An evaluation of the efficacy of a four-grade fat infiltration classification method, presented for the first time in literature

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Abstract

Background

The aim of this study was to evaluate the efficacy of a semi-quantitative simplified 4-grade fat infiltration measurement system, described for the first time in literature, through comparison with the existing simplified 3-grade fat infiltration system in the prediction of lumbar disc herniation.

Material and Method

The study included 39 lumbar disc herniation patients (LDH) and 38 healthy subjects (control), comprising 33 (42.9%) males and 44 (57.1%) females with a mean age of 37 ± 11.3 years (range, 20–64 years). The patients were evaluated in respect of fat infiltration of the right and left lumbar multifidus and erector spina muscles on axial magnetic resonance imaging slices passing through the centre of the disc at L3-S1 level using the 3 and 4-grade fat infiltration measurement systems. The results were compared and the correlations of the results of the two systems with lumbar disc herniation were examined.

Results

The 3-grade fat infiltration system was found to be insufficient in the prediction of lumbar disc herniation ($p > 0.05$) and the 4-grade fat infiltration system was determined to be effective in the prediction of lumbar disc herniation ($p = 0.003$).

Conclusion

The 4-grade fat infiltration system was seen to be more effective than the 3-grade fat infiltration system in the determination of the level of fat infiltration in the paraspinal muscles and the prediction of lumbar disc herniation. The 4-grade fat infiltration system is an effective semi-quantitative grading system which can be used instead of the simplified 3-grade system.

Background

Lumbar disc herniation is a common disease of the lumbar spine and a frequent cause of back pain, muscle spasms, and restricted movement [1–3]. The paraspinal muscles play a role in the functional and structural stabilisation of the lumbar spine. The outer layer, which is thought to be primarily responsible for spinal and extremity movements, is formed of the larger surface back muscles. The inner layer is a layer of deep muscle and primarily controls intersegmental movement [4].

Several methods are used to measure and evaluate fat infiltration of the paraspinal muscles, including several non-invasive methods such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), magnetic resonance spectroscopy, chemical shift MRI, and multinuclear MRI (4). Evaluation of fat infiltration can be made qualitatively, semi-quantitatively, and quantitatively [4]. MRI provides a clear image with high contrast and high resolution for soft tissue without radiation exposure.

Moreover, the reliability of the results has been stated to be better than those of CT [5]. Therefore, it has become more preferred in recent years [6, 7].

Qualitative evaluation of muscles was first shown on CT scans by Goutallier et al [8] in a 5-grade visual spectrum of fat tissue infiltration of the rotator cuff muscle system. With developments in MRI, Fuchs et al [9] compared rotator cuff fat infiltration with CT and MRI evaluations. The 5-grade classification stated by Goutallier et al was reduced to a 3-grade classification of normal, moderate, and severe. A simplified system was recommended by Slabough et al [10]. Using standard criteria in adults, Solgaard Sorenson et al visually classified fat infiltration as normal, mild, or severe, according to involvement at one or more lumbar levels [11]. Parkkola stated visual fat infiltration in 4 grades as normal, mild, significant, and severe [12]. Then by adding a percentage to this visual evaluation, it became semi-quantitative and was stated as a simplified 3-grade system evaluation by various authors [13–16]. More recently, fat infiltration of the paraspinal muscles has started to be measured quantitatively [17–23].

In the widely used semi-quantitative evaluation of fat infiltration, the 3-grade (< 10%, 10%-50%, > 50%) fat infiltration system is used [13–16]. However, in this grading system, 15% and 45% fat infiltration are included in the same percentage slice (10%-50%). This creates a weakness, and starting from the hypothesis that this could be insufficient to reach detailed results, a new alternative measurement method is here presented of 4 grades of fat infiltration (< 10%, 10%-30%, 30%-50%, > 50%), and the sensitivity of this system was evaluated. To confirm this hypothesis, the aim of the current study was to compare and evaluate the efficacy of the 3 and 4-grade fat infiltration measurement systems in the prediction of lumbar hernia.

Material And Method

Subjects

The study included 39 patients (LDH) who presented at the Orthopaedics and Traumatology Department of Büyük Anadolu Hospital between November 2020 and February 2021 with the complaint of low back pain and were diagnosed with lumbar disc herniation. A control group was formed of 38 healthy subjects, selected at random from those invited to participate via social media and announcements, who had not experienced any low back pain in the last year and were not determined with any lumbar problem in physical or radiology examinations. The LDH group included patients aged <65 years, with low back pain ongoing for the last 3 months, who were diagnosed with lumbar hernia on MRI. For patients with suspected root compression, EMG was requested, and after confirmation of no root compression, these patients were included in the study.

