Original Article

Can lumbar paraspinal muscle/fat ratio and spinopelvic parameters predict short-term outcomes after decompressive surgeries in lumbar disc herniation and lumbar spinal stenosis?

ABSTRACT

Background and Objectives: We aimed to investigate whether the lumbar paraspinal muscle/fat ratio influences the outcomes of patients who had simple decompressive surgeries for lumbar disc herniation (LDH) or lumbar spinal stenosis. We also wanted to see if the spinopelvic parameters change with surgery and whether this change influences the outcomes.

Materials and Methods: This was a prospective study on patients with lumbar spinal stenosis (20 patients) and LDH (20 patients) who underwent simple discectomy or decompressive surgery between November 2021 and May 2022. Visual Analog Scale (VAS) for back and leg pain, Oswestry Disability Index, and Japanese Orthopedic Association (JOA) score were performed before and 3 months after surgery. Spinopelvic parameters were measured on whole spine radiographs before and 3 months after surgery. On axial magnetic resonance images, paraspinal muscle volume and muscle/fat ratios were calculated. All data were statistically analyzed with SPSS program.

Results: There was a significant improvement in VAS, Oswestry, and JOA scores after surgery. We observed that more preoperative paraspinal muscle mass was positively correlated with lumbar lordosis (LL) and negatively correlated with sagittal vertical axis (SVA), VAS leg scores, and Oswestry scores. Furthermore, we observed a positive correlation between preoperative SVA and VAS leg scores.

Conclusion: Despite limited number of patients, and shorter follow-ups, this prospective study demonstrates a correlation among the lumbar paraspinal muscle/fat ratio, preoperative/postoperative spinopelvic parameters, and surgical outcomes. Increased paraspinal muscle ratio was correlated with lower SVA values and increased LL; lower VAS leg scores; higher Oswestry scores which reflects better surgical outcomes.

Keywords: Lumbar disc herniation, lumbar stenosis, paraspinal muscle atrophy, sagittal balance, Visual Analog Scale

INTRODUCTION

Low back pain (LBP) is a common condition and 65%–85% of general population experience LBP once in their life.[1] Lumbar disc herniation (LDH) is one of the most common causes of LBP and leads to leg pain (sciatic) along with LBP.[2] Lumbar spinal canal stenosis (LSS) is another cause of LBP which frequently seen among elderly. Its main manifestation is leg pain, neurogenic claudication.Bending forward widens the spinal canal and can alleviate symptoms which may cause sagittal imbalance.[3] Sagittal spinal balance has been defined as the presence of lumbar lordosis (LL) and thoracic kyphosis (TK) in equilibrium. Restoring the sagittal spinal balance has been associated

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with pain relief after spine surgery in several diseases.[4] In addition, paraspinal muscle atrophy and fatty infiltration of paraspinal muscles may also correlate with LBP.[5] Erector spinae (ES) and lumbar multifidus (LM) are two important muscles of lower back which have a crucial role in maintaining spinal stability.[6] Therefore, evaluating these muscle groups is vital to understand the effect of paraspinal muscles on LBP. Magnetic resonance imaging (MRI) is commonly used in the assessment of the lumbar spinal anatomy and pathology and provides quantitative and qualitative measurements such as fatty infiltration, muscle size (cross sectional area or volume), and muscle/fat ratio.[1]

The aim of our prospective clinical study is to investigate whether the lumbar paraspinal muscle/fat ratio influences the outcomes of patients who had simple decompressive surgeries for LDH or lumbar spinal stenosis. We also wanted to see if the spinopelvic parameters change with surgery and whether this change influences the outcomes. In order to obtain more precise results, measurements of lumbar paraspinal muscle were performed using the three-dimensional (3D) slicer program on lumbar MRI images.[7]

Our hypotheses for this study were as follows: (a) patients with lumbar spinal stenosis are expected to have worse spinopelvic parameters than patients with LDH, (b) patients with lumbar spinal stenosis are expected to have worse paravertebral muscle mass and more atrophic muscles than patients with LDH, (c) the preoperative spinopelvic parameters are expected to be abnormal in preoperative period and improve postoperatively, and (d) patients with less lumbar paravertebral muscle mass and more fat are expected to have a worse outcome.

MATERIALS AND METHODS

Study design

We designed a prospective study on patients with lumbar spinal stenosis and LDH who underwent simple discectomy or decompressive surgery between November 2021 and May 2022. Patients were from Ege University Hospital, Gazi Hospital Izmir, and Memorial Hospital, Istanbul, Turkey. The local ethics committee approved the study protocol (15.10.2021/E-99166796-050.06.04-359159).

