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The Effect of Low Back Pain on Paraspinal Muscle Volumes in Adolescents

Adolesanlarda Bel Ağrısının Paraspinal Kas Volümleri Üzerine Etkisi

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ABSTRACT

Objectives: The objective of the study was to investigate whether low back pain (LBP) with or without lumbar disc herniation (LDH) would affect paraspinal muscle volumes in adolescents.

Methods: A total of 205 adolescent patients were distributed into two groups – LBP with LDH (Group A) and LBP without LDH (Group B). Multifidus (MF), erector spinae (ES), and psoas major (PM) volumes at the L4–5 and L5-S1 intervertebral disc levels were measured.

Results: No statistically significant difference in bilateral MF, ES, and PM volumes was observed between the groups at the L4–5 and L5-S1 levels. The right side ES volumes at the L4–5 were lower than the left volumes in Group A (p=0.000/p<0.05). At the L5-S1, the right MF and ES volumes were lower than those on the left (MF p=0.008/p<0.05; ES p=0.000/p<0.05). In Group B, the right MF and ES volumes were lower than those on the left (MF p=0.001/p<0.05 and ES p=0.000/p<0.05) at the L4–5 level. At the L5-S1, the right MF, ES, and PM volumes were lower than those on the left (MF p=0.001/p<0.05; ES p=0.000/p<0.05; and PM p=0.024/p<0.05).

Conclusion: Paraspinal muscle volume loss can be seen as a result of LBP in adolescents like in adults. Since LDH more commonly occurs as the central type in the pediatric age, perhaps it may not contribute to volume changes of paraspinal muscle.

Keywords: Adolescent; low back pain; lumbar disc hernia; paraspinal muscles.

ÖZET

Amaç: Adolesanlarda lomber disk hernisiyle (LDH) birlikte olan ve olmayan bel ağrısının multifidus (MF), erektör spina (ES) ve psoas major (PM) kas volumleri üzerine etkisi olup olmadığını araştırmak.

Yöntem: 205 bel ağrılı adolesan hasta LDH olan (grup A) ve olmayan (grup B) olmak üzere iki gruba ayrıldı. MF, ES ve PM volümleri, L4-5 ve L5-S1 intervertebral disk seviyesinden aksiyel T2 ağırlıklı görüntüler kullanılarak ölçüldü.

Bulgular: İki grup arasında L4-5 ve L5-S1 seviyelerinde bilateral MF, ES ve PM volumlerinde anlamlı fark yoktu. Grup A'da L4-5 seviyesinde sağ taraf ES volumleri soldan (sağ/sol p=0.000/p<0.05), L5-S1 seviyesinde sağ MF ve ES volümleri soldakilerden anlamlı düzeyde düşüktü (MF p=0.008/p<0.05; ES p=0.000/p<0.05). Grup B'de L4-5 seviyesinde sağ MF ve ES volumleri soldakilerden (MF right/left p=0.001/p<0.05; ES p=0.000/p<0.05), L5-S1 seviyesinde sağ MF, ES ve PM volümleri soldakilerden anlamlı düzeyde düşüktü (MF p=0.001/p<0.05; ES p=0.000/p<0.05; PM p=0.024/p<0.05).

Sonuç: Paraspinal kas volüm kaybı erişkinlerde olduğu gibi adolesan yaş grubunda da bel ağrısının bir sonucu olarak görülebilir. LDH'nin bu yaş grubunda sıklıkla santral yerleşimli olması nedeniyle paraspinal kas volum kaybına etkisi olmadığı düşünülebilir.

Anahtar sözcükler: Adolesan; bel ağrısı; lomber disk hernisi; paraspinal kaslar.