Patients were excluded from the study if radiculopathy was determined on MRI or EMG, if they had any rheumatological or infectious disease, any spine or hip deformity, a history of lumbar surgery, or acute pain in any other part of the body.

Demographic data and disease-related information were recorded on a demographic information form in face-to-face interviews. When necessary for the diffierential diagnosis, hemogram, erythrocyte sedimentation rate, full urine analysis, ASO, CRP, RF, salmonella, and brucella tests were requested. The physical examinations of 77 patients were performed by the same orthopaedics and traumatology specialist, experienced in spinal surgery, and the MRIs were analyzed by the same radiology specialist (K.T.) experienced on this subject and blinded to the clinical history. All the MRIs were taken by the same radiology technician.

Approval for the study was granted by the Local Ethics Committee (YDU/2020/83-1160). Informed consent was obtained from all the study participants.

Measurements

Magnetic Resonance Imaging

Images were obtained using a 1.5 Tesla MRI unit (Sigma Explorer SV25.3 with up-to-date software and 16 channels; General Electric, Milwaukee, WI, USA). With the patient in a supine position, a pillow was placed under the knees and the coil was placed on the spine. The measurements were taken with a routine protocol applied to the lumbar spine to pass through the centre of the disc at the measurement level between L3-S1 (L3-4/L4-5/L5-S1) without leaning to the right or left. Turbo-spin echo T1 and T2-weighted sagittal slices and turbo-spin echo T2 axial slices parallel to the disc spaces were obtained at a thickness of 4mm. Evaluations were made on the T2 axial slices. Fat content was evaluated at all 3 levels of L3-S1 of the left and right erector spina (m. iliocostalis+m. longissimus) and the m. multifidus.

Fat infiltration of the muscles was evaluated semi-quantitatively, using the simplified 3-grade system and the 4-grade system. In the simplified 3-grade system, fat infiltration is graded as Grade 1: normal (fat infiltration of up to 10% of the muscle cross-sectional area [CSA), Grade 2: moderate (10%-50%) and Grade 3: severe (>50%) (Figure 1) [3]. In the simplified 4-grade system, fat infiltration is graded as Grade 1: normal (fat infiltration of up to 10% of the muscle CSA), Grade 2: mild (10%-30%), Grade 3: moderate (30%-50%), and Grade 4: severe (>50%) (Figure 2).

For internal reliability, 10 randomly selected patients were evaluated again by the same radiologist after an interval of 1 month. Intra-observer agreement was examined with Kappa and the Kappa value obtained was 0.934 for the 3-grade system, and 0.921 for the 4-grade system.

Statistical Evaluation

Data obtained in the study were analyzed statistically using IBM SPSS vn. 23 software. The risk factors affecting lumbar disc herniation were examined with binary logistic regression analysis, and the results were presented as odds ratio (OR) and 95% confidence interval (CI). In the univariate analysis, each variable was added separately to the model and the effect of each variable alone was examined. In the multivariate analysis, all the variables were placed in the model at the same time and the effect of these

 st hoc power analysis, a minimum of 50 subjects should be included in the study to provide 95% CI (1-α), 95% test power (1-β), and degeneration values of 0.32 and 0.80. Taking the potential loss of patients into consideration, the study was completed with a total of 77 subjects, with test power of 99.5% according to the post hoc power analysis [24].

Results

The demographic data of the LDH and control groups are shown in Table 1. No significant difference was determined between the groups in respect of age, gender, and BMI (p:0.429, p:0.895, p:0.988, respectively).