The patients were divided into two groups: LDH (Group 1 – 23 patients) and lumbar spinal stenosis (Group 2 – 22 patients). Five patients were lost to follow-up and excluded from the study. The remaining 40 patients (Group 1 – 20 patient and Group 2 – 20 patient) were analyzed. Thirty-two of 40 patients were operated on in Ege University Neurosurgery Clinic, and eight of them were operated in other clinics. The operations were performed by a total of 11 different surgeons.

Inclusion criteria

Patients older than 18 years who require only decompressive surgery due to LDH or stenosis.

Exclusion criteria

(1) Patients under the age of 18, (2) patients who had previous low back surgery, and (3) patients with significant instability and requiring fusion surgery.

One of the patients with LDH was reoperated 2.5 months later due to the development of a far lateral disc herniation at the same level.

Clinical evaluation

Apart from routine neurological evaluation, the following tests were performed in the preoperative period and 3 months after surgery: (1) Visual Analog Scale (VAS): Back and leg pain, (2) the Oswestry Disability Index, and (3) Japanese Orthopedic Association (JOA) score. Data on age, gender, comorbidity, gait disturbance (kyphotic/scoliotic gait), duration of surgery, amount of bleeding during surgery, intraoperative complications (dura laceration/bleeding over 500 cc etc.), and length of hospital stay were collected.

Radiologic evaluation

Whole spine radiograms and spinopelvic parameters

Preoperative standing full spine radiographs (including C2 and femoral head) were taken and the radiographs were repeated at the postoperative 3rd month. Patients were asked to stand in a standardized erect posture with the hands placed on his/her chest.

TK, LL, sagittal vertical axis (SVA), T1-pelvic angle (TPA), sacral slope (SS), pelvic tilt (PT), and pelvic incidence (PI) were measured using “Surgimap software” (Nemaris Inc., USA) [Figure 1].

Lumbar magnetic resonance imaging muscle/fat measurements

On axial T2-weighted lumbar magnetic resonance (MR) images, total cross-sectional area (TCSA) was measured in the LM and ES muscles using RadiAnt DICOM viewer (Medixant, PL-Poznan). Measurements were done at L1-2, L2-3, L3-4, L4-5, and L5-S1 level from the right and left sides. LM and ES were measured as total value without muscle/fat distinction [Figure 2].

Muscle and fat segmentation were performed using a 3D slicer program.[7] Muscle and fat ratios were measured at L1-S1 levels in total and L2-3; L3-4; and L4-5 separately [Figure 3].

Statistical analysis

Statistical analyzes were performed using the SPSS software (version 25.0; SPSS IBM; Armonk, NY, USA).[8] Chi-squared test, independent sample *t*-test, paired sample *t*-test, and correlation analysis were the tests used.

In Group 1, correlation tests were performed between total lumbar paraspinal muscle ratio, muscle ratio at L4-5-disc level, postoperative LL, and postoperative SVA.

In Group 2, correlation tests were performed between total lumbar paraspinal muscle ratio, postoperative SVA, and VAS leg change.

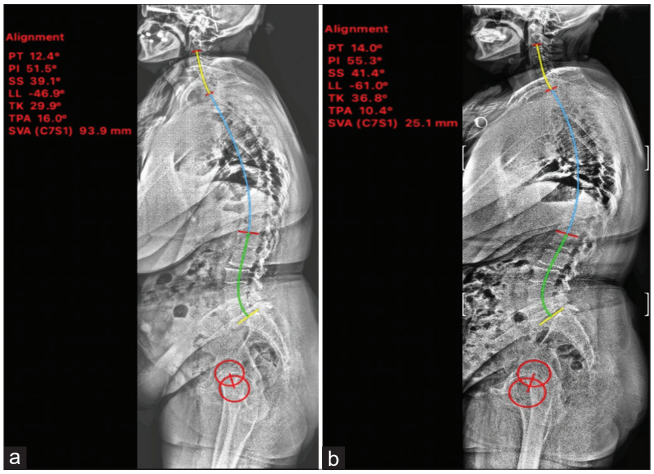

Figure 1: Preoperative and postoperative spinopelvic parameters of one patient measured via Surgimap program. whole spine radiograph before surgery (a) and after surgery (b), red circles represent femoral heads. There was an increase in lumbar lordosis, increase in thoracic kyphosis, and decrease in sagittal vertical axis values. PT - Pelvic tilt, PI - Pelvic incidence, SS - Sacral slope, LL - Lumbar lordosis, TK - Thoracic kyphosis, TPA - T1-pelvic angle, SVA - Sagittal vertical axis

