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Importance of paravertebral muscle quality in the etiology of degenerative lumbar spinal stenosis

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ABSTRACT

Objectives: Degenerative lumbar spinal stenosis (DLSS) is the leading cause of pain, disability, and loss of independence in older adults. In this study, the relationship between DLSS and paravertebral muscle thickness and density was investigated using computed tomography (CT) and magnetic resonance imaging (MRI) methods. Thus, the importance of muscles has been examined to take precautions in the name of preventive medicine.

Methods: This study was planned as a cross-sectional study. The patient group (n = 77) who had surgery for DLSS and the control group (n = 77) were examined. A total of 154 participants (55 females and 22 males in each group) were evaluated retrospectively in terms of cross-sectional area (CSA) and density in the psoas, erector spina and multifidus muscles. In both groups age, gender and body mass index values equalized. Measurements was averaged from the mid-lumbar 3 level from both sides and multi-points.

Results: There was no significant difference between muscle thicknesses ($p > 0.05$). When evaluated in terms of muscle densities, a significant difference was found between the patient and the control group in terms of psoas muscle ($p < 0.05$). Likewise, there is the same relationship between erector spinae muscle density and multifidus muscle density ($p < 0.05$).

Conclusions: Roughly no difference was found between the patient and control groups in terms of CSA of the psoas, erector spinae and multifidus muscles, but it was observed that the muscle density, especially in the multifidus, decreased significantly in the patients. Our results suggest that paravertebral muscle density assessment is an important criterion in disease prediction and can inform preventive treatment.

Keywords: Paravertebral muscle quality, degenerative lumbar spinal stenosis, preventive medicine, literature review

Paraspinal muscles are the most important structure in maintaining stability and function of the lumbar vertebra [1]. The lumbar spine is inherently unstable, and its stability depends on the integrated function of active, passive, and neural subsystems [1]. Degenerative lumbar spinal stenosis (DLSS) is an age-related chronic disease [2, 3]. It progresses with the degradation of 3 joint complexes and ligamentum flavum hypertrophy [2, 4]. Spinal instability plays an important role in DLSS [5].

The density and cross-sectional area (CSA) of the paraspinal muscle are known to vary with age, sex,

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and weight [6]. Literature suggests that these muscles have smaller CSA in patients with chronic back pain than in similarly aged healthy individuals [7]. Muscle CSA and density are believed to reflect the performance of individuals. Muscle status information such as density and CSA can be obtained using non-invasive medical imaging techniques that offer high reproducibility [8]. Magnetic resonance imaging (MRI) and computed tomography (CT) have been used to measure CSA and the rate of muscle degeneration in patients with muscular diseases [9].

Although several studies have been published on the importance of paravertebral muscle quality, consensus on the subject does not exist; furthermore, most studies have several inadequacies [7, 10-18]. Analyzing the shortcomings of these studies, we took the subject again with a new model.

In this study, the association between DLSS and paravertebral muscle thickness and density was investigated using CT and MRI methods. Thus, the importance of muscles has been examined to take precautions. We believe that the results of our study will help design medical strategies to prevent DLSS onset and progression.

METHODS

This study recruited participants into 2 groups. For the first (DLSS) group, patients visiting the Cumhuriyet University Medical Faculty Hospital who were evaluated for spinal stenosis between January 1, 2015, and December 30, 2019, were included. These patients were referred to lumbar MR imaging and CT scans given their symptoms of spinal stenosis, and they received surgical treatment after imaging. Inclusion criteria were reduction in the CSA of the lumbar spinal canal (< 100 mm^2) in at least 1 level with concurrent symptoms associated with spinal stenosis (intermittent claudication, and radicular pain) [19]. In addition, images of the patients in the first group were taken at least at 6 months and at most at 5 years after surgery. For the second (control) group, the same number of asymptomatic male and female of similar body mass indices (BMI) (± 5) and age who had undergone lumbar MR and CT scans for other reasons and did not have lumbar stenosis, were enrolled at the same time frame and same institution. Exclusion criteria included congenital stenosis, traumatic fractures, spondylolysis, spinal tumors, Paget disease, long-term steroid therapy, renal colic, and scoliosis of > 10 degrees [20]. Lumbar MR and CT images of the patients archived on Picture Archiving and Communication Systems (PACS) were screened. Measurements were made by author using the Sisoft imaging program used at our hospital. Random and blind consistency control was performed by 2 separate neurosurgeons.