Table 1
Demographic data of the study groups

	Control group		LDH		Total		
	$\bar{x} \pm \sigma$	Median (min-max)	$\bar{x} \pm \sigma$	Median (min-max)	$\bar{x} \pm \sigma$	Median (min-max)	
Age (years)	36.61 ± 11.83	34.5 (21–64)	37.41 ± 10.9	43 (20–51)	37.01 ± 11.3	40 (20–64)	0,429[1]
BMI (kg/m^2)	25.76 ± 3.55	25.93 (19.25–32.79)	26.21 ± 5.34	26.12 (17.71–36.2)	25.99 ± 4.52	26.12 (17.71–36.2)	0,988[1]
Duration of low back pain (months)		—	38.13 ± 51.49	7 (3–240)			
VAS resting			2.33 ± 1.34	2 (1–6)			
VAS activity			4.28 ± 1.85	4 (2–8)			
Gender	n (%)		n (%)				
Male	16 (42.1)		17 (43.6)		33 (42.9)		0,895[2]
Female	22 (57.9)		22 (56.4)		44 (57.1)		

[1]Mann Whitney U, [2] Pearson Chi Square

1.1. 3-Grade Fat Infiltration Classification System

According to the 3-grade classification of the fat infiltration of the paraspinal muscles of the LDH group and the control group, age, gender, and BMI were not determined as risk factors for the left and right M. MF and left and right M.ES values ($p > 0.05$) (Table 2).

Table 2
Logistic regression analysis results of risk factors affecting lumbar disc herniation with the simplified 3-grade fat infiltration system

	Univariate		**Multivariate**	
	OR (95% CI)	P	OR (95% CI)	P
Gender	0.941 (0.559–1.585)	0.820	0.828 (0.474–1.448)	0.508
Age (years)	1.006 (0.984–1.030)	0.586	1.002 (0.972–1.033)	0.913
BMI (kg/m^2)	1.022 (0.965–1.083)	0.454	1.028 (0.952–1.11)	0.479
Right musculus multifidus*	0.864 (0.515–1.449)	0.579	0.868 (0.374–2.015)	0.741
Left musculus multifidus*	0.864 (0.517–1.442)	0.576	0.883 (0.376–2.075)	0.775
Right musculus erector spina*	1.057 (0.650–1.719)	0.822	1.535 (0.638–3.691)	0.339
Left musculus erector spina*	0.931 (0.564–1.537)	0.780	0.72 (0.287–1.807)	0.484
*The bands of < 10%; 10%-50%, > 50% were used in the classification				

1.2. 4-Grade Fat Infiltration Classification System

The fat infiltration of the LDH group and the healthy control group was evaluated according to the 4-grade fat infiltration classification system (Table 3). As a result of the univariate analysis, when < 10% was taken as the reference value for the right m. multifidus, the risk of lumbar disc herniation of patients with 10%-30% fat infiltration was increased by mean 2.74-fold and up to 5.37-fold (p = 0.003). Similarly in the multivariate analysis, when < 10% was taken as the reference value for the right m. multifidus, the risk of lumbar disc herniation of patients with 10%-30% fat infiltration was increased by mean 5.226-fold and up to 15.475-fold (p = 0.003). The simplified 4-grade fat infiltration system predicted a strong relationship between fat infiltration and lumbar disc herniation (Table 4).

Table 3
Logistic regression analysis results of risk factors affecting lumbar disc herniation with the simplified 4-grade fat infiltration system

	Univariate		**Multivariate**	
	OR (95% CI)	P	OR (95% CI)	P
Gender	0.941 (0.559–1.585)	0.820	0.864 (0.487–1.531)	0.616
Age (years)	1.006 (0.984–1.030)	0.586	0.998 (0.967–1.03)	0.912
BMI (kg/m^2)	1.022 (0.965–1.083)	0.454	1.03 (0.952–1.115)	0.464
Right musculus multifidus*	**Reference: <10%**		**Reference: <10%**	
10%-30%	2.740 (1.398–5.370)	**0.003**	5.226 (1.765–15.475)	**0.003**
30%-50%	1.650 (0.547–4.981)	0.374	2.56 (0.728–9.004)	0.143
Left musculus multifidus*	0.847 (0.622–1.152)	0.289	1.577 (0.933–2.666)	0.089
Right musculus erector spina*	0.904 (0.672–1.215)	0.503	1.264 (0.772–2.071)	0.352
Left musculus erector spina*	0.760 (0.559–1.033)	0.080	0.708 (0.422–1.189)	0.192
*The bands of < 10%; 10%-30%, 30%-50%, > 50% were used in the classification				

Table 4
The predictive strength of simplified 3 and 4 grade fat infiltration systems in lumbar herniation outcome

