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RELATIONSHIP OF LUMBAR SPINAL ANATOMICAL STRUCTURES WITH LUMBAR DISC HERNIA AND SPINAL STENOSIS

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ABSTRACT

Objective: We aimed to radiologically evaluate the clinical and demographic features accompanying ligamentum flavum hypertrophy and possible accompanying differences in anatomical structures.

Materials and Methods: We evaluated vertebral alignment, integrity of neural structures, diameter of the central canal, posterior longitudinal ligament, ligamentum flavum integrity, and position of the facet joints in patients with lumbar disk herniation and lumbar spinal canal stenosis using magnetic resonance imaging (MRI). Furthermore, we examined the age, body mass index (BMI), and employment status of the patients and the status of the vertebral and paravertebral anatomical structures using MRI. Age, BMI, employment status, ligamentum flavum thickness at the L4–L5 level, interspinous ligament thickness, facet joint diameter, posterior longitudinal ligament integrity, psoas muscle diameter, erector spina muscle diameter, and mean multifidus muscle diameter were also analyzed.

Results: Significant differences were found in age, BMI, employment status, ligamentum flavum thickness, interspinous ligament thickness, mean facet diameter, mean multifidus muscle diameter, mean erector spina muscle diameter, and mean psoas muscle diameter. In addition, separate statistical analyses were conducted between sex, age, employment status, BMI, and lumbar anatomical parameters. Significant correlations were found between lumbar disk herniation and spinal stenosis pathologies based on radiological measurements of lumbar structures, such as the ligamentum flavum, interspinous ligament, and facet diameter, and demographic parameters, such as age, sex, employment status, and BMI.

Conclusion: We examined changes in the anatomical structures accompanying the vertebral column and existing discal or stenotic pathologies. In addition to the demographic characteristics of the patients, changes in the accompanying lumbar spinal anatomical structures, such as degeneration, hypertrophy, and atrophy, may be important. These factors and changes will help plan the treatment process and guide the results.

Keywords: Facet hypertrophy, ligamentum flavum, lumbar disk hernia, lumbar spinal stenosis

INTRODUCTION

Lumbar disk herniation and lumbar canal stenosis are common pathologies in neurosurgery practice. The development of vertebral surgical interventions is important for the treatment of these diseases. Patients with these pathologies often complain of lower back pain, leg pain, paresis, and decreased mobility. In lumbar disk herniation, the clinical symptoms of hernia are caused by the compression of the nucleus pulposus on neural structures, whereas canal stenosis is generally caused by ligamentum flavum or facet hypertrophy[1-5].

Magnetic resonance imaging (MRI) is the most commonly used radiological method in the diagnosis and treatment planning of these diseases[6]. Vertebral alignment, integrity of the neural structures, spinal canal diameter, posterior longitudinal ligament integrity, and position of the facet joints are the major components of MRI evaluation[7]. Along with these assessments, we assumed that additional patient factors such as the patient's age, sex, body mass index (BMI), employment status, and MRI measurements like paravertebral muscle mass, paravertebral ligament thickness could guide the development of diagnostic treatment plans for these patients. Thus, in this study, we aimed to evaluate the effects and accompaniments of factors such as the patient's age, BMI, employment status, and vertebral–paravertebral anatomical conditions on the development of pathologies in patients with lumbar disk herniation and lumbar spinal stenosis.

MATERIALS AND METHODS

We started this study with the assumption of the presence of vertebral-paravertebral pathologies accompanying and causing lumbar disc herniation and lumbar canal stenosis

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in retrospective design. This study analyzed data from 215 patients who underwent surgery in our clinic for lumbar disk herniation and spinal stenosis (study group) and 69 patients who applied to our outpatient clinic for lower back pain where no pathology was found on lumbar MRI (control group). The age, sex, BMI, and employment status of the study and control groups were evaluated.