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The paraspinal muscles, including the multifidus (MF), erector spinae (ES), interspinales, intertransversarii, psoas major (PM), and quadratus lumborum, are responsible for the movement and stabilization of the lumbar spine.[1] The main stabilizer is the MF, which plays an important role in chronic low back pain (LBP). Atrophy of these muscles (particularly the MF) is frequently encountered in adults with chronic LBP and lumbar disc herniation (LDH).[2,3] Disuse and immobilization of the trunk in chronic LPB possibly will lead to atrophy of both the flexor and extensor muscles.[4] Two possible causes of muscle atrophy in patients with LDH have been postulated as denervation and disuse. Muscle atrophy may result from nerve inhibition, restricting muscle activity to protect the injured tissue. Such restriction further exacerbates muscle atrophy and as a result leading to LBP.[2,5] However, there is still no consensus whether volume loss of the paraspinal muscles is a cause or result of LDH.[3,6]

LBP is a common problem and the leading reason for disability throughout the world. LBP would be often seen in adolescence (defined by the ages of between 10 and 19 years by the World Health Organization) with similar prevalence as in adulthood.[7] The non-specific, self-limiting type is the most common type of LBP in this age group. LDH is rare in adolescents and usually presents with LBP, with or without radiculopathy. It generally occurs L4–5 or L5-S1 and mostly presents central type.[8]

Although many researches have examined the relation between paraspinal muscle volumes and LBP and/or LDH in adults,[9–11] there are very few studies in the adolescent age group.[12,13] Knowing the presence of volume loss in the paraspinal muscles may be useful in the rehabilitation program planning and follow-up in patients with LBP. The objective of this study was to examine whether chronic LBP and LDH affect paraspinal muscle volumes in adolescents.

Methods

Demographic and radiological (lumbar spinal magnetic resonance imaging [MRI]) data of patients with LBP persisting for at least 12 weeks between January 2018 and 2020 were studied. Patients without LDH or who have only single-level (L4–5 or L5-S1) LDH were included in the study. Patients were excluded from the study if they had conditions as follows: Multilevel disc hernia, spondylolysis-spondylolisthesis, inflammatory spine diseases, spine deformity including scoliosis and kyphosis, spinal tumors/infection, and previous spinal surgery. Finally, 205 patients were included in the study. Patients were distributed into two groups – with LDH (Group A) and without LDH (Group B).

MRI of lumbar spine was conducted with a 1.5 Tesla imaging system (General Electric Healthcare, Milwaukee, WI) set to an amplitude of 44 mT/m and a slew rate gradient configuration of 200 T/m/s. The captured images were analyzed on a GE Advantage Workstation (GE Healthcare, Buc, France) and Volume Share software v.7.0.

PM, MF, and ES muscle volumes on both sides at L4-L5 and L5-S1 intervertebral disc levels were measured in Axial T2-weighted fast spin-echo sequences (TR/TE: 2858/85 ms, matrix: 256 £ 192, slice thickness: 4 mm, FOV: 20) (Fig. 1). Quantitative volume measurement was carried out with the Volume Viewer (GE Healthcare, Buc, France) and semi-automated measurement tools. Muscles were defined by drawing manually at disc levels. Afterward, the fat components were eliminated by applying the threshold technique based on differences in pixel signal intensities. The volume measurement of the muscles in the cross-sectional images was made with the automatic volume calculation tool.

All muscle volumes were measured by the same experienced radiologist. Informed consent forms have been obtained from the all patients. The local ethical committee approval was obtained for this study (04.06.2020-17073117-050.06-E.101). The study was conducted in accordance with the principles of the Helsinki Declaration.

Statistical evaluation was conducted with IBM SPSS Statistics 22 software (IBM SPSS, Turkey). Parameters' compatibility with normal distribution was assessed utilizing the Shapiro–Wilk test. In addition to descriptive statistical methods (mean, standard deviation, and frequency), when comparing normally distributed quantitative data, one-way analysis of variance was performed. Non-normally distributed parameters were compared between the groups with the Kruskal–Wallis test and the Mann–Whitney U-test to identify groups responsible for the variation. The Student's t-test was utilized for two-group comparisons of normally distributed parameters, and the Mann–Whitney U-test was used to compare non-normally distributed parameters. The paired samples t-test was utilized for intragroup right and left side comparisons of normally distributed quantitative data, and the Wilcoxon signed-rank test was used for non-normally distributed intragroup right and left side comparisons. The Chi-square test was applied to compare qualitative data. Significance level was set as $p<0.05$.