	Effect (strength) in predicting hernia
Simplified 3-grade fat infiltration system	
Grade 1: <10% fat infiltration (normal)	nA
Grade2: 10–50% fat infiltration (moderate)	nA
Grade 3: <50% fat infiltration (severe)	nA
Simplified 4-grade fat infiltration system	
Grade 1: <10% fat infiltration (normal)	nA
Grade 2: 10–30% fat infiltration (mild)	5.226-fold (1.765–15.475)
Grade 3: 30–50% fat infiltration (moderate)	2.56-fold (0.728–9.004)
Grade 4: >50% fat infiltration (severe)	nA
nA:not applicable	

The main finding of this study was that the simplified 4-grade fat infiltration classification system was more effective than the simplified 3-grade system in the prediction of lumbar disc herniation. Different opinions have been stated about the fat infiltration of paraspinal muscles, which could be due to the weaknesses of different measurement methods. Therefore, there is a need for more sensitive measurement methods. In this study, a simplified 4-grade measurement method was formed and the sensitivityof this method was determined. There is no previous definition of a simplified 4-grade system in literature.

Different methods are used in the evaluation of fat infiltration. In the qualitative Goutallier method with the semi-quantitative simplified 3-grade system, inter and intra-observer reliability have been reported to be good [16, 25]. Kjaer et al found inter and intra-observer reliability to be satisfactory but reported that visual evaluation of fat infiltration did not provide satisfactory results for adolescents [13]. Therefore, visual examination alone cannot give a result sufficient to determine the degree of fat infiltration in muscles [4].

While the risk of lumbar disc herniation cannot be revealed with fat infiltration in the 10%-50% band in the simplified 3-grade system, when this band is split into 10%-30% and 30%-50% in the 4-grade system, a strong correlation was determined between the risk of lumbar disc herniation and fat infiltration in the 10%-30% band. In the 4-grade system, the risk of lumbar disc herniation of individuals in the 10%-30% band was observed to be increased 15.474-fold. This result can be attributed to the outlying values (< 15%->45%) being included in the very wide band of 10%-50% in the 3-grade system. Therefore, separating the 10%-50% band into the two bands of 10%-30% and 30%-50% is of great importance in reaching detailed, accurate results.

Fat infiltration seems to be a late stage of muscle degeneration, and fat infiltration of the lumbar musculus multifidus increases with increasing age in adults, irrespective of body composition [13]. Kidde et al suggested that in respect of mobility function, muscle fat infiltration could be more important than muscle weakness [26]. Previous studies have stated a relationship between fat infiltration and lumbar disc herniation [11, 14, 15, 18, 23, 27–29]. In obese individuals, body fat accumulates naturally in the muscles along the muscle system of the back, and although spine problems are frequently seen, it does not settle at the level of the last two lumbar vertebrae. That fat infiltration is mainly found in these two problem areas tends to show that it is lower back pain that initiates muscle changes (4).

Muscle degeneration is characterised morphologically by muscle atrophy and increased fat accumulation (12, 30). Similar to the findings of the current study, many studies have shown greater fat infiltrationn in individuals with low back pain compared to healthy subjects [13, 14, 25]. Conflicting results have been reported in literature on the subject of a relationship between fat infiltration and lumbar disc hernia. Some studies have reported a relationship between fat infiltration and only the m. multifidus [13, 30], some have shown a relationship with both the m.multifidus and the m. erector spina [13, 14, 30], and others have reported no relationship with either muscle [31, 28]. In extended review studies, the relationship between the paraspinal muscle morphology and chronic lumbar back pain has been shown to be uncertain. These studies have stated conflicting results for fat infiltration of the multifidus muscle and presented limited evidence for the erector spina muscle [23, 332, 33].

Limitations of this study were the relatively small sample size, even though the test power was 99.5% with 77 subjects according to the post hoc power analysis, there were few cases with fat infiltration of > 50%, and that there are no studies with the same content for comparison of the 4-grade system.

Conclusion

In conclusion, the results of this study demonstrated that the simplified 3-grade fat infiltration classification system could not predict lumbar disc herniation, whereas a strong correlation was determined with the 4-grade system. This shows the importance of using the semi-quantitative, simplified 4-grade fat infiltration classification system, which provides effective results in the prediction of the risk of lumbar disc herniation in individuals, rather than the simplified 3-grade fat infiltration system for the measurement of fat infiltration of muscles.

Abbreviations

CT: Computed Tomography; MRI: Magnetic Resonance Imaging; US: Ultrasound, LDH: Lumbar Disc Herniation

Declarations

Ethical Approval and Consent

The study was conducted in compliance with the principles of the Helsinki Declaration. Approval for the study was granted by the Ethics Committee of near East University (YDU/2020/83-1160). All the participants provided informed consent.