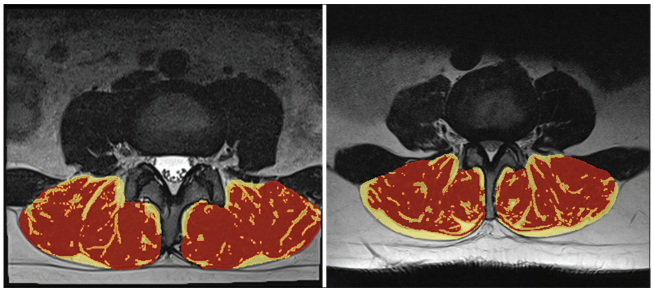

Figure 3: Slicer three-dimensional muscle and fat measurement on axial magnetic resonance image of two different cases. Red areas represent muscle tissue, while yellow areas represent fat tissue.

In Group 1 and 2, correlation tests were performed between lumbar paraspinal muscle ratio, muscle ratio at L4-5-disc level, preoperative and postoperative LL, preoperative and postoperative SVA, preoperative TK, TCSA, preoperative VAS leg scale, preoperative Oswestry scale, and change in the Oswestry scale. $P \leq 0.05$ was considered statistically significant.

RESULTS

Table 1 shows demographic data of both the groups. There were more males in the LDH group and more females in the lumbar spinal stenosis group. The mean age of the LDH group was lower than the lumbar stenosis group.

The mean duration of surgery was longer in patients with lumbar spinal stenosis. Besides, decompressive laminectomy was associated with more bleeding, while there was no case with bleeding 500 cc or more in LDH group, there were two patients with 500 cc or more bleeding in lumbar spinal stenosis group.

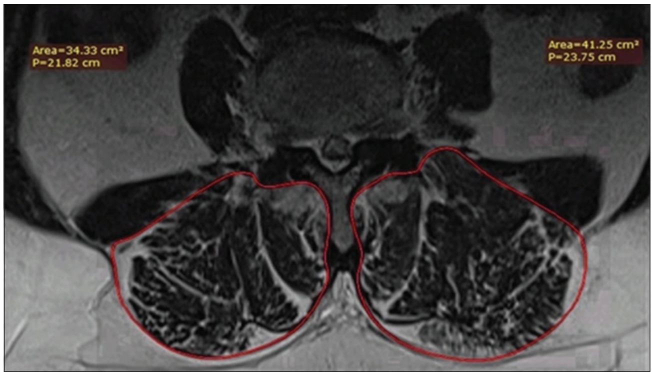

Figure 2: Total cross-sectional area measurements on axial magnetic resonance images

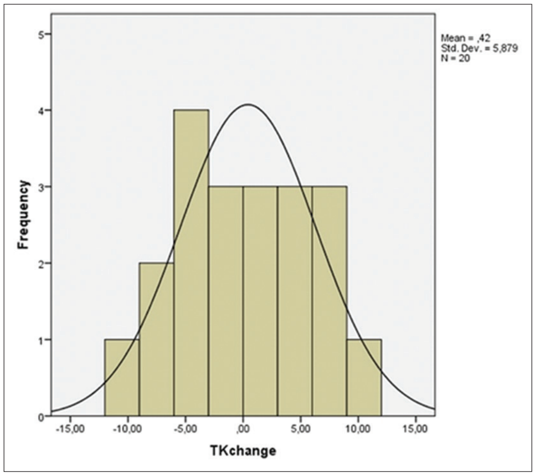

Figure 4: Group 1 (lumbar disc herniation) thoracic kyphosis change histogram. Frequency indicates number of patients, mean change is 0.42, and the amount of change varies between – 10 and 10. TK - Thoracic kyphosis

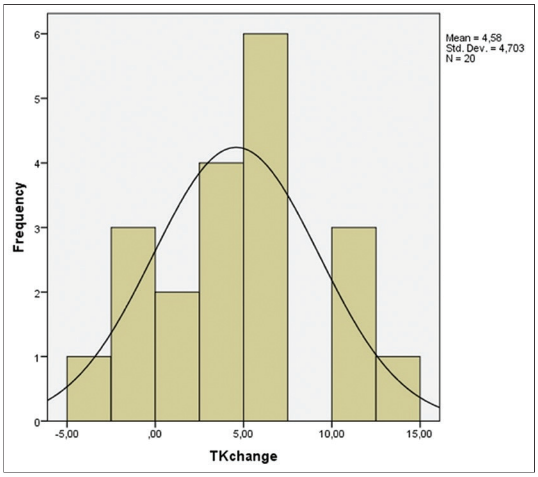

Figure 5: Thoracic kyphosis change histogram in Group 2 (lumbar spinal stenosis). Frequency indicates number of patients, mean change is 4.58, and the amount of change varies between – 5 and 15. TK - Thoracic kyphosis

Dural laceration was more common in patients with lumbar stenosis, depending on age, dural adhesions, and fragility of the dura.