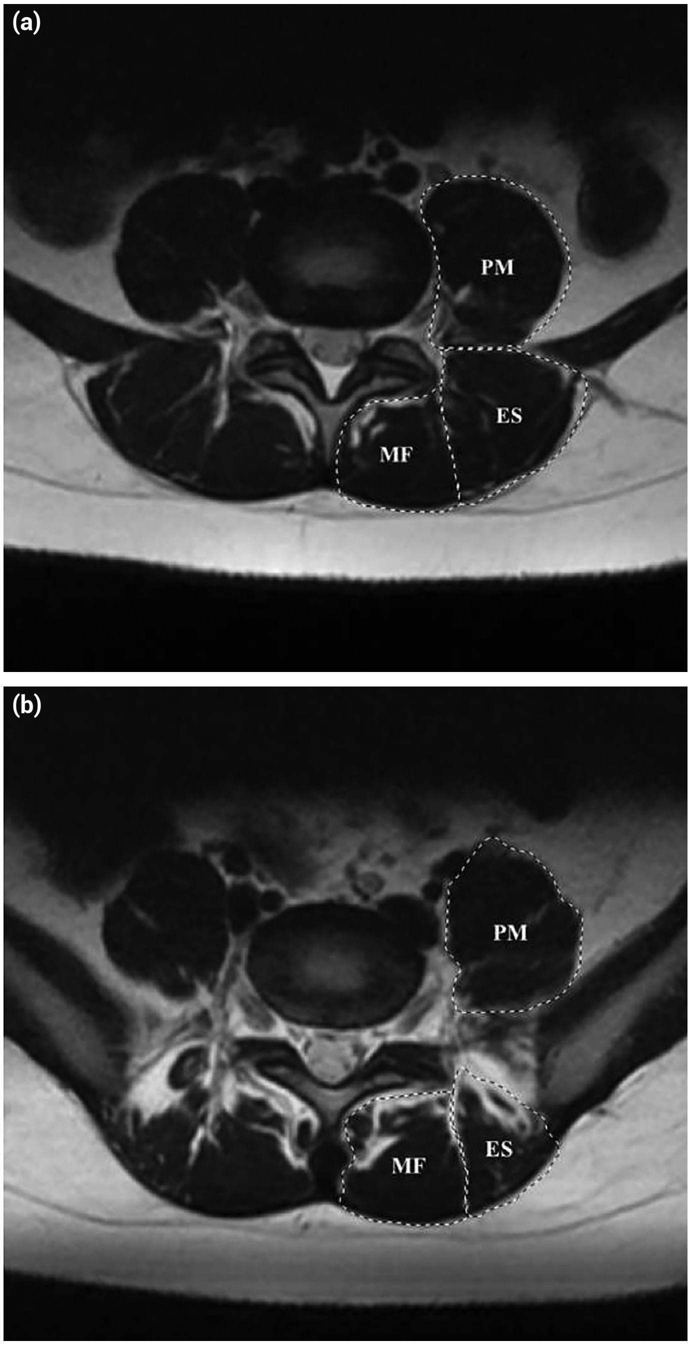

Figure 1. Lumbar spinal magnetic resonance imaging of a patient. Contours of the psoas major, multifidus, and erector spinae muscles in axial T2-weighted images at **(a)** L4–5 and **(b)** L5-S1 intervertebral disc levels

Results

The mean age was 14.99±1.89 years in Group A and 14.64±2.08 years in Group B (p=0.240). Group A was consisted of 43 (56.6%) girls and 33 (43.4%) boys, and for Group B, this distribution was as 74 (57.4%) girls and 55 (42.6%) boys (p=0.913). Detailed demographic characteristics are shown in Table 1.