Permission to publish

Not applicable.

Conflict of Interests

The authors have no conflict of interests to declare.

Data and materials availability

The data obtained and analyzed in this study is not available to the public because of ethical regulations and local management procedures, but can be obtained on request.

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Author Contributions

A.Y. and T.Y. designed the study, interpreted the data, and made major contributions to the writing of the article. A.O. managed the study. A.Y. evaluated the suitability of the patients and referred potential participants to the polyclinics. All the authors examined the final draft of the manuscript, made changes, and approved it.

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References

1. Hoy D, March L, Brooks P, Blyth F, Wolf A, Bain C,et al. The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis 2014; 73(6): 968–974. https://doi.org/10.1136/annrheumdis-2013-204428.
2. Kong WZ, Goel VK, Gilbertson LG, Weinstein JN. Effects of muscle dysfunction on lumbar spine mechanics: a finite element study based on a two motion segments model. Spine (PhilaPa 1976) 1996; 21(19): 2197–2206. https://doi.org/10.1097/00007632-199610010-00004.
3. Kreiner S, Hwang S, Easa J, Resnick DK, Baisden J, Bess S, et al. Clinical Guidelines for Multidisciplinary Spine Care Diagnosis and Treatment of Lumbar Disc Herniation with Radiculopathy.North American Spine Society, USA; 2012
4. Kalichman L, Carmeli E, and Ella Been. The Association between Imaging Parameters of the Paraspinal Muscles, Spinal Degeneration, and Low Back Pain. Biomed Res Int 2017;2017:2562957. https://doi.org/10.1155/2017/2562957.
5. Hu ZJ, He J, Zhao FD, Fang XQ, Zhou LN, Fan SW. An assessment of the intra- and inter-reliability of the lumbar paraspinal muscle parameters using CT scan and magnetic resonance imaging. Spine. 2011 Jun;36(13):E868-74. https://doi.org/10. 1097/BRS.0b013e3181ef6b51.
6. D'Aprile P, Tarantino A, Jinkins JR, Brindicci D. The value of fat saturation sequences and contrast medium administration in MRI of degenerative disease of the posterior/perispinal elements of the lumbosacral spine. Eur Radiol 2007;17:523–531. https://doi.org/10.1007/s00330-006-0324-0
7. Kumar Y, Hayashi D. Role of magnetic resonance imaging in acute spinal trauma: a pictorial review. BMC Musculoskelet Disord 2016;17:310. https://doi.org/10.1186/s12891-016-1169-6
8. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: pre- and post operative evaluation by CT scan. Clin Orthop Relat Res. 1994;304:78–83.