The density and CSA of the psoas, erector spine, and multifidus muscles were measured at the midlumbar (L) 3 level [20, 21]. The muscles to be inves-

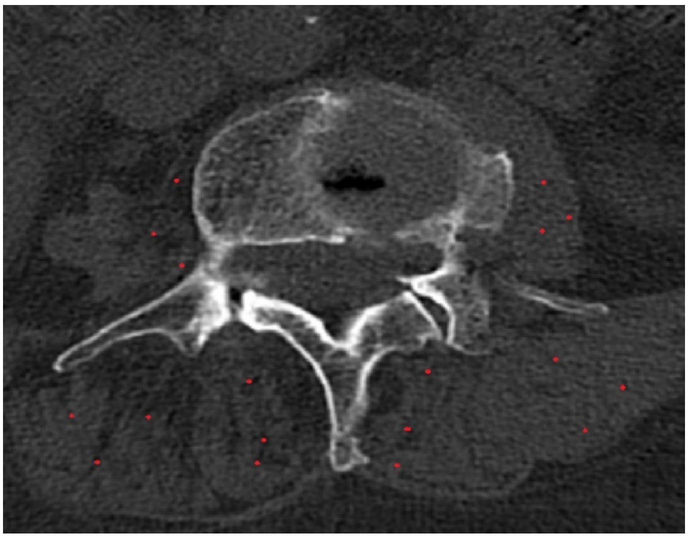

Fig. 1. Density measurement with Hounsfield units from computed tomography using 3 random points from each muscle.

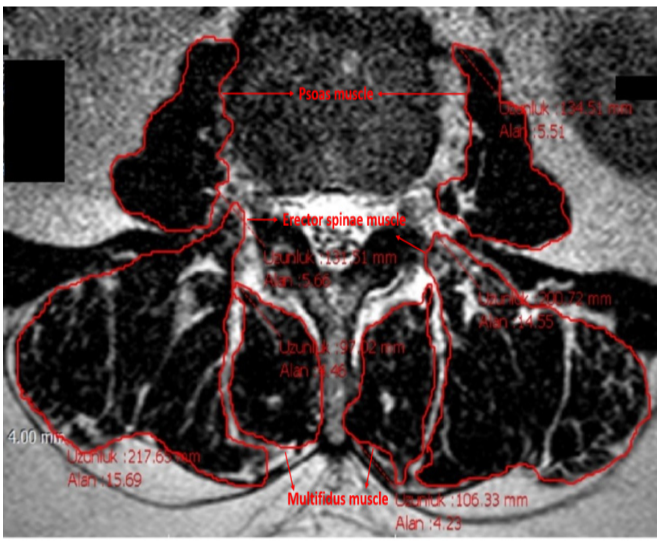

Fig. 2. The cross-sectional area measurement of the psoas, multifidus, and erector spinae muscles.

tigated at this level are at their widest and the most appropriate level in terms of separating the erector spinae from the multifidus [20, 21]. In addition, all the images were obtained with the patient in the supine position and feet stretched out. No contrast was used.

The density of the psoas, multifidus and erector spinae muscles were measured in Hounsfield units (HU) using CT combined with MRI to obtain clearer separation. The density value for each side was calculated as the average density from 3 random regions. Then, the final muscle density was calculated as the mean of the densities of the right and left muscles (Fig. 1).