We observed higher VAS leg scores in LDH group. Although VAS back scores were higher in lumbar spinal stenosis group, Oswestry scores were lower and JOA scores were higher.

While gait disturbances such as kyphosis and scoliosis observed in more than half of the patients with LDH, this rate was limited to 20% in patients with lumbar spinal stenosis.

Table 2 gives muscle/fat and TCSA ratios of both the groups. There was no significant difference in the muscle/fat ratio and in TCSA measurements. There was a decrease in muscle ratio caudal to the L2-3-disc level. The average muscle ratio at L3-4 level (75.56) was like the average of total muscle ratio (74.12).

Table 3 shows preoperative and postoperative VAS, Oswestry, and JOA scores of patients in Group 1 and 2. There was a significant improvement in all scores after surgery. We observed that improvement in VAS, Oswestry, and JOA scores was greater in LDH group as compared to lumbar spinal stenosis group.

Sagittal parameters of patients in both the groups are in Table 4. TK, TPA, LL, PT, and PI increased, while SS and SVA decreased in patients with LDH after surgery. However, these changes are not statistically significant. TK, LL, and SS increased and PT, PI, SVA, and TPA decreased in patients with lumbar spinal stenosis after surgery. Only the increase in the TK was statistically significant [Figures 4 and 5].

Table 1: Demographic data and clinical features of patients in Group 1 (lumbar disc herniation) and Group 2 (lumbar spinal stenosis)

	Group 1	Group 2	*P*
Male/female	12/8	4/16	0.024
Age	48.4±13.36	62.5±10.16	0.001
Duration of surgery	88.5±48.39	143.5±62.3	0.003
Level of surgery, *n* (%)			
Single	17	9	0.02
2 levels	3	10	0.043
3 levels	0	1	0.3
Bleeding volume	87.75±80.71	186.5±155.64	0.01
Hospitalization	1.2±0.61	1.5±1.05	0.278
Complication, *n* (%)			
Dura laceration	1 (5)	6 (30)	0.037
Excessive bleeding	0	2 (10)	0.487
Other	0	1 (5)	1
Preoperative VAS leg	7.1±2.59	6.7±2.63	0.631
Preoperative VAS back	5.4±2.39	5.7±2.55	0.704
Oswestry score	63.10±21.9	56.9±20.67	0.363
JOA score	10.8±5.26	13.15±4.43	0.135
Kyphotic/scoliotic gate, *n* (%)	11 (55)	4 (20)	0.05

VAS - Visual Analog Scale; JOA - Japanese Orthopedic Association

Table 2: Muscle/fat and total cross-sectional area ratios in Group 1 (lumbar disc herniation) and Group 2 (lumbar spinal stenosis) patients

	Group 1	Group 2	*P*
L2-3 muscle ratio	79.41±10.3	78.98±5.51	0.869
L2-3 fat ratio	20.58±10.3	21.01±5.51	0.870
L3-4 muscle ratio	75.56±9.39	74.01±7.5	0.567
L3-4 fat ratio	24.43±9.39	25.98±7.53	0.566
L4-5 muscle ratio	70.94±8.71	69.17±7.92	0.506
L4-5 fat ratio	29.05±8.76	30.82±7.92	0.507
Total muscle ratio	74.12±8.56	72.62±5.99	0.525
Total fat ratio	25.87±8.56	27.36±5.99	0.528
TCSA L1-2 right	22.22±5.02	22.32±5.59	0.957
TCSA L1-2 left	23.31±5.21	21.5±4.84	0.277
TCSA L2-3 right	24.44±5.32	23.54±4.65	0.572
TCSA L2-3 left	25.62±5.21	23.77±4.85	0.252
TCSA L3-4 right	25.96±5.36	24.94±4.46	0.519
TCSA L3-4 left	27.02±5.41	25.33±4.6	0.293
TCSA L4-5 right	26.17±6.17	25.26±5.01	0.614
TCSA L4-5 left	26.44±6.12	25.47±4.99	0.587
TCSA L5-S1 right	20.27±4.52	20.27±5.81	1
TCSA L5-S1 left	20.22±5.34	20.36±5.74	0.937
TCSA L1-S1 right	117.98±24.32	115.24±22.25	0.713
TCSA L1-S1 left	121.47±24.56	115.38±22.58	0.420
TCSA L1-S1 total	239.45±48.71	230.63±44.35	0.553
Number of MRI slice	22.65±4.55	24.5±4.66	0.212