As occupational groups can be divided into various subcategories; in the present study, employment status was divided into three categories: not working in any job (non-worker), working in a job (worker), and working in heavy jobs (heavy worker). People who work in jobs that create a heavy workload or that cause a lot of physical stress were considered heavy workers. As there is a one-to-one correlation between the level being operated on and hypertrophy, only descriptive results were presented. Interspinous ligament thickness, ligamentum flavum thickness, facet joint diameter, erector spinae muscle group volume, psoas muscle group volume, and multifidus muscle group volumes were measured on preoperative lumbar MRI, in sections passing through the pathological segments of the study group and L4-L5 level of the control group (Figure 1). MRI scans were acquired using the Siemens Aera 1.5 Tesla MRI scanner (Siemens, Erlangen, Germany). All measurements were performed using the Sectra IDS7 Workstation (Linköping, Sweden). This study was conducted in accordance with the Declaration of Helsinki and was approved by the Sivas Cumhuriyet University Human Research Ethics Committee (approval number: 2021-01/06).

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, US). To investigate whether variables had a normal distribution and that variance homogeneity assumptions were met, Kolmogorov-Smirnov and Levene tests were used, respectively. Categorical data were expressed as numbers (n) and percentage (%), whereas quantitative data were given as mean ± standard deviation and median (25^{th}-75^{th}) percentiles. The mean differences between groups were compared using Student's t-test, while the Mann-Whitney U test was applied to compare variables without normal distribution. Since there were more than two independent groups, quantitative data were evaluated using a One-Way analysis of variance (ANOVA) or the Kruskal-Wallis test, where appropriate. When the One-Way ANOVA or Kruskal-Wallis test

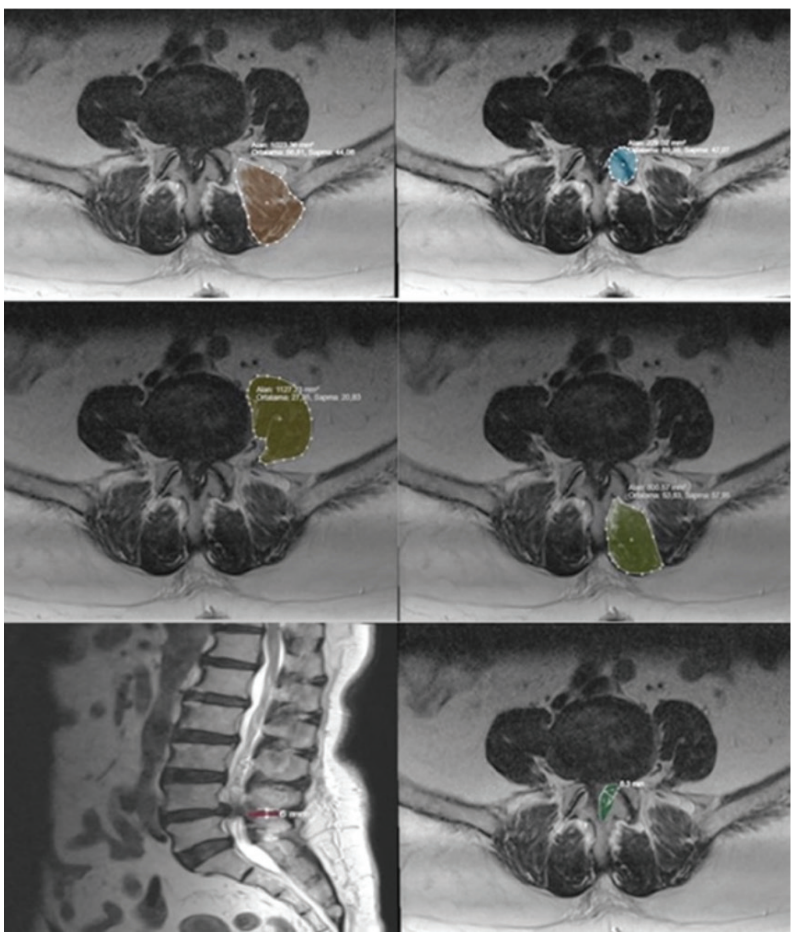

Figure 1. Measurement of interspinous ligament and ligamentum flavum thickness, facet joint, multifidus, erector spinae and psoas muscle areas in sagittal and axial lumbar MRI sections

