability of data and materials:**

N/A

**Competing Interests:**

The authors declare no competing interests to disclose.
**Funding:**

This case report did not receive financial support.

**Acknowledgements:**

N/A

**Conflict of Interest:**

The authors declare no conflict of interest regarding this study

**Funding:**

This study did not receive financial support

**Ethics Considerations:**

Informed consent form was obtained from the patients for this study to use patient information for publication purpose.

**References**


Figures
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.