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Original Article

Morphometric MRI assessment of lumbar region in healthy individuals

Ismail Istemen, Semih Kivanc Olguner, Ali Arslan, Vedat Acik

Department of Neurosurgery, Adana City Education and Research Hospital, Adana,Turkey

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Abstract

Aim: In our study, we aimed to obtain normal anatomical data in healthy individuals by magnetic resonance imaging, which we frequently use in our daily practice. We encounter quite frequently with the lumbar pathologies. To identify the pathological one, the normal one must first be defined. For this, anatomical studies are the most ideal methods, but costly and challenging studies. Morphometric assessment of the lumbar region by magnetic resonance imaging in the normal population is not common in the literature.

Material and Methods: The workup of 100 patients who presented to our clinic, did not have low back pain, underwent lumbar MRI examination for different reasons and whose results were reported to be normal, were evaluated using the PACS system. Morphological evaluation of the paravertebral muscles, ligamentum flavum, and the spinal canal was performed on the right and left sides separately. The data were analyzed by age, gender, and body mass index.

Results: Forty-nine patients were females, and 51 were males. The mean age of the patient group was 34.62±9.54 years, and mean BMI was 24.96±3.32 kg/m^2. Ligamentum flavum thickness and muscle areal measurements were similar between both sides. The comparisons of clinical measurements between females and males revealed that the areas of muscles were significantly higher among males and all other measurements were similar between sexes. There was a weak and positive correlation between age and both right and left erector spinae area. The only parameters that weakly and positively correlated with body mass index were right and left erector spinae areas.

Conclusion: In our study, we reported the morphological characteristics of the lumbar region in healthy individuals. An increase in the cross-sectional areas of the erector spinae and the spinal canal at the L5-S1 level was observed with the age. An asymmetry may develop in LF measurements with the age. There was also a positive correlation between body mass index and the cross-sectional area of erector spinae.

Keywords: Healthy people; lumbar anatomy; lumbar morphology

INTRODUCTION

Lumbar pathologies are quite common in our practice. The normal morphological structure of the spinal region changes due to degenerative changes and pathologies that develop with the age. To identify the pathological one, the normal one must first be defined. For this purpose, the most ideal method is conducting anatomical studies, but it is very costly and obtaining enough specimens is difficult. Morphometric measurements with radiological examinations are easier and faster in the normal population. Various morphometric studies are conducted for a long time by computed tomography (CT) and magnetic resonance imaging (MRI) (1-3). CT provides very valuable information about bone structures but leads to significant radiation exposure (4,5), MRI shows soft tissues and neural structures quite well. However, the data of patients with degenerative lumbar spinal stenosis have been published frequently in studies conducted with MRI in the literature (3,6,7), and morphometric evaluation of the lumbar region in the normal population is not common. In this study, we aimed to reveal the morphometric structure of the lumbar region in normal individuals.

MATERIAL and METHODS

The workup of 100 patients without low back pain who presented to our clinic between 2016 and 2017, underwent lumbar MRI for different reasons, and whose results have been reported to be normal, were evaluated using the PACS system. The cross-sectional area of the paravertebral muscles (multifidus, psoas, erector spinae), the cross-sectional area of the spinal canal at the disc levels, the thickness of ligamentum flavum (LF) and the cross-sectional area of LF at the same level were measured (Figure 1). The right and left sides were measured separately. Measurements were performed by

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Corresponding Author: Ismail Istemen, Department of Neurosurgery, Adana City Education and Research Hospital, Adana,Turkey
E-mail: drismailistemen@gmail.com

three different clinicians and the mean values were used. The data were analyzed by age, gender, and body mass index (BMI). Approval was obtained from the Clinical Research Ethics Committee of our Hospital for the study (403/13.03.2019).

Statistical analyses

The descriptive statistics were presented with frequency and percent for categorical variables, and the mean and the standard deviation for numerical variables. The comparisons of clinical parameters between independent groups were done using the Mann-Whitney U test. The correlations between numerical variables were analyzed using Spearman's test. The normal reference ranges of the variables were calculated as mean ± 2xS.E.M. (standard error of the mean, which is the standard deviation divided by the square-root of sample size). A p-value lower than 0.05 was considered significant. SPSS 21 (IBM Inc., Armonk, NY) was used for the analyses.