MRI: Magnetic resonance imaging

indicated significance, post-hoc Tukey honestly significant difference test or Dunn-Bonferroni multiple comparison tests were used to find which group differed from the others. Categorical data were analyzed using Pearson's $\chi2$ test. The degrees of association between continuous variables were evaluated using Spearman's rank-order correlation analyses. Whether being operable and the presence of hypertrophy had a significant effect on clinical measurements were investigated using quantile regression analyses after adjustment for age, sex, BMI, and employment status. The coefficient of regression, 95% confidence intervals, and t-statistics for each independent variable were also calculated. Quantile regression analyses were performed using STATA 16.1 (Stata Corp., TX, USA). A p-value <0.05 was considered significant.

RESULTS

Descriptive statistics regarding the demographic and clinical characteristics of the patients are shown in Table 1. Comparisons of the demographic and clinical characteristics of the cases according to the operated and non-operated groups are given in Table 2. Both the mean age and BMI were significantly higher in the operated group than in the non-operated group (p<0.001 and p=0.004). No significant difference was found between the groups for male-female distribution and employment status (p=0.223 and p=0.649, respectively). Interspinous ligament thickness, mean facet diameter, mean multifidus muscle diameter, mean erector spinae diameter, and mean psoas muscle diameters were significantly higher in the operated group than in the non-operated group (p<0.05).

Table 1. Demographic and clinical features

	n=284
Age (year)	47.1±14.6
Age range (year)	16-90
Sex	
Male	125 (44.0%)
Female	159 (56.0%)
Employment status	
Non-worker	172 (60.6%)
Worker	68 (23.9%)
Heavy worker	44 (15.5%)
BMI (kg/m^2)	28.9±4.7
Pathology	
Normal	69 (24.3%)
L4-L5 disk herniation	92 (32.4%)
L5-S1 disk herniation	60 (21.1%)
L3-L4 stenosis	19 (6.7%)
L4-L5 stenosis	44 (15.5%)
Interspinous ligament thickness	6.02 (5.01-7.77)
Facet joint diameter	250.4 (193.3-307.3)
Multifidus muscle diameter	816.7 (710.2-983.1)
Erector spinae muscle diameter	1047.7 (920.6-1232.0)
Psoas muscle group diameter	1069.4 (879.0-1481.1)
Ligamentum flavum thickness	5.40 (3.66-6.30)
Operated group	215 (75.7%)
Ligamentum flavum hypertrophy (+)	150 (52.8%)

BMI: Body mass index

Table 3 shows the comparisons of the demographic and clinical characteristics of the cases in the non-operated group with and without lumbar ligamentum flavum hypertrophy. A significant difference was found in the mean age between the groups: control group, non-operated group with ligamentum flavum hypertrophy, and operated group with ligamentum flavum hypertrophy (p<0.001). No significant difference in sex was found between the groups (p=0.026). Moreover, a significant difference was found in the BMI averages of the control group, non-operated group with ligamentum flavum hypertrophy, and operated group with ligamentum flavum hypertrophy (p<0.001). In addition, a significant difference in occupational status was found between the groups, and the unemployment rate in the operated group without hypertrophy was lower than those in the other two groups (p<0.05). The interspinous ligament thickness was higher in the hypertrophy group than in the non-operated group (p=0.021). A significant difference in the mean facet diameters was found between the groups (p<0.001). No significant difference in the mean psoas muscle volumes was noted between the groups (p=0.129).

Table 4 shows the correlation coefficients and significance levels between the age and BMIs of all cases and clinical measurements. Regarding age, a significant inverse correlation was found between the levels of interspinous ligament thickness and psoas muscle diameter, and the same significant correlation was observed between the mean facet diameter and mean multifidus muscle diameter (p<0.05). While a significant inverse correlation was found between BMI and psoas muscle diameters in all cases (r=-0.151 and p=0.011), a significant correlation was found in the mean facet joint diameter, mean multifidus muscle diameter, and mean erector spinae muscle diameter (p<0.001).