MRI - Magnetic resonance imaging; TCSA - Total cross sectional area

Change rates in sagittal parameters are shown in Table 5. There was further improvement in TK-LL in patients with lumbar stenosis; on the other hand, SVA improved more in patients with LDH.

Table 3: Pre- and postoperative Visual Analog Scale, Oswestry Disability Index, and Japanese Orthopedic Association scores in Group 1 (lumbar disc herniation) and Group 2 (lumbar spinal stenosis) patients

	Group 1			Group 2		
	Preoperative	Postoperative	*P*	Preoperative	Postoperative	*P*
VAS leg	7.1±2.59	0.45±1.27	<0.001	6.7±2.63	2.15±2.13	0.001
VAS back	5.44±2.39	1.60±1.72	0.001	5.7±2.55	3.15±2.6	<0.001
Oswestry score	63.1±21.9	8.75±8.13	<0.001	56.9±20.67	19.15±18.23	<0.001
JOA score	10.80±5.26	24.4±3.05	<0.001	13.15±4.43	22±3.89	0.002

VAS - Visual Analog Scale; JOA - Japanese Orthopedic Association

Table 4: Pre- and postoperative sagittal parameters in Group 1 (lumbar disc herniation) and Group 2 (lumbar spinal stenosis) patients

	Group 1			Group 2		
	Preoperative	Postoperative	*P*	Preoperative	Postoperative	*P*
TK	28.72±7.04	29.19±8.008	0.76	26.88±10.31	31.46±9.31	<0.001
TPA	11.04±13.84	11.53±12.4	0.72	13.98±8.19	13.25±7.69	0.349
LL	(−) 46.03±14.91	(−) 46.86±16.2	0.642	(−) 47.55±12.88	(−) 50.57±11.52	0.058
SS	31.71±11.04	31.14±12.82	0.599	33.55±10.79	33.89±9.48	0.372
PV	15.32±13.29	16.87±12.6	0.225	18.78±7.9	18.09±7.38	0.371
PI	47.02±10.93	48.01±10.75	0.464	52.32±14.46	51.92±12.79	0.689
SVA	10.06±44.22	4.84±34.6	0.458	10.34±35.55	9.75±33.98	0.941

SVA - Sagittal vertical axis; TPA - T1-pelvic angle; LL - Lumbar lordosis; TK - Thoracic kyphosis; SS - Sacral slope; PV - Pelvic tilt; PI - Pelvic incidence

Table 5: Changes of sagittal parameters with surgery in Group 1 (lumbar disc herniation) and Group 2 (lumbar spinal stenosis)

	Group 1	Group 2	*P*
TK change (%)	0.42±5.87	4.58±4.7	0.018
LL change (%)	2.04±7.56	3.01±6.67	0.670
SVA change (%)	6.55±30.48	4.07±34.86	0.812

SVA - Sagittal vertical axis; LL - Lumbar lordosis; TK - Thoracic kyphosis

We also looked Pearson's correlations of some parameters. Table 6 shows correlation test between lumbar paraspinal muscle ratio, postoperative sagittal parameters, and change in LL in Group 1. We observed that in patients with LDH, as the muscle ratio increased, postoperative LL increased ($P = 0.007$) and SVA decreased ($P = 0.002$). It was determined that when the muscle ratio at L4-5 level increased, the LL improved more after surgery ($P = 0.017$). These correlations were statistically significant.

Similarly, we looked Pearson's correlations between total paraspinal muscle ratio, postoperative SVA, and change in VAS leg in Group 2 [Table 7]. We found that in patients with lumbar spinal stenosis, as the muscle ratio increased, postoperative SVA decreased ($P = 0.041$) and VAS leg scores improved more ($P = 0.027$). These correlations were also statistically significant.