The CSA of the psoas, multifidus and erector spinae muscles were measured from the fascia border using MRI on both sides separately. Then average values were calculated for the right and left muscles (Fig. 2).

An informed consent form for lumbar spine surgery was obtained from each of the patients in the current National Brain and Nerve Surgery Association consent form list, and written consents were obtained from outpatient clinic applications which clearly stated that the data could be used within ethical limits. The signed consents are in the file archive of Cumhuriyet University Faculty of Medicine. Ethical approval for the study was obtained with the decision numbered 2020-08/18 of the non-interventional ethics committee of Cumhuriyet University, where I worked on the specified dates.

Statistical Analysis

The sample size of this study was based on the statistical power analysis. Descriptive statistics (arithmetic mean, standard deviation, minimum-maximum and median values) and frequency distributions of the study data were obtained. Statistical analyses were performed using SPSS program (version 22.0). If the data provided parametric test assumptions for evaluation (data obtained by interval, ratio scale, normal distribution), a t-test for two groups (independent, conjugate); when not fulfilled (Kolmogorov-Smirnov) a Mann-Whitney U test and a chi-squared test used. Chi-squared exact test was used to determine the chi-squared value of Fisher's exact test Monte Carlo model. A p - value of < 0.05 was considered statistically significant.

RESULTS

The study included 154 participants (77 patients, 77 controls). Of total, 110 (71.42%) were females and 44 (28.58%) were males. Both the patient and control groups had 22 males and 55 females. In order to rule out the effect of age on the muscles, control group patients were selected as the same ages as the DLSS patents. The mean age of the females was 58.6 years (range: 27-80 years; median: 59 years) and that of the males was 63 years (range: 34-80 years; median: 64 years), respectively. The mean age across both the patient and control groups was 59.8 years. We did not match the number of females and males to avoid further reducing the sample size. Furthermore, the statistical analyses were conducted separately for the males and females to eliminate the effect of the differences in age and sex (Table 1).

Weight also affects muscle properties. To eliminate the effect of weight on the study results, we selected patients with similar (± 5 units) BMI in both groups. In this respect the mean BMI among the female patients with stenosis was 31.45 kg/m^2 (median: 31 kg/m^2; range: 24-43 kg/m^2; standard deviation: 4.68

Table 1. Patient and control group age descriptive statistics

Variables			Value
Age*	Female	Mean	58.6
		Median	59
		Minimum	27
		Maximum	80
		Standard deviation	12.7
	Male	Mean	63
		Median	64
		Minimum	34
		Maximum	80
		Standard deviation	10.9
	Total	Mean	59.8
		Median	63
		Minimum	27
		Maximum	80
		Standard deviation	12.3

*Patient and control group ages were equal, and 55 females 22 males were found in both groups

Table 2. Patient and control group body mass index descriptive statistics

Variables			Female	Male	Total
*Weight	Patient group	Mean	31.45	29	30
		Median	31	29	30
		Minimum	24	22	22
		Maximum	43	35	43
		Standarddeviation	4.68	3.39	4.46
	Controlgroup	Mean	31.3	29	30
		Median	31	30	31
		Minimum	20	21	20
		Maximum	44	38	44
		Standarddeviation	5.79	5.36	5.72

*Body mass index, There is no statistical difference in weight between the patient and control groups ($p > 0.05$)

years). Among the female controls, the mean BMI was 31.3 kg/m^2 (median: 31 kg/m^2; range: 20–44 kg/m^2; standard deviation: 5.79 kg/m^2). Among the men with stenosis, the mean BMI was 29 kg/m^2 (median: 29 kg/m^2; range: 22–35 kg/m^2; standard deviation: 3.39 kg/m^2). Among the male controls, the mean BMI was 29 kg/m^2 (median: 30 kg/m^2; range: 21-38 kg/m^2, standard deviation: 5.36 kg/m^2). The mean BMI of all patients with stenosis was 30 kg/m^2 (median: 30 kg/m^2; range: 22-43 kg/m^2; standard deviation: 4.46 kg/m^2); the mean BMI of the entire control group was 30 kg/m^2 (median: 31 kg/m^2; range: 20-44; standard deviation: 5.72 kg/m^2). No significant difference in BMI was found between the stenosis and control groups (males, females, and total participants; $p > 0.05$). Thus, the variables that could affect muscle thickness and density were eliminated (Table 2).