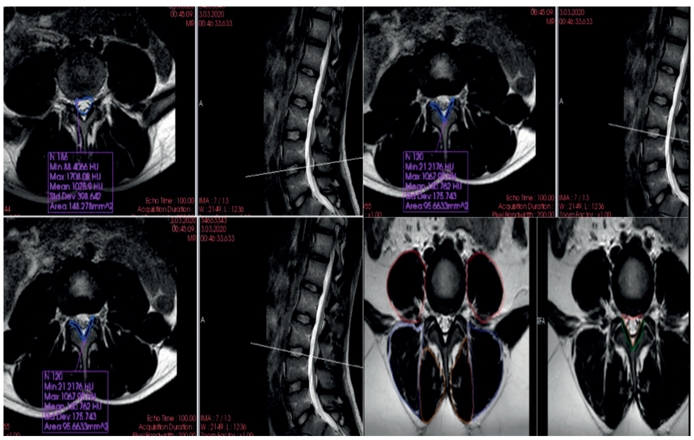

Figure 1. The measurements of anatomical structures on Magnetic Resonance Imaging

RESULTS

The demographic characteristics of the patients were presented in Table 1. Forty-nine patients were females, and 51 were males. The mean age of the patient group was 34.62±9.54 years, and mean BMI was 24.96±3.32 kg/m^2.

Table 1. Demographic characteristics

	n	%
Sex		
Female	49	49.0
Male	51	51.0
	Mean	**SD**
Age (years)	29.62	6.54
BMI (kg/m^2)	24.96	3.32

The normal reference ranges for clinical measurements were presented in Table 2, and the comparisons between the right and left sides were summarized in Table 3.

Accordingly, L.F. thickness and muscle areal measurements were similar between both sides. The comparisons of clinical measurements between females and males revealed that multifidus area, psoas area, and erector spinae area were significantly higher among males ($p<0.05$ for all), and all other measurements were similar between sexes (Table 4).

Table 2. Normal reference ranges for clinical measurements

	Mean	S.E.M.	95% CI of Mean
Lordosis angle			
Canal area (mm^2)			
L_3-L_4	194.55	3.99	186.56 - 202.54
L_4-L_5	202.30	4.38	193.54 - 211.07
L_5-S_1	245.32	6.04	233.25 - 257.4
L.F. Thickness (mm)			
L_3-L_4(right)	3.40	0.08	3.24 - 3.56
L_3-L_4 (left)	3.41	0.08	3.25 - 3.57
L_4-L_5 (right)	3.80	0.06	3.67 - 3.92
L_4-L_5 (left)	3.85	0.07	3.72 - 3.98
L_5-S_1 (right)	3.60	0.10	3.39 - 3.8
L_5-S_1 (left)	3.60	0.11	3.38 - 3.81
L.F. Area (mm^2)			
L_3-L_4	105.70	2.16	101.39 - 110.02
L_4-L_5	117.98	2.30	113.38 - 122.59
L_5-S_1	125.75	10.21	105.33 - 146.17
Multifidus area (mm^2)			
Right	874.96	22.82	829.31 - 920.61
Left	888.84	21.43	845.97 - 931.71
Psoas area (mm^2)			
Right	1361.61	41.36	1278.89 - 1444.33
Left	1373.16	40.79	1291.59 - 1454.73
Erector spina area (mm^2)			
Right	1403.69	32.81	1338.07 - 1469.31
Left	1416.75	31.83	1353.09 - 1480.4

The associations of clinical measurements with patient age and BMI were summarized in Table 5.

There was a weak and positive correlation between age and L5-S1 canal area ($r=0.202$; $p=0.043$); weak and negative correlations between age and L3-L4 right L.F. thickness ($r=-0.219$; $p=0.028$), age and L4-L5 right L.F. thickness ($r=-0.229$; $p=0.022$), and age and L3-L4 L.F. area ($r=-0.198$; $p=0.049$); weak and positive correlations between age and right erector spinae area ($r=0.23$; $p=0.021$) and left erector spinae area ($r=0.27$; $p=0.007$). The only parameters that weakly and positively correlated with BMI were right ($r=0.266$; $p=0.007$) and left ($r=0.291$; $p=0.003$) erector spinae areas.