Table 1. Distribution of general characteristics

	Min–Max	Mean±SD	
Age (years)	10–17	14.77±2.02	
Height (m)	1.27–1.85	1.61±0.12	
Weight (kg)	25–102	57.83±14.81	
BMI (kg/m²)	15.26–32.72	21.81±3.23	
	Group A Mean±SD n (%)	**Group B Mean±SD n (%)**	**p**
Age	14.99±1.89	14.64±2.08	[1]0.240
Sex			
Girl	43 (56.6%)	74 (57.4%)	[2]0.913
Boy	33 (43.4%)	55 (42.6%)	

1: Student's t-test; 2: Chi-square test; SD: Standard deviation; BMI: Body mass index; Min: Minimum; Max: Maximum.

The distribution of herniation types in Group A (n=76) was protrusion in 96.05% and extrusion in 3.94%. Herniation levels were L4–5 in 31.6% of patients and L5-S1 in 68.4%. Sixty-eight (89.4%) herniations were central. Bilaterally PM, MF, and ES muscle volumes at both vertebral levels were significantly higher in boys than in girls (p<0.05) (except left ES muscle volume at the L5-S1 level) (Table 2). A significant positive association was observed between age, height, weight, and body mass index (BMI) and bilateral PM, ES, and MF volumes at both levels (p<0.05) (except left ES muscle volume at the L5-S1 level) (Table 3).

Comparison of Groups A and B revealed no statistically significant difference in bilateral MF, ES, and PM muscle volumes at the L4–5 and L5-S1 levels (p>0.05) (Table 4). Analysis of Group A revealed lower ES volumes on the right side than on the left at the L4–5 level (p=0.000; p<0.05), while no difference was observed between the right and left MF and PM muscle volumes (p>0.05). MF volumes (p=0.008; p<0.05) and ES volumes (p=0.000; p<0.05) at the L5-S1 level were lower on the right than on the left. No differences were observed between the right and left PM muscle volumes (p>0.05). Analysis of Group B revealed significantly lower MF volumes (p=0.001; p<0.05) and ES volumes (p=0.000; p<0.05) on the right than on the left at the L4–5 level, while no significant difference was observed between PM volumes (p>0.05). At the L5-S1 level, MF (p=0.001; p<0.05), ES (p=0.000; p<0.05), and PM (p=0.024; p<0.05) volumes were lower on the right than on the left (Table 5).

Table 2. Right and left muscle volume parameters by gender

	Sex		p
	Girl Mean±SD	Boy Mean±SD	
Multifidus volume (cm³) L4–5			
Left	15.99±4.34	19.76±5.17	[1]**<0.0001***
Right	15.45±4.14	19.36±5.3	[1]**<0.0001***
Erector spinae volume (cm³) L4–5			
Left	26.13±7.4	32.72±10.83	[1]**<0.0001***
Right	23.81±7.04	31.33±10.33	[1]**<0.0001***
Psoas volume (cm³) L4–5			
Left	26.19±8	36.74±11.34	[1]**<0.0001***
Right	25.49±7.28	36.45±11.13	[1]**<0.0001***
Multifidus volume(cm³) L5-S1 (median)			
Left	19.15±5.01 (18.9)	22.56±6.93 (22.4)	[2]**<0.0001***
Right	18.53±4.96 (18)	21.95±6.66 (20.9)	[2]**<0.0001***
Erector spinae volume (cm³) L5-S1 (median)			
Left	16.06±8.01 (14)	17.95±9.87 (16)	[2]**0.177**
Right	13.82±7.47 (12.6)	16.39±8.94 (14.7)	[2]**0.032***
Psoas volume (cm³) L5-S1 (median)			
Left	27.54±8.27 (26.7)	35.07±12.29 (35)	[2]**<0.0001***
Right	26.45±7.64 (25)	35.63±12.57 (34.2)	[2]**<0.0001***

1: Student's t-test; 2: Mann–Whitney U-test; *: P<0.05; SD: Standard deviation.