When we made statistical analysis between psoas muscle thicknesses, there was no significant difference between the males and females and the all participants between the patient and control groups ($p > 0.05$). A significant difference was found between the thickness of the erector spinae in females ($p < 0.05$). No difference was found in males ($p > 0.05$). When evaluated as the all participants, a significant difference was found due to excess number of females ($p < 0.05$). On the other hand, when the number is ignored, the relationship gets weaker. There was no difference between the thickness of the multifidus muscle amongst the patient and control groups in both females, males, and the total participants ($p > 0.05$) (Table 3) (see Table 5).

On comparing muscle densities, a significant difference was found between the patient and the control group in terms of psoas muscle in females, males, and in the total participants ($p < 0.05$). Likewise, there is the same relationship between erector spinae muscle density and multifidus muscle density ($p < 0.05$) (Table 4) (see Table 5). All values of the patients and control groups are reported in the table with the statistical results (Table 5).

DISCUSSION

DLSS is a common disease of the lumbar spine among the elderly [22]. Degenerative changes in the intervertebral disc ligamentum flavum and facet joints cause stenosis in the spinal canal and neural foramen [3]. Clinical manifestations of DLSS are low back and leg pain [3]. Neurogenic claudication is characteristic of DLSS [3]. DLSS is the leading cause of pain, disability, and loss of independence in elderly patients [23]. Given the aging population, the prevalence, and economic burden of DLSS is increasing exponentially [23]. Hence, understanding its etiology is important. Preventive medicine inhibits all treatment and job loss related costs as well as increases the life quality of the population.

There are limited number of studies with low sam-

Table 3. Paravertebral muscle cross-sectional area descriptive statistics.

Variables			Female	Male	Total
Psoas cross-sectional area*	Patient group	Mean	587.4	957.2	693
		Median	583	941	640
		Minimum	299	264	264
		Maximum	935	1841	1841
		Standard deviation	22.1	341.8	282.5
	Control group	Mean	651.6	947	710.3
		Median	628	892	657
		Minimum	283	605	283
		Maximum	1052	1613	1613
		Standard deviation	22.8	268.2	251.1
Erector spinae cross-sectional area	Patient group	Mean	1391.5	1719.5	1485.2
		Median	1396	1641.5	1419
		Minimum	646	479	479
		Maximum	2667	2769	2769
		Standard deviation	59.5	539.1	490.4
	Control group	Average	1643.9	1777.9	1682.2
		Mean	1651	1743	1660
		Minimum	109	854	109
		Maximum	2478	2881	2881
		Standard deviation	55.3	482.2	433.2
Multifidus cross-sectional area	Patient group	Mean	435.6	538,9	465.1
		Median	389	439,5	420
		Minimum	123	197	123
		Maximum	1014	1709	1709
		Standard deviation	26.2	320.9	239.8
	Control group	Mean	471	509.9	482.6
		Median	446	492,5	469
		Minimum	176	320	176
		Maximum	943	891	943
		Standard deviation	18.1	149.9	139.2

*mm^2

ple size about the effect of muscles on the etiology of DLSS [7, 10-18]. Results of these studies are inconsistent [7, 10-18]. In comparison, our study is one of the few studies with the highest sample. In addition, variables that affect muscle quality, such as age, weight, gender, and socioeconomic characteristics, which were not present in other studies, were analyzed by equalizing on the base parameters of patients, not by regression analysis. Furthermore, to eliminate patient, position and device related artefacts, bilateral and multi-point measurements were made, and the average values used for analyses, and all analyses were performed with the same software. These measures lend robustness to our results (Figs. 1 and 2).