9. Fuchs B, Weishaupt D, Zanetti M, Hodler J, Gerber C. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. J Shoulder Elbow Surg. 1999;8:599–605. doi: 10.1016/S1058-2746(99)90097-6.
10. Slabaugh MA, Friel NA, Karas V, Romeo AA, Verma NN, Cole BJ. Interobserver and intraobserver reliability of the Goutallier classification using magnetic resonance imaging: proposal of a simplified classification system to increase reliability. Am J Sports Med. 2012;40(8):1728–1734. https://doi.org/10.1177/ 0363546512452714
11. Solgaard Sorensen J, Kjaer P, Jensen ST, Andersen P. Low-field magnetic resonance imaging of the lumbar spine: reliability of qualitative evaluation of disc and muscle parameters. Acta Radiol 2006;47(9):947–53. https://doi.org/10.1080/02841850600965062.
12. Parkkola R, Kormano M. Lumbar disc and back muscle degeneration on MRI: correlation to age and body mass. J Spinal Disord. 1992;5(1):86–92. https://doi.org/10.1097/00002517-199203000-00011.
13. Kjaer P, Bendix T, Sorensen JS, Korsholm L, Leboeuf-Yde C. Are MRI-defined fat infiltrations in the multifidus muscles associated with low back pain? BMC Med 2007: 5: 2. https://doi.org/10.1186/1741-7015-5-2
14. Kader DF, Wardlaw D, Smith FW. Correlation between the MRI changes in the lumbar multifidus muscles and leg pain. Clin Radiol 2000; 55(2): 145–9. https://doi.org/10.1053/crad.1999.0340.
15. Min JH, Choi HS, Rhee WI, Lee JI. Association between radiculopathy and lumbar multifidus atrophy in magnetic resonance imaging. Journal of Back and Musculoskeletal Rehabilitation 2013;26(29:175–181 175. https://doi.org/10.3233/BMR-13036
16. Kalichman L, Klindukhov A, Li L, Linov L. Indices of Paraspinal Muscles Degeneration: Reliability and Association With Facet Joint Osteoarthritis: Feasibility Study. *J* Spinal Disord Tech 2016;29(9):465–470. doi: 10.1097/BSD.0b013e31828be943.
17. Fortin M, Gibbons LE, Videman T, Battie MC. Do variations in paraspinal muscle morphology and composition predict low back pain in men? Scand J Med Sci Sports 2015: 25: 880–887. doi: 10.1111/sms.12301
18. Faur C, Patrascu JM, Haragus H, Anglitoiu B. Correlation between multifidus fatty atrophy and lumbar disc degeneration in low back pain. BMC Musculoskelet Disord. 2019;20(1):414. doi: 10.1186/s12891-019-2786-7. PMID: 31488112; PMCID: PMC6729014.
19. Fortin M, Videman T, Gibbons LE, Battie MC. Paraspinal muscle morphology and composition: a 15-yr longitudinal magnetic resonance imaging study. Med Sci Sports Exerc 2014;46:893–901. https://doi.org/10.1249/ MSS.0000000000000179
20. Hebert JJ, Kjaer P, Fritz JM, and Walker BF. The relationship of lumbar multifidus muscle morphology to previous, current, and future low back pain: a 9-year population-based prospective cohort study. Spine 2014;39(17): 1417–1425. https://doi.org/10.1097/brs.0000000000000424.
21. Niemela¨inen R, Briand MM, Battie´ MC. Substantial asymmetry in paraspinal muscle cross-sectional ... ue as a marker of low back pain and pathology. Spine

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2011;36(25):2152–2157. https://doi.org/10.1097/BRS.0b013e318204b05a.

22. Chan ST, Fung PK, Ng NY, Ngan TL, Chong MY Tang CN et al. Dynamic changes of elasticity, cross-sectional area, and fat infiltration of multifidus at different postures in men with chronic low back pain. Spine J 2012;12(5):381–388. https://doi.org/10.1016/j.spinee.2011.12.004.
23. Fortin M, Macedo L. Multifidus and paraspinal muscle group cross-sectional areas of patients with low back pain and control patients: a systematic review with a focus on blinding. Phys Ther 2013: 93 (7): 873–888. https://doi.org/10.2522/ptj.20120457.
24. Parkkola R, Rytokoski U, Kormano M. Magnetic resonance imaging of the discs and trunk muscles in patients with chronic low back pain and healthy control subjects. Spine 1993;18(7):830–6. https://doi.org/10.1097/00007632-199306000-00004.
25. Battaglia PJ, Maeda Y, Welk A, Hough B, Kettner N. Reliability of the Goutallier classification in quantifying muscle fatty degeneration in the lumbar multifidus using magnetic resonance imaging. J Manipulative Physiol Ther. 2014;37(3):190–7. https://doi.org/10.1016/j.jmpt.2013.12.010.
26. Kidde J, Marcus R, Dibble L, Smith S, LaStayo P. Regional muscle and whole body composition factors related to an older individual's level of mobility: A review. Physiother Can, 2009; 61(4): 197–209. https://doi.org/10.3138/physio.61.4.197
27. Hodges P, Holm AK, Hansson T, Sten H. Rapid atrophy of the lumbar multifidus follows experimental disc or nerve root injury. Spine (PhilaPa 1976) 2006;31(25): 2926–2933. https://doi.org/10.1097/01.brs.0000248453.51165.
28. Colakoglu B, Alis D. Evaluation of lumbar multifidus muscle in patients with lumbar disc herniation: are complex quantitative MRI measurements needed? J Int Med Res 2019;47(8): 3590–3600. https://doi.org/10.1177/0300060519853430
29. Fortin M, Lazáry A, Varga PP, McCall I, Battié MC. Paraspinal muscle asymmetry and fat infiltration in patients with symptomatic disc herniation. 2016;25(5):1452–1459. https://doi.org/10.1007/s00586-016-4503-7.
30. Mengiardi B, Schmid MR, Boos N et al. Fat content of lumbar paraspinal muscles in patients with chronic low back pain and in asymptomatic volunteers: quantification with MR spectroscopy. Radiology 2006: 240 (3): 786–792. https://doi.org/10.1148/radiol.2403050820.
31. Hides J, Gilmore C, Stanton W, Bohlscheid E. Multifidus size and symmetry among chronic LBP and healthy asymptomatic subjects. Man Ther 2008:13 (1): 43–49. https://doi.org/10.1016/j.math.2006.07.017.
32. Suri P, Fry AL, Gellhorn AC. Do Muscle Characteristics on Lumbar Spine Magnetic Resonance Imaging or Computed Tomography Predict Future Low Back Pain, Physical Function, or Performance? A Systematic Review. PM R 2015;7(12):1269–81. doi:10.1016/j.pmrj.2015.04.016.
33. Ranger TA, Cicuttini FM, Jensen TS, Peiris WL, Hussain SM, Fairley J, et al. Are the size and composition of the paraspinal muscles associated with low back pain? A systematic review. Spine J 2017;17(11):1729–48. https://doi.org/10.1016/j.spinee.2017.07.002.