Table 3. Comparison of muscle are and L.F. thickness on right and left sides

	Measurements Mean±SD		p
	Right	Left	
L.F. Thickness (mm)			
L_3-L_4	3.4 ± 0.79	3.41 ± 0.8	0.787
L_4-L_5	3.8 ± 0.63	3.85 ± 0.67	0.374
L_5-S_1	3.6 ± 1.02	3.6 ± 1.08	0.645
Area (mm²)			
Multifidus	874.96 ± 228.25	888.84 ± 214.34	0.266
Psoas	1361.61 ± 413.58	1373.16 ± 407.86	0.304
Erector spina	1403.69 ± 328.11	1416.75 ± 318.28	0.415

Table 4. Comparison of clinical measurements between males and females

	Female	Male	p
	Mean±SD	Mean±SD	
Lordosis angle	46.95 ± 8.1	45.46 ± 7.74	0.304
Canal area (mm²)			
L_3-L_4	188.08 ± 39.5	200.76 ± 39.77	0.087
L_4-L_5	195.87 ± 38.8	208.49 ± 47.74	0.076
L_5-S_1	236.51 ± 60.38	253.79 ± 59.7	0.206
L.F. Thickness (mm)			
L_3-L_4(right)	3.44 ± 0.81	3.36 ± 0.78	0.709
L_3-L_4 (left)	3.43 ± 0.79	3.39 ± 0.81	0.780
L_4-L_5 (right)	3.77 ± 0.59	3.82 ± 0.67	0.609
L_4-L_5 (left)	3.9 ± 0.64	3.8 ± 0.7	0.425
L_5-S_1 (right)	3.67 ± 1	3.53 ± 1.05	0.443
L_5-S_1 (left)	3.71 ± 1.16	3.48 ± 0.99	0.171
L.F. Area (mm²)			
L_3-L_4	109.23 ± 24.32	102.32 ± 18.21	0.379
L_4-L_5	123.05 ± 26.16	113.11 ± 18.52	0.136
L_5-S_1	115.43 ± 23.82	135.67 ± 141.04	0.809
Multifidus area (mm²)			
Right	803.79 ± 125.52	943.34 ± 279.81	0.001
Left	814.57 ± 133.32	960.2 ± 251.61	0.001
Psoas area (mm²)			
Right	1126.52 ± 362.58	1587.48 ± 326	<0.001
Left	1143.76 ± 364.18	1593.56 ± 317.69	<0.001
Erector spina area (mm²)			
Right	1341.53 ± 330	1463.4 ± 318.11	0.029
Left	1343.72 ± 330.64	1486.91 ± 292.2	0.010

Table 5. Association of clinical measurements with patient age and BMI

	Age		BMI	
	r	p	r	p
Lordosis angle	-0.031	0.760	-0.136	0.179
Canal area				
L_3-L_4	-0.006	0.949	-0.080	0.428
L_4-L_5	0.088	0.383	-0.053	0.600
L_5-S_1	0.202	0.043	-0.012	0.907
L.F. Thickness				
L_3-L_4(right)	-0.219	0.028	-0.056	0.581
L_3-L_4 (left)	-0.167	0.096	-0.114	0.259
L_4-L_5 (right)	-0.114	0.258	0.130	0.198
L_4-L_5 (left)	-0.229	0.022	0.022	0.828
L_5-S_1 (right)	-0.139	0.169	0.163	0.106
L_5-S_1 (left)	-0.134	0.185	0.112	0.266
L.F. Area				
L_3-L_4	-0.198	0.049	0.033	0.748
L_4-L_5	-0.196	0.051	-0.048	0.638
L_5-S_1	-0.092	0.363	-0.009	0.928
Multifidus area				
Right	0.065	0.519	0.028	0.780
Left	0.059	0.560	0.014	0.892
Psoas area				
Right	0.124	0.218	0.089	0.377
Left	0.143	0.156	0.077	0.447
Erector spina area				
Right	0.23	0.021	0.266	0.007
Left	0.27	0.007	0.291	0.003