Table 5 shows the comparisons of clinical measurements according to sex and employment status. Compared with men, women had significantly lower mean facet diameters, mean multifidus muscle volume, and mean psoas muscle volume (p<0.01). The mean psoas levels were higher in workers and heavy workers than in non-workers (p<0.001).

Table 6 shows the correlation coefficients and significance levels between clinical measurements. Regarding interspinous ligament thickness, a significant and the same directional correlation was observed between the mean facet joint diameter, mean psoas muscle diameter, and mean erector spinae muscle diameter (p<0.05). With the mean facet joint diameters, a significant and the same directional correlation were found between the mean multifidus muscle diameter, mean psoas muscle diameter, and mean erector spinae muscle diameter

Table 2. Demographic and clinical characteristics of the operated and non-operated groups

	Non-operated (n=69)	Operated (n=215)	p-value
Age (year)	37.9±12.1	50.1±14.1	<0.001†
Sex			0.223‡
Male	26 (37.7%)	99 (46.0%)	
Female	43 (62.3%)	116 (54.0%)	
Employment status			0.649‡
Non-worker	41 (59.4%)	131 (60.9%)	
Worker	15 (21.7%)	53 (24.7%)	
Heavy worker	13 (18.8%)	31 (14.4%)	
BMI (kg/m^2)	27.5±4.3	29.3±4.7	0.004†
Pathology			N/A
Normal	69 (100.0%)	-	
L4–L5 disk herniation	-	92 (42.8%)	
L5–S1 disk herniation	-	60 (27.9%)	
L3–L4 stenosis	-	19 (8.8%)	
L4–L5 stenosis	-	44 (20.5%)	
Interspinous ligament thickness	5.90 (5.00-6.75)	6.20 (5.05-8.10)	0.012¶
Facet joint diameter	186.1 (155.5-213.1)	273.3 (216.2-327.6)	<0.001¶
Multifidus muscle diameter	715.8 (660.5-823.0)	855.5 (737.9-1025.9)	<0.001¶
Erector spinae muscle diameter	976.5 (829.1-1111.3)	1081.5 (941.4-1262.0)	<0.001¶
Psoas muscle group diameter	1018.0 (816.3-1195.6)	1106.0 (884.2-1515.5)	0.043¶

†: Student's t test, ‡: Pearson's χ^2 test, ¶: Mann-Whitney U test, N/A: Not applicable, BMI: Body mass index

(p<0.001). For the mean multifidus muscle measurements, a significant and the same directional correlation were noted between the mean erector muscle and mean psoas muscle diameters (p<0.001). Finally, a significant and the same directional correlation were found between the mean erector spinae and mean psoas muscle diameters (p<0.001).

DISCUSSION

This study evaluated the clinical and demographic features accompanying ligamentum flavum hypertrophy and possible accompanying differences in anatomical structures radiologically.

The ligamentum flavum is located between the upper and lower vertebrae lamina, posterior of the dural sac, and provides protection and stability to the spinal column. In diseases such as lumbar disk herniation and lumbar spinal stenosis, ligamentum flavum hypertrophy can aggravate the clinical symptoms. Many studies on this subject have shown that age, high BMI, and heavy working conditions can cause ligamentum hypertrophy[8-10]. In the present study, the results obtained support literature data. In addition, changes in the facet joints, paravertebral muscle volume, and other ligamentous structures can be expected following changes in the ligamentum flavum. The results of some studies also support this finding[11,12].

In the present study, no significant difference was found between the groups in terms of male-female distribution. In the literature, no significant sex difference was found in this regard[13]. Moreover, this study focused on the detection of changes in lumbar spinal anatomical structures and accompanying degenerative pathologies. The interspinous ligament thickness, mean facet diameter, and mean multifidus, erector, and psoas volumes were significantly higher in the operated group than in the non-operated group.

Previous studies have reported the relationship between paraspinal muscles and fat volume around the paraspinal muscle and lumbar spinal degeneration[13-15]. These studies have reported that patients with ligamentum flavum hypertrophy also have atrophy of the paravertebral (especially multifidus) muscles and lubrication around the muscle. However, the direct relationship between lumbar spinal degenerative changes and BMI was not investigated in these studies. By contrast, in the present study, a significant correlation was found between high BMI, ligamentum flavum hypertrophy, and surgical indication due to lumbar spinal degenerative diseases.