Table 4. Paravertebral muscle density descriptive statistics

Variables			Female	Male	Total
Psoas density*	Patient group	Mean	46	51.2	47.5
		Median	45	52	48
		Minimum	22	35	22
		Maximum	87	60	87
		Standard deviation	1.4	5.4	9.5
	Control group	Mean	85	97,3	89
		Median	90	101	95
		Minimum	41	69	41
		Maximum	109	120	120
		Standard deviation	2.5	14.6	18.4
Erector spinae density	Patient group	Mean	40.7	46.6	42.4
		Median	42	47	43
		Minimum	19	32	19
		Maximum	62	57	62
		Standard deviation	1.1	7	8.6
	Control group	Mean	63	74.8	66.4
		Median	63	80	65
		Minimum	22	31	22
		Maximum	101	118	118
		Standard deviation	2.5	26.7	22
Multifidus density	Patient group	Mean	30.2	43	33.9
		Median	31	44,5	35
		Minimum	10	22	10
		Maximum	54	55	55
		Standard deviation	1.4	8.4	11.8
	Control group	Mean	47.8	55.6	50.1
		Median	41	52,5	45
		Minimum	20	33	20
		Maximum	103	94	103
		Standard deviation	2.7	19.3	20

*Hounsfield units

As far as we understand from the data, there is no gender-related change among CSA of muscles between the groups, except for erector spinae thickness. This could be attributed to the larger number of female participants in the study. However, statistical significance is maintained when considering the averages even if the difference is reduced. Higher density of this muscle in men, in addition to its being the thickest muscle among the muscle groups, could be the likely reason for this observation. However, no effect of muscle thickness on DLSS was seen in the general population. Spinal instability has been described by Pope and Panjabi [24] as a mechanical phenomenon associated with a loss of rigidity. Paraspinal muscles play an important role in lumbar spine dynamics [25]. The multifidus muscles are the deep muscle group re-

Table 5. **Final results between patient and control groups**

Variables	Psoas cross-sectional area*	Erector spinae cross-sectional area*	Multifidus cross-sectional area*	Psoas density**	Erector spinae density**	Multifidus density**
Female	$p > 0.05$	$\boldsymbol{p < 0.05}$	$p > 0.05$	$\boldsymbol{p < 0.05}$	$\boldsymbol{p < 0.05}$	$\boldsymbol{p < 0.05}$
Male	$p > 0.05$	$p > 0.05$	$p > 0.05$	$\boldsymbol{p < 0.05}$	$\boldsymbol{p < 0.05}$	$\boldsymbol{p < 0.05}$
Total	$p > 0.05$	$\boldsymbol{p < 0.05}$	$p > 0.05$	$\boldsymbol{p < 0.05}$	$\boldsymbol{p < 0.05}$	$\boldsymbol{p < 0.05}$