DISCUSSION

Lumbar pathologies are perhaps the most common pathologies seen in the daily practice of neurosurgery. Our greatest assistant in the evaluation of patients is radiological examinations. X-ray, tomography, and MRI are frequently used. We can evaluate the soft tissue elements, the neural tissue, and the morphological structure of the spinal canal other than the bone structure best by MRI. There are many articles on this subject. Some studies evaluate the volume of paravertebral muscles, the volume, and area of the spinal canal, and even the spinal canal morphology by MRI scans performed in the standing position (1,3,4,8). However, most of the time, these studies have been carried out in patients with clinical and radiological pathological findings. In others, MRI techniques not used in routine were used. In a study of Boissiere L. et al., 10 patients with lumbar spinal stenosis were included in the study. Volumetric measurements of the paravertebral muscles and the spinal canal were done by performing 3-dimensional reconstruction on the MRI scan results of the patients (4). There was no significant difference in muscular mass and muscular fat infiltration between the right and left sides. The results were also obtained by making volume calculations with 3D reconstruction and software calculations in this study. It is difficult to correlate the results of the study with the results of the 2D MRI we use in our daily practice.

Lang G. et al. performed MRI scans in 3 different positions, in the supine position, 800 upright positions, and 800 upright + hyperlordotic position, in 10 patients with L4-L5 spondylolisthesis. They reported morphological changes in different positions (8). However, these standing MRI scans are not yet routinely used in our daily practice. In our study, we reported normal morphometric values in the workup of patients without complaints whose MRI results were reported to be normal (Table 2).

In studies comparing healthy control groups with patients with low back pain, the area of paravertebral muscles was reported to be higher in the healthy group. Besides, the cross-sectional area of the paravertebral muscles was found to be lower on the painful side (9-11). A multifidus asymmetry of 68% and a psoas asymmetry of 5% were reported in studies carried out in individuals without pain (12,13). Valentin S. et al. did not detect any asymmetry in the muscle groups in young people and found a significant reduction in the multifidus surface area in the elderly group(14). In our study, no significant side-difference was detected in the measurements of the paravertebral muscles at the L4-L5 level and the ligamentum flavum at the L3-L4, L-4-L5, L5-S1 levels. In patients with chronic low back pain, the cross-sectional area of the multifidus muscle at the L4-L5 level has been reported within the range of 3.47-7.08 cm^2 (15). In our study, this value was found to be 8.8 cm^2 on average in healthy individuals. The reason for this can be explained by the absence of pain complaints and the relatively low mean age in the participants of our study.

When we examine the effect of aging, albeit weak, a positive correlation was found between the age and erector spinae muscles in healthy individuals in our study. No age-related changes were detected in the multifidus and psoas muscles. However, the mean age of our patients was found to be 34.62±9.54. Among the participants, there were 9 patients aged 50 and over, of which only one was 60 years old. Mengiardi B. et al. reported that the volume of paravertebral muscle did not correlate with age and the fat infiltration was increased. The increase in muscular fat infiltration with aging was considered to be the cause of low back pain (16). Valentin S. et al. detected a significant decrease in the multifidus surface area and a mild statistically insignificant decrease in the psoas surface area in elderly individuals without pain. As a result, they suggested that they cannot generalize the changes in the muscles with age (14). Meakin et al. found a negative correlation between the surface area of the erector spinae and the age in their study composed of female participants with an average age of 44 and no pain (17). In the study carried out by Fortini M. et al. with a 15-year follow-up, they reported a decrease in the surface area of the muscles and an increase in fat infiltration with age. In the study of Fortini, the mean age of patients increased from 47.3 to 62.3 at the end of follow-up (18). There were two more studies conducted in the wider age range. Takahashi K. et al. and Lexell et al. reported that muscle atrophy became more prominent after the age of 50 and reached its maximum in the 70s in the studies they conducted in the age range of 20-79 years and the age range of 15-83 years, respectively (19,20). Our participants were younger. Having a study with a younger and painless population explains the difference in findings.

There have been many studies on the subject since BMI has been reported to be effective on muscles (16,21-24). In the studies of Kjaer et al. and Fortin M. et al., BMI has been reported to not affect muscle composition and volume (22). Fortin M. et al. reported that BMI has a negative effect on the area of the erector spinae, but did not affect the muscular fat infiltration in another study (18). Valentin S. et al. reported that BMI does not affect muscular mass (14). In our study, a bilateral increase in the erector spinae area was found along with an increase in BMI. It did not affect other muscles. However, the mean BMI (24.96±3.32 kg/m^2) in our patients was not very high. Therefore, these results may have been obtained due to the development of compensatory extensor muscle in slight increases in BMI.