Other studies have reported facet joint hypertrophy and osteoarthritis in the etiology of ligamentum flavum hypertrophy. The results of these studies agreed with our findings[15]. Factors that influence the development of ligamentum flavum hypertrophy include age, spinal level, mechanical stress, and growth factors. Histologically, increased ligamentum flavum thickness is associated with an increase in fibrosis and a decrease in elastic fibers[15]. Thus, as reported in the present study

Table 3. Demographic and clinical characteristics of the patients with and without lumbar ligamentum flavum hypertrophy

	Non-operated (n=69)	Hypertrophy (-) (n=65)	Hypertrophy (+) (n=150)	p-value
Age (year)	37.9±12.1[a]	42.6±12.2[b]	53.3±13.6[a,b]	<0.001[†]
Sex				0.026[‡]
Male	26 (37.7%)[c]	38 (58.5%)[b,c]	61 (40.7%)[b]	
Female	43 (62.3%)[c]	27 (41.5%)[b,c]	89 (59.3%)[b]	
Employment status				<0.001[‡]
Non-worker	41 (59.4%)[c]	25 (38.5%)[b,c]	106 (70.7%)[b]	
Worker	15 (21.7%)	22 (33.8%)	31 (20.7%)	
Heavy worker	13 (18.8%)	18 (27.7%)[b]	13 (8.7%)[b]	
BMI (kg/m^2)	27.5±4.3[a]	27.5±4.0[b]	30.1±4.8[a,b]	<0.001[†]
Pathology				N/A
Normal	69 (100.0%)	-	-	
L4–L5 disk herniation	-	39 (60.0%)	53 (35.3%)	
L5–S1 disk herniation	-	26 (40.0%)	34 (22.7%)	
L3–L4 stenosis	-	-	19 (12.7%)	
L4–L5 stenosis	-	-	44 (29.3%)	
Interspinous ligament thickness	5.90 (5.00-6.75)[a]	6.00 (5.15-7.35)	6.55 (5.00-8.25)[a]	0.025[¶]
Facet joint diameter	186.1 (155.5-213.1)[a]	204.6 (173.7-253.5)[b]	299.9 (255.0-342.3)[a,b]	<0.001[¶]
Multifidus muscle diameter	715.8 (660.5-823.0)[a]	737.9 (659.1-879.7)[b]	919.7 (794.7-1090.4)[a,b]	<0.001[¶]
Erector spinae muscle diameter	976.5 (829.1-1111.3)[a]	1000.0 (880.8-1122.8)[b]	1121.8 (982.5-1320.4[a,b]	<0.001[¶]
Psoas muscle group diameter	1018.0 (816.3-1195.6)	1186.6 (861.3-1522.5)	1086.3 (884.8-1516.8)	0.129[¶]

[a]: The difference between the non-operated group and the group with hypertrophy is significant (p<0.05), [b]: The difference between the group without hypertrophy and the group with hypertrophy is significant (p<0.05), [c]: The difference between the non-operated group and group without hypertrophy was significant (p<0.05), [†]: One-Way ANOVA, ‡: Pearson's χ^2 test, [¶]: Kruskal-Wallis test, N/A: Not applicablea, BMI: Body mass index

Table 4. Correlation coefficients and significance levels between age and body mass index of all cases and clinical measurements

	Age		BMI	
	Correlation coefficient	p-value[†]	Correlation coefficient	p-value[†]
Interspinous ligament thickness	-0.154	**0.009**	-0.075	0.208
Facet joint diameter	0.476	**<0.001**	0.236	**<0.001**
Multifidus muscle diameter	0.123	**0.038**	0.197	**<0.001**
Erector spinae muscle diameter	0.049	0.410	0.228	**<0.001**
Psoas muscle group diameter	-0.154	**0.009**	-0.151	**0.011**

[†]: Spearman's rank-order correlation analysis, BMI: Body mass index

and previous studies, facet joint hypertrophy accompanied with ligamentum flavum hypertrophy may indicate that mechanical stress is an important factor in the etiology of both.