Discussion

Our study findings revealed that the presence of LDH in adolescents produced no significant difference in paraspinal muscle volumes. The absence of a significant difference between the two groups may be due to the majority of disc herniations in our patient population being as central, in other words, to their not creating root pressure. However, the intragroup analysis revealed lower right ES muscle volumes than on the left at the L4–5 level and lower right MF and ES muscle volumes at the L5-S1 in Group A. In Group B, the right MF and ES volumes at the L4–5 level and all three muscle volumes at the L5-S1 level were statistically significantly lower than all the left. The mechanism of such variations has not been still fully revealed. The right-left differences within groups may be due to disuse following reflex inhibitory mechanisms and/or histochemical changes (water content, blood flow, and differentiation at the cellular level) in muscles as reported in the literature.[14] Another reason may be overlooked spinal curvatures below 10 degrees.

Rahmani et al.[13] compared the MF muscle volumes of adolescent boys aged 15–18 years with LBP with those of healthy control and reported lower MF muscle volume in the LBP group than in the healthy control group, while muscle size was significantly correlated with pain intensity and functional disability levels. That study also investigated the relationship between muscle size and demographic data. While no correlation was observed between muscle size and age, muscle size exhibited a significant correlation with height, weight, and BMI. In this study, we observed a significant correlation between muscle volume (except for left ES volume at the L5-S1 level) and age, height, weight, and BMI.

One study involving longitudinal analysis of paraspinal muscle volumes in healthy individuals compared measurements between the ages of 20 and 30 of the same patients and reported that the cross-sectional area (CSA) of the MF and ES tended to increase in both sexes.[1] Paraspinal muscle volumes reduce with age, particularly in the old population, and men have larger muscle volumes than women.[15] Similarly, in the present study, muscle volumes were larger in boys than in girls.

Patient groups with unilateral lumbar radiculopathy have generally been investigated in adult patients, denervation and disuse have been implicated as causes of the muscular atrophy. The previous studies have reported MF atrophy at the intervertebral disc level one below the segmental rel-

Table 3. Correlations between age, height, weight, and BMI and right and left muscle volume parameters

	Age	Height	Weight	BMI
Multifidus volume L4–5				
Left				
r	0.342	0.634	0.694	0.593
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Right				
r	0.335	0.659	0.724	0.617
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Erector spinae volume L4–5				
Left				
r	0.330	0.674	0.790	0.693
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Right				
r	0.309	0.656	0.788	0.707
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Psoas volume L4–5				
Left				
r	0.401	0.661	0.764	0.666
P	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Right				
r	0.384	0.645	0.760	0.674
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Multifidus volume L5-S1				
Left				
r	0.378	0.633	0.666	0.532
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Right				
r	0.357	0.626	0.656	0.523
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Erector spinae volume L5-S1				
Left				
r	0.132	0.348	0.382	0.298
p	0.060	<0.0001*	<0.0001*	<0.0001*
Right				
r	0.144	0.373	0.416	0.328
p	0.039*	<0.0001*	<0.0001*	<0.0001*
Psoas volume L5-S1				
Left				
r	0.383	0.583	0.652	0.549
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Right				
r	0.400	0.612	0.702	0.597
p	<0.0001*	<0.0001*	<0.0001*	<0.0001*

Pearson correlation analysis, *: P<0.05; BMI: Body mass index.

evant nerve root due to unisegmental innervation of the MF.[16] Similarly, Chon et al.[10] declared that the MF is frequently affected at the L5-S1 intervertebral disc level as a result of denervation of the dorsal ramus with L5-S1 radiculopathy, that atrophy of the MF and ES muscles occurs only at the L4–5 level in patients with symptoms lasting 3 months or more, and that atrophy at that level may be associated with disuse.