Figures

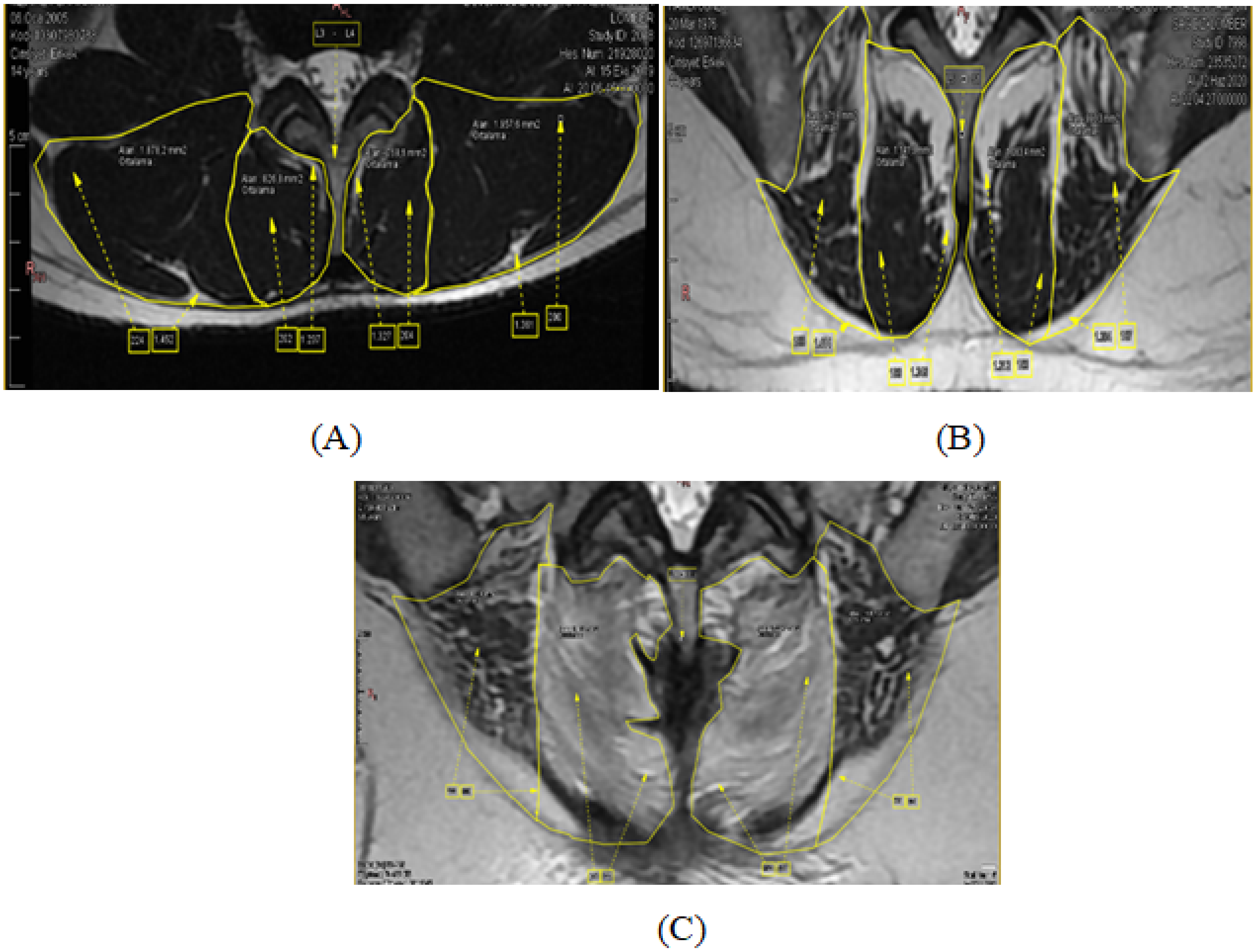

Figure 1

T2 axial magnetic resonance imaging slices showing location of the muscles and degree of fat infiltration, evaluated with the simplified 3-grade system. A: Grade 1: <10% fat infiltration, B: Grade 2: 10%-50% fat infiltration, C: Grade 3: >50% fat infiltration