Study Limitations

One of the limitations of our study; radiological measurements could not be made in 3D. Apart from this, the group examined in this single-centered study could have been larger and th control group could be larger though. We believe that stronger results can be achieved with multicenter studies in the future, with study series in which the study group is larger and technology can be used more powerfully.

CONCLUSION

Lumbar disk herniation and lumbar spinal stenosis are very common diseases in daily neurosurgery practice. In this study, we examined changes in the anatomical structures accompanying the vertebral column and existing discal or stenotic pathologies. In addition to the demographic characteristics of the patient,

Table 5. Comparisons of clinical measurements according to sex and employment groups

	Interspinous ligament thickness	Facet joint diameter	Multifidus muscle diameter	Erector spinae muscle diameter	Psoas muscle group diameter
Sex					
Male	6.30 (5.20-8.10)	262.7 (199.4-337.9)	845.9 (729.5-1068.4)	1101.5 (919.4-1260.7)	1511.6 (1223.6-1798.4)
Female	6.00 (5.00-7.60)	236.2 (187.9-296.9)	794.3 (695.6-945.9)	1032.1 (922.9-1173.4)	916.5 (777.3-1052.0)
p-value†	0.171	**0.007**	**0.009**	0.149	**<0.001**
Employment status					
Non-worker	6.00 (5.00-7.60)	251.7 (193.3-316.4)	806.6 (709.4-958.4)	1038.1 (932.0-1190.4)	955.2 (800.3-1097.9)[a,b]
Worker	6.40 (5.28-8.80)	258.2 (201.6-300.4)	819.9 (697.8-1056.6)	1024.3 (862.8-1247.6)	1491.3 (1223.4-1727.1)[a]
Heavy worker	6.15 (5.33-7.18)	207.5 (173.6-281.6)	879.3 (721.7-1065.9)	1103.3 (989.1-1271.4)	1394.9 (1136.7-1825.8)[b]
p-value‡	0.199	0.083	0.427	0.310	**<0.001**

Descriptive statistics; displayed as median (25th-75th) percentile, †: Mann-Whitney U test, ‡: Kruskal-Wallis test, a: The difference between non-workers and workers is significant (p<0.001), b: The difference between non-workers and heavy workers is significant (p<0.001)

Table 6. Correlation coefficients and significance levels between clinical measurements

	Facet joint diameter	Multifidus muscle diameter	Erector spinae muscle diameter	Psoas muscle group diameter
Interspinous ligament thickness				
Correlation coefficient	0.144	0.065	0.118	0.194
p-value†	**0.015**	0.273	**0.046**	**<0.001**
Facet joint diameter				
Correlation coefficient		0.467	0.275	0.243
p-value†		<0.001	**<0.001**	**<0.001**
Multifidus muscle diameter				
Correlation coefficient			0.528	0.369
p-value†			**<0.001**	**<0.001**
Erector spinae muscle diameter				
Correlation coefficient				0.285
p-value†				**<0.001**

†: Spearman's rank-order correlation analysis

changes in the accompanying spinal anatomical structures such as degeneration, hypertrophy, and atrophy may be important. Considering these factors and changes will help clinicians plan the treatment processes and choose the treatment method and outcomes.

Ethics

Ethics Committee Approval: All measurements were performed using the Sectra IDS7 Workstation (Linköping, Sweden). This study was conducted in accordance with the Declaration of Helsinki and was approved by the Sivas Cumhuriyet University Human Research Ethics Committee (approval number: 2021-01/06).

Informed Consent: Retrospective study.

Authorship Contributions

Surgical and Medical Practices: H.C.K., F.K., E.K., Ü.Ö., Concept: H.C.K., Ü.Ö., Design: H.C.K., Ü.Ö., Data Collection or Processing: F.K., E.K., Analysis or Interpretation: H.C.K., Literature Search: H.C.K., F.K., E.K., Ü.Ö., Writing: H.C.K., F.K.

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