Table 8 examines the Pearson's correlations between paraspinal muscle ratio, preoperative and postoperative sagittal parameters, TCSA, preoperative and postoperative pain scales, and change in Oswestry Disability Index of patients in Group 1 and 2. When the groups were examined together, we observed that as the muscle ratio increased, preoperative and postoperative LL increased ($P = 0.002$; $P = 0.001$), preoperative and postoperative SVA decreased ($P < 0.001$; $P < 0.001$); As the muscle ratio increased, preoperative VAS leg scores decreased ($P = 0.04$), as L4-5 muscle ratio increased, preoperative Oswestry scores decreased ($P = 0.044$), preoperative VAS leg scores decreased ($P = 0.011$); As preoperative LL increased, preoperative Oswestry scores decreased ($P = 0.041$) and the change in Oswestry score increased ($P = 0.016$); As the SVA value increased, the preoperative VAS leg scores also increased ($P = 0.045$). It was determined that as the TCSA increased, the preoperative TK also increased ($P = 0.025$). These correlations were statistically significant.

DISCUSSION

With advancing age, several processes occur in the spine due to degeneration such as decrease in disc height, hypertrophy in facet joints and ligamentum flavum, reconstruction of bone structures, and atrophy in muscles.[9,10] Paraspinal muscles play an important role in maintaining spinal alignment. Forward displacement of sagittal balance can happen due to degeneration of the spine, atrophy of the paraspinal muscles, decreased LL, and increased PT.[11] Compensatory mechanisms come into play to correct the deteriorated sagittal balance due to degeneration such as pelvic retroversion, knee flexion, ankle extension, spine hyperextension, and retrolisthesis. While these mechanisms support the body to stand upright, they can also cause changes in spinopelvic parameters.[11,12] Various studies demonstrate that spinal sagittal imbalance

Table 6: Correlation between lumbar paraspinal muscle ratio, postoperative sagittal parameters, and change in lumbar lordosis in Group 1 (lumbar disc herniation) patients

	Correlations				
	LL change	**L4.5 muscle**	**Muscle percentile**	**Postoperative LL**	**Postoperative SVA**
LL change					
Pearson's correlation	1	−0.528*	−0.341	0.225	0.125
Significant (two-tailed)		0.017	0.141	0.341	0.600
n	20	20	20	20	20
L4.5 muscle					
Pearson's correlation	−0.528*	1	0.911**	−0.489*	−0.475*
Significant (two-tailed)	0.017		0.000	0.029	0.034
n	20	20	20	20	20
Muscle percentile					
Pearson's correlation	−0.341	0.911**	1	−0.584**	−0.642**
Significant (two-tailed)	0.141	0.000		0.007	0.002
n	20	20	20	20	20
Postoperative LL					
Pearson's correlation	0.225	−0.489*	−0.584**	1	0.555*
Significant (two-tailed)	0.341	0.029	0.007		0.011
n	20	20	20	20	20
Postoperative SVA					
Pearson's correlation	0.125	−0.475*	−0.642**	0.555*	1
Significant (two-tailed)	0.600	0.034	0.002	0.011	
n	20	20	20	20	20

*Correlation is significant at the 0.05 level (two-tailed); **Correlation is significant at the 0.01 level (two-tailed). SVA - Sagittal vertical axis; LL - Lumbar lordosis

Table 7: Correlation between total paraspinal muscle ratio, postoperative sagittal vertical axis, and Visual Analog Scale for leg in Group 2 (lumbar spinal stenosis) patients

	Correlations		
	Muscle percentile	**Postoperative SVA**	**VAS leg change**
Muscle percentile			
Pearson's correlation	1	−0.460*	−0.494*
Significant (two-tailed)		0.041	0.027
n	20	20	20
Postoperative SVA			
Pearson's correlation	−0.460*	1	0.127
Significant (two-tailed)	0.041		0.592
n	20	20	20
VAS leg change			
Pearson's correlation	−0.494*	0.127	1
Significant (two-tailed)	0.027	0.592	
n	20	20	20

*Correlation is significant at the 0.05 level (two-tailed). SVA - Sagittal vertical axis; VAS - Visual Analog Scale

and lumbar paraspinal intramuscular fat infiltration are associated with LBP in adults.[4,13] In our study, we aimed to analyze whether there is a correlation between spinal sagittal imbalance, fatty infiltration of lumbar paraspinal muscles, and LBP.