*mm^2, **Hounsfield units

sponsible for spinal extension, rotation, and stabilization [25]. It spreads over three joint segments and works to stabilize the spine [25]. Thus, it enables each vertebra to work more effectively and reduces the degeneration of joint structures [25]. The erector spinae muscle group is responsible for spinal hyperextension, rotation, and lateral flexion [25]. The psoas muscle is main flexor relative to the hip joint. While this muscle acts as the spine extensor in the lumbar area, it functions as an active postural muscle for the body [25]. These three muscles have different functions in stabilizing the lumbar spine. Although some studies have reported results that are in line with our findings, some have presented differing results, particularly with regard to erector spinae and multifidus thickness [7, 10-18]. This could primarily be attributed to factors affecting muscles not being well identified; however, basis our study results, muscle volume is not important to DLSS development. Regarding muscle density, however, significant differences were seen between patients with DLSS and healthy controls in each muscle group in both women and men. Although the multifidus muscle volume does not change after surgery, the muscle fibers lose their density and show fatty changes and fibrosis becomes highly evident. This result was thought to be since the multifidus muscle is the main muscle that controls spinal movement and contributes to most of the spinal stability [26]. Erector spinae is less affected by surgery. Although the psoas muscle was essentially untouched by the surgeon, the density change highlights the importance of muscle quality change in degenerative processes. This difference in density after surgery signifies the importance of muscle quality in degenerative processes more objectively than other muscles even if the psoas muscle is the least affected. Most previous studies attributed the decrease in density to denervation and muscle disuse in patients with a degenerative spine [27, 28]. Abbas *et al*. [20] suggested that muscle hypertrophy seen at higher levels is a response to degeneration at lower levels, which is more common. Although the same level was examined in our study, the opposite result was observed. Similar to the study by Abbas *et al*. [20], our study had more patients with DLSS at lower levels; however, we only examined patients who received surgical treatment. Although some of our patients had degeneration at the L3 level, most of them had degeneration at lower levels. However, no significant effect of surgery on muscle volume underlines the importance of muscle density. In addition, our follow-up of the patients within 6 months to 5 years after surgery suggests that we may have ruled out reflex hypertrophy that could occur in the first stage and that we examined patients in the late stage of the disease. It was thought that the results of some studies contrary to our article were because of examinations were conducted according to either radiological or clinical criteria as well as low back pain rather than as a stenosis patient who had undergone surgery [7, 10-18]. In the end, it was the factors that could affect muscle quality were not ruled out properly in the selection of patients. Our data firmly supports this.

DLSS is an important health problem today and, given the aging population, increasing exponentially. As can be understood from all these data, the quality of paravertebral muscles plays a key role in the etiology of DLSS. We think the results in this study will shed light on preventing the occurrence of DLSS. It is a known fact that long-term problems such as adjacent segment disease and the need for reoperation after narrow canal surgery are common and do not definitively cure DLSS [29]. It is observed that although the surgery provides short-term decompression of the spinal nerves the decrease in the quality of the erector spinae and psoas muscle that is not intervened, especially in the multifidus muscle that is intervened by surgery, does not affect the progression of the DLSS in the long term. It has also been proven by our data that post-surgical compensation mechanisms are not sufficient. Being alert about the low paravertebral muscle density we see in our patients followed up with stenosis and taking early precautions is the best treatment option in DLSS. Early awareness and rehabilitation maintain muscle quality as well as provide preventive medicine. There is a also need for studies related to the long-term rehabilitation follow-up of patients with DLSS.

Limitations

To mention the limitations, we saw in our study, although no patients in our study engaged in sport, daily activities differed among patients. Different races have not been studied. In order to make a more ideal evaluation, it would be appropriate if the number of men and women were equal, but in terms of not limiting the number of cases, the case and control group gender equality were provided, and situation was taken into consideration in the evaluation and statistical analysis. Lastly, although our study had one of the largest sample sizes compared to studies on this topic, further research with larger groups and multi-center designs are needed.

CONCLUSION

In this study, the relationship between DLSS and paravertebral muscle thickness and density was investigated using CT and MR imaging methods. No significant difference was found between the patient and control groups regarding CSA of the psoas, erector spinae, and multifidus muscles; however, the patients with DLSS had significantly lower muscle density, particularly in the multifidus muscle. Considering the prevalence and economic burden of DLSS and given their exponential increase owing to population aging, preventive treatment is critical. Our results suggest that paravertebral muscle density assessment is an important criterion in disease prediction and can inform preventive treatment. The importance of the study was explained by making an appropriate literature comparison.

Authors' Contribution

Study Conception: İK; Study Design: İK; Supervision: İK; Funding: İK; Materials: İK; Data Collection and/or Processing: İK; Statistical Analysis and/or Data Interpretation: İK; Literature Review: İK; Manuscript Preparation: İK and Critical Review: İK.

Conflict of interest

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