When we compare the results we obtained in our study by gender, surface area measurements in muscle groups were higher in men. This was a highly anticipated result and was compatible with the literature (1,15). Spinal canal width was also high in men, but not statistically significant. There was no significant difference between the other results.

When we examined the measurements associated with LF, the thickness and cross-sectional area of the ligament was measured at the L3-L4, L4-L5, L5-S1 levels. It was observed that there were no differences by the gender and side. However, it was seen that as the age increased, there were significant differences between the right and left sides, albeit weak. Similarly, it has been reported that it may be thicker on the right or left side in the literature (25-27). This may be related to the use of dominant hands and feet or the degenerations they experience in their daily lives. Kim Y.U. et al. reported that LF thickness and LF area were both significantly effective. However, they reported that the measurement of LF thickness may lead to asymmetric results. They, therefore, recommend using the measurement of the LF area. In the study, it was determined that the LF area has a precision of 80.1%, a sensitivity of 76%, LF thickness has a precision of 70.5% and a sensitivity of 66.5% (28). Besides, the results of our study were consistent with the LF thickness and LF area values given for the L4-L5 level in this study. The reason for emphasizing the L4-L5 distance is that this level has been reported to be the place where LF was the thickest in the literature. Besides, lumbar spinal stenosis develops most commonly at this level. In the same study, a positive correlation was reported between BMI and LF thickness (29). Unlike it, no relationship was found between BMI and the thickness and area of LF in our study.

One of the most important parameters while evaluating the pathology of lumbar spinal stenosis is the cross-sectional area of the spinal canal. First of all, caution should be exercised that the cross-sectional scans are taken properly. Axial sections obtained parallel to the disc distance should be used. In the study of Henderson L. et al., it was reported that if the shooting angle was not parallel to the disc, significant false results were obtained (3). The measurement results of the spinal canal and dural sac were also significantly different. Kim Y.U. et al. reported the spinal canal area as 197.1 mm^2 (SD 65.8) at the L4-L5 distance and the dural sac area as 149.5 mm^2 (SD 57.3) (30). This spinal canal value was consistent with our results (202.3 mm^2, 193.54-211.07). Fortin M. reported the dural sac area as an average of 68mm^2 in his study in patients with lumbar spinal stenosis. When the relationship was examined clinically, he reported this value as 73 mm^2 in patients with mild restriction with an ODI score of 42 and below. In patients with severe restriction and an ODI score above 42, the result was reported to be 63 mm^2 (15). The results of the study were significantly lower than the results we obtained in the normal population. In the study of Boissiere L. et al., volumetric measurements of the spinal canal were performed. The volume of the total spinal canal was reported to be 31.3 ± 5.5 cm^3. Spinal canal volume decreases from L1-L2 to L5-S1. However, these results are the results of patients with lumbar stenosis at the lumbar 4-5 level (4). It does not include the values of the normal population. In our study, it was found that the canal area increased towards the L5-S1 level in the normal population. The findings in this study cannot help us because they are not included in our daily use. In our study, the cross-sectional area of the spinal canal was evaluated in healthy individuals. Normal values were determined using axial sections taken parallel to the disc at L3-L4, L4-L5, L5-S1 levels.

LIMITATIONS

The limitations of our study include the small number of participants, narrow age distribution, and a narrow range of BMI. However, it is difficult to find healthy individuals at advanced ages or with high BMI and without pain and any pathological findings in the tests. In prospective studies, it will be possible to detect the changes that will occur by following-up the healthy large patient groups for a long time.

CONCLUSION

We reported the morphological results of the lumbar region obtained in healthy individuals in our study. It was found that the cross-sectional areas of the erector spinae and L5-S1 spinal canal increase with the age. Asymmetry may develop in LF measurements with advancing age. There is also a positive correlation between BMI and the erector spinae area.

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Ethical approval: Approval was obtained from the Clinical Research Ethics Committee of our Hospital for the study (403/13.03.2019).

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