In the last few decades, our knowledge on the importance of the sagittal balance and associated pathologies has increased. Schwab *et al*. demonstrated that realignment of SVA values <50 mm is associated with better quality of life in patients with adult spinal deformity.[14] Dohzono *et al*. examined patients with lumbar spinal stenosis, which they performed laminotomy and found that patients who had preoperative forward bending posture had less LL and lower preoperative JOA score as compared to patients without forward bending posture; however, they also found that improvement in JOA scores and postoperative VAS leg scores did not differ between the groups.[15] Another study involving LSS patients also demonstrated correlation between SVA and JOA scores.[3] Endo *et al*. also showed correlation between SVA and JOA scores in patients with LDH.[16] In our study, we did not demonstrate a statistically significant correlation between SVA and JOA scores; however, we found that patients who had preoperative higher SVA values also had greater VAS leg scores ($P = 0.045$). In addition, as preoperative LL increased, preoperative Oswestry scores decreased ($P = 0.041$) and the change in Oswestry scores increased ($P = 0.016$).

Considering the relationship of lumbar paraspinal muscles with sagittal alignment, measuring the muscle/fat ratio has paramount importance. To evaluate the fatty infiltration in the muscles, qualitative and quantitative methods have been described. Goutallier introduced the first qualitative classification in 1994, and in this computed tomography (CT)-based study, the fat infiltration rates of the rotator cuff muscle were evaluated and classified between 0 and 4: Grade 0, normal muscle; Grade 1, linear adiposity;

Table 8: Correlation between paraspinal muscle ratio, preoperative and postoperative sagittal parameters, total cross-sectional area, pre- and post-operative pain scales, Oswestry Disability Index in Group 1 (lumbar disc herniation) and Group 2 (lumbar spinal stenosis) patients

	Muscle percentile	L4.5 Muscle	Postop LL	Postop SVA	Preop Oswestry	Preop LL	Preop SVA	TCSA Total	Preop TK	Preop VAS Leg	Oswestry Change
Muscle percentile											
Pearson Correlation	1	0.902**	-0.487**	-0.563**	-0.197	-0.478**	-0.543**	0.028	-0.170	-0.326*	-0.098
Sig. (2-tailed)	40	0.000	0.001	0.000	0.223	0.002	0.000	0.865	0.294	0.40	0.548
n		40	40	40	40	40	40	40	40	40	40
L4.5 Muscle											
Pearson Correlation	0.902**	1	-0.392*	-0.374*	-0.320*	0.483**	-0.506**	-0.30	-0.149	-0.397*	-0.139
Sig. (2-tailed)	0.000	40	0.12	0.18	0.44	0.002	0.001	0.856	0.359	0.11	0.393
n	40		40	40	40	40	40	40	40	40	40
Postop LL											
Pearson Correlation	-0.487**	-0.392*	1	0.367*	0.297	0.864**	0.261	-0.291	0.033	0.250	0.323*
Sig. (2-tailed)	0.001	0.12	40	0.020	0.063	0.000	0.104	0.069	0.838	0.119	0.042
n	40	40		40	40	40	40	40	40	40	40
Postop SVA											
Pearson Correlation	-0.563**	-0.374*	0.367*	1	0.080	0.206	0.615**	-0.095	0.174	0.163	0.000
Sig. (2-tailed)	0.000	0.18	0.020	40	0.623	0.201	0.000	0.560	0.284	0.315	1.000
n	40	40	40		40	40	40	40	40	40	40
Preop Oswestry											
Pearson Correlation	-0.197	-0.320*	0.297	0.080	1	0.324*	0.056	-0.039	0.090	0.727**	0.754**
Sig. (2-tailed)	0.223	0.44	0.063	0.623	40	0.041	0.733	0.812	0.579	0.000	0.000
n	40	40	40	40		40	40	40	40	40	40
Preop LL											
Pearson Correlation	-0.478**	-0.483**	0.864**	0.206	0.324*	1	0.361*	-0.187	-0.196	0.288	0.378*
Sig. (2-tailed)	0.002	0.002	0.000	0.201	0.041	40	0.022	0.249	0.226	0.071	0.016
n	40	40	40	40	40		40	40	40	40	40
Preop SVA											
Pearson Correlation	-0.543**	-0.506**	0.261	0.615**	0.056	0.361*	1	0.097	-0.089	0.319*	0.020
Sig. (2-tailed)	0.000	0.001	0.104	0.000	0.733	0.022	40	0.550	0.587	0.045	0.904
n	40	40	40	40	40	40		40	40	40	40
TCSA Total											
Pearson Correlation	0.028	-0.030	-0.291	-0.95	-0.039	-0.187	0.097	1	0.353*	-0.100	-0.046
Sig. (2-tailed)	0.865	0.856	0.069	0.560	0.812	0.249	0.550	40	0.025	0.539	0.776
n	40	40	40	40	40	40	40		40	40	40
Preop TK											
Pearson Correlation	-0.170	-0.149	0.033	0.174	0.090	-0.196	-0.089	0.353*	1	-0.036	-0.057
Sig. (2-tailed)	0.294	0.359	0.838	0.284	0.579	0.226	0.587	0.025	40	0.827	0.726
n	40	40	40	40	40	40	40	40		40	40
Preop VAS Leg											
Pearson Correlation	-0.326*	-0.397*	0.250	0.163	0.727**	0.288	0.319*	-0.100	-0.036	1	0.510**
Sig. (2-tailed)	0.40	0.11	0.119	0.315	0.000	0.071	0.045	0.539	0.827	40	0.001
n	40	40	40	40	40	40	40	40	40		40
Oswestry Change											
Pearson Correlation	-0.098	-0.139	0.323*	0.000	0.754**	0.378*	0.020	-0.046	-0.057	0.510**	1
Sig. (2-tailed)	0.548	0.393	0.042	1.000	0.000	0.016	0.904	0.776	0.726	0.001	40
n	40	40	40	40	40	40	40	40	40	40	