Table 4. Bilateral muscle volume parameters between the groups

	Group B Mean±SD	Group A Mean±SD	
Multifidus volume (cm³) L4–5			
Left	17.2±5	18.3±5.11	[1]**0.136**
Right	16.68±4.86	17.89±5.3	[1]**0.096**
Erector spinae volume (cm³) L4–5			
Left	28.08±9.4	30.46±9.78	[1]**0.087**
Right	26.13±8.99	28.58±9.81	[1]**0.070**
Psoas volume (cm³) L4–5			
Left	29.96±10.45	32.01±11.56	[1]**0.194**
Right	29.38±10.51	31.59±10.7	[1]**0.151**
Multifidus volume (cm³) L5-S1 (median)			
Left	20.48±6.27 (19.9)	20.85±5.92 (20)	[2]**0.689**
Right	19.87±6.14 (19.5)	20.21±5.73 (19)	[2]**0.646**
Erector spinae (cm³) volume L5-S1 (median)			
Left	16.92±8.96 (15)	16.79±8.82 (14.3)	[2]**0.941**
Right	15.03±8.49 (14)	14.74±7.78 (13.2)	[2]**0.862**
Psoas volume (cm³) L5-S1 (median)			
Left	30.59±11.21 (28.5)	31.08±10.21 (28.6)	[2]**0.652**
Right	29.83±11.12 (28)	31.34±10.83 (28.8)	[2]**0.306**

1: Student's t-test; 2: Mann–Whitney U-test; SD: Standard deviation.

In radiological studies, muscle atrophy manifests with two main findings, decreased muscle volume and increased intramuscular fat deposition.[17] Long-term neuro¬logical inhibition resulting in muscle atrophy may also lead to adipose tissue replacing healthy lumbar MF fibrils.[18] Kjaer et al.[19] investigated adolescents with LBP together with adult patients and observed fat infiltration in 81% of adults but only 14% of adolescents. Those authors concluded that fat infiltration is rare in adolescents and attributes this to LBP in adolescents not being of sufficient duration to result in such changes. Since the duration of pain was also short in our patient group, we performed no radiological examination in terms of fat infiltration. Ekşi et al.[20] reported that when compared to boys, girls had significantly more fatty infiltration in the paraspinal muscles, and fat infiltration in the paraspinal muscles and disc degeneration were closely related with end-plate changes in children and adolescents with LBP.

The most frequently investigated muscle group on this subject is the MF, which lies in the most medial position and is the widest muscle group. One study reported that MF atrophy is more common in women, that the prevalence and severity both increase with age, and that disc herniation is more common in individuals with MF atrophy.[21] Hyun et al.[11] described MF asymmetry as a very useful finding when evaluating unilateral lumbosacral radiculopathy.A review of 15 studies suggested that the findings indicated atrophy in chronic LBP in the MF, but not in the ES.[22]

In terms of studies regarding PM muscle volume, Hides et al.[23] compared the bilateral PM volumes of elite cricketers (mean age 21.2) with and without LBP, while Gildea et al.[24] compared the PM sizes of dancers (mean age 23.7±3.6) with and without LBP, and no statistically significant differences were detected. In contrast, Parkkola et al.[4] reported a significant reduction in CSAs of the PM in patients with LBP compared to healthy controls.

Various studies involving adult age groups have evaluated the relationship between the duration of LBP or LDH and muscle atrophy.[5,25,26] Kim et al.[25] reported that the CSA of the MF was reduced by LDH in case of symptoms persisting for 3 months or more. Conversely, Farshad et al.[26] reported no association between MF asymmetry and severity or duration of nerve root compression in the lumbar spine. A review study published in 2017 reported evidence that MF CSA was inversely correlated with and predictive of LBP up to 12 months but suggested that evidence for an association between LBP and ES, psoas, and quadratus lumborum CSA was inconsistent.[27] In contrast to the previous research involving patients with LDH, another study reported observing