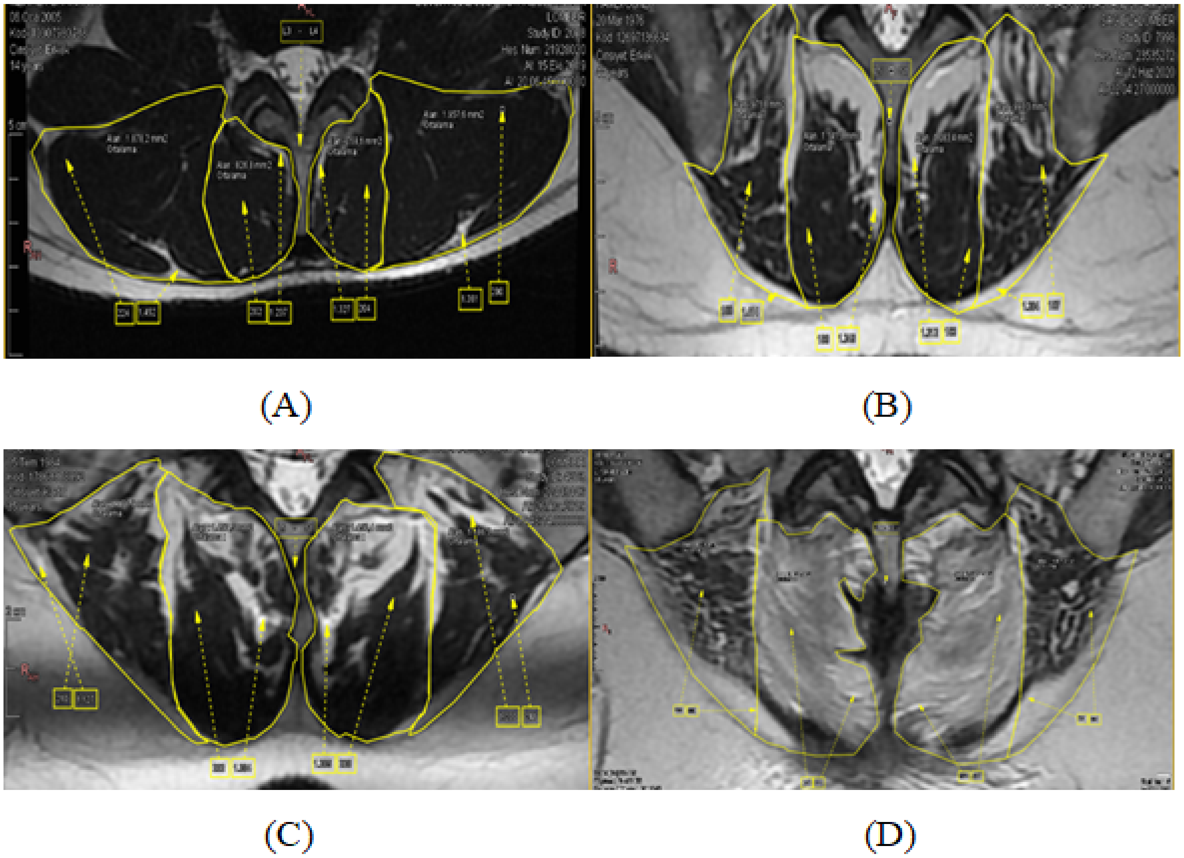

Figure 2

T2 axial magnetic resonance imaging slices showing location of the muscles and degree of fat infiltration, evaluated with the 4-grade system. A: Grade 1: <10% fat infiltration, B: Grade 2: 10%- 30% fat infiltration, C: Grade 3: 30%-50% fat infiltration, D: Grade 4: >50% fat infiltration