Grade 2, muscle > fat; Grade 3, muscle = fat; and Grade 4, fat > muscle.[17] In 2000, Kader *et al*. evaluated fat infiltration in an MRI-based study, in which they evaluated the LM muscle, divided into three groups as <10, <50, and >50 fat infiltration.[18] In 2012, Slabaugh *et al*.[19] assessed the intraobserver and interobserver reliability of the Goutallier classification as moderate in a study, in which the rotator cuff muscles were evaluated in MRI. Slabaugh *et al*. proposed a simpler classification which is reduced into 3 grades: Grade 0, normal to mild fatty infiltration; Grade 1: moderate fatty infiltration; and Grade 2: fat > muscle. They suggested that this simpler version has significantly higher intraobserver and interobserver reliability.[19] On the contrary, Battaglia *et al*. stated that the reliability of the Goutallier classification was high in their study which they evaluated the LM muscle on MRI.[20] In our study, the 3D slicer program was used to evaluate muscle and fat ratio of ES and LM collectively. Although it is time-consuming, this method was preferred to measure the muscle/fat ratio numerically and to obtain more objective measurements.

In addition, there are various quantitative methods such as: measurement of TCSA, functional cross-sectional area (FCSA) using signal intensity in MR and Hounsfield unit in CT;[21] measurement of thickness and echo intensity of paraspinal muscles on ultrasonography.[22] Measuring TCSA is a simple method which may indicate muscle atrophy. However, a review article by Hu et al. has shown that even if there is an increase in the proportion of fat or fibrous tissue in atrophied muscle, TCSA of muscles does not change significantly. They also denote that TCSA is more reliable in assessing fat infiltration, whereas FCSA is in assessing muscle atrophy.[21] In our study, we did not find correlation between TCSA and muscle or fat ratios.

Mengiardi *et al*. detected considerable amount of fat in LM of patients with chronic LBP.[13] Getzman *et al*. suggested that fatty infiltration of paraspinal muscles is associated with higher disability and poor health-related quality of life.[23] Zotti *et al*. demonstrated that less muscle mass of LM was correlated with worse outcome in patients who had decompression surgery for LSS.[24] In line with those studies and our hypothesis, we also found a correlation between increased muscle ratio and patient's pain. We demonstrated as muscle ratio increased, preoperative VAS leg scores decreased ($P = 0.04$); as L4-5 muscle ratio increased, preoperative Oswestry scores decreased ($P = 0.044$), scores and preoperative VAS leg scores decreased ($P = 0.011$). In addition, we showed an association between increased muscle volume and increased preoperative/postoperative LL ($P = 0.002$; $P = 0.001$), decreased preoperative/postoperative SVA value ($P < 0.001$; $P < 0.001$).

Our study has several limitations. Follow-up period of 3 months is short for observing the spinopelvic measurements and surgical outcomes of LSS and LDH patients. Small number of patients in each group is one of the limitations. Besides, we did not measure LM and ES muscle separately. We also did not examine interobserver and intraobserver reliability of our radiological measurements.

CONCLUSION

Although this prospective study was conducted with a limited number of patients, we demonstrated a correlation among the lumbar paraspinal muscle/fat ratio, preoperative/postoperative spinopelvic parameters, and surgical outcomes. Our results showed that an increased paraspinal muscle ratio was correlated with lower SVA values and increased LL; lower VAS leg scores; higher Oswestry scores which indicate better surgical outcomes.

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Conflicts of interest

There are no conflicts of interest.

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