Table 5. Group A and Group B right and left muscle volume parameters

Group	Right Mean±SD	Left Mean±SD	p
Group B			
L4–5			
Multifidus volume (cm³)	16.68±4.86	17.2±5	[1]**0.001***
Erector spinae volume (cm³)	26.13±8.99	28.08±9.4	[1]**<0.0001***
Psoas volume (cm³)	29.38±10.51	29.96±10.45	[1]**0.067**
L5-S1 (median)			
Multifidus volume (cm³)	19.87±6.14 (19.5)	20.48±6.27 (19.9)	0.001*
Erector spinae volume (cm³)	15.03±8.49 (14)	16.92±8.96 (15)	<0.0001*
Psoas volume (cm³)	29.83±11.12 (28)	30.59±11.21 (28.5)	0.024*
Group A			
L4–5			
Multifidus volume (cm³)	17.89±5.3	18.3±5.11	[1]**0.105**
Erector Spinae volume (cm³)	28.58±9.81	30.46±9.78	[1]**<0.0001***
Psoas volume (cm³)	31.59±10.7	32.01±11.56	[1]**0.312**
L5-S1 (median)			
Multifidus volume (cm³)	20.21±5.73 (19)	20.85±5.92 (20)	[2]**0.008***
Erector spinae volume (cm³)	14.74±7.78 (13.2)	16.79±8.82 (14.3)	[2]**<0.0001***
Psoas volume (cm³)	31.34±10.83 (28.8)	31.08±10.21 (28.6)	[2]**0.686**

1: Paired samples t-test; 2: Wilcoxon signed-rank test; *: P<0.05; SD: Standard deviation.

MF atrophy on the symptomatic side in <1 month.[28] Hodges et al.[14] suggested that MF asymmetry might be a potential early sign of acute, painful disc lesions with no clear nerve root involvement and associated denervation, and concluded that such asymmetry might, therefore, also be a potential marker for use in localizing painful pathologies of the lumbar disc. Hides et al.[2] reported that asymmetry exceeding 10% in the MF CSA can be used as a potential marker of spinal abnormality. However, Niemeläinen et al.[29] reported that paraspinal muscle asymmetry exceeding 10% was frequently encountered in men with no history of LBP. This appears to indicate that discretion should be employed when level- and side-specific paraspinal muscle asymmetry is employed to determine individuals with LBP and spinal pathology.

The present study has some limitations. First, due to the retrospective design of this study, we have practiced on the data of patients admitted to our outpatient clinic as a result we could not perform a prior sample size estimation analysis. The absence of a control group and the lack of interobserver and intraobserver evaluation in the present study can be viewed as other limitations. In addition, the size of the sample group may have affected the difference between the right and left muscle volumes. As far as we know, no study measured muscle volumes or presented normal value ranges of healthy adolescents. Furthermore, we still do not know whether there is a paraspinal volume difference between the right and left sides in adolescents without LBP. For this reason, we did not have a chance to compare our results with reference values. Further prospective follow-up studies also containing healthy control groups should be conducted this age group when growth, muscle, and bone development are continuing and when LBP is also frequently seen. Another limitation of this study is that we were unable to determine factors capable of affecting muscle structures, such as whether participants engaged in sports or whether they rested because of their LBP.

Conclusion

We observed that LDH did not result in a significant difference in paraspinal muscle volume measurements. This may be due to central type herniation being more common and root pressure being rare in the pediatric age group. The reasons for the right and left side paraspinal muscle volume differences may be due to disuse/immobilization, histochemical changes in paraspinal muscles, or spinal asymmetry. Detecting the volume changes of the paraspinal muscles at a young age and strengthening these muscle groups with the exercise programs in adolescent LBP patients may reduce the risk of continuing the problem in adulthood.

Disclosures

Ethics Committee Approval: The Fatih Sultan Mehmet Training and Research Hospital Clinical Research Ethics Committee granted approval for this study (date: 04.06.2020, number: E101).

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – F.E.B.Ü., Ö.G.İ.; Design – F.E.B.Ü.; Supervision – Ö.G.İ.; Materials – Ö.G.İ.; Data collection and/or processing – Ö.G.İ.; Analysis and/or interpretation – F.E.B.Ü.; Literature search – Ö.G.İ.; Writing – F.E.B.Ü., Ö.G.İ.; Critical review – F.E.B.Ü.

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