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A new equation for correlation of clinical and radiological factors affecting multifidus muscle degeneration in magnetic resonance imaging

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Abstract

Background: Multifidus muscle (MF) is one of the back muscles of the spine that is involved in the pathogenesis of low back pain. Its role as a stabilizer of the spine continues to present diagnostic and therapeutic challenges. The degree of MF degeneration is dependent on multiple clinical and radiological factors. We proposed a new equation to predict MF degeneration based upon clinical and radiological changes in magnetic resonance imaging.

Methods: Clinical factors associated with MF degeneration include visual analogue scale (VAS) for pain, body mass index, duration of complaint, age of the patients and the presence of sciatica. Other radiological factors include the number of disc pathologies, neural canal stenosis and facet joint arthropathies, by building a module of a univariate and multivariate linear regression analysis for the parameters affecting MF degeneration score as a dependent variable.

Results: Regarding the univariate and multivariate linear regression for factors affecting MF degeneration, the most common factors associated with increased multifidus score were the duration in years and VAS score in the multivariate analysis model with B value equal to 0.184 according to duration in years and equal to 0.287 with VAS score according to 95% confidence interval.

Conclusion: The equation for multifidus score is a helpful method to predict the degree of MF degeneration in relation to clinical variable.

Keywords: Lumbar spine, Magnetic resonance imaging, Low back pain, Multifidus muscle, Lumbosacral

Background

Low back pain (LBP) is a highly prevalent problem in society; approximately 60% to 80% of the population will experience an episode of LBP during their lifetime. Multiple factors are associated with LBP, including clinical and radiological findings in magnetic resonance imaging (MRI) [1].

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Degenerative spine changes are presented in MRI by disc pathologies, neural canal stenosis, facet arthropathies, Modic end plate changes and back muscles degeneration, especially in the intrinsic multifidus muscle. Multifidus muscle (MF) is one of the muscles of the back; it has a role as a spine stabilizer. MF degeneration is presented by fatty replacement of the muscle fibres and better assessed by MRI [2, 3].

The degree of degenerative changes is influenced by body mass index (BMI) and duration of complaint. Patients with sciatica and more pain as assessed by visual

analogue scale (VAS) have more degenerative changes [4, 5].

MF degeneration is measured in the lowest three levels in lumbar region starting from level of intervertebral disc between third and fourth lumbar vertebral bodies [6, 7].

The aim of this study was to build a new equation that assesses the degree of MF degeneration by a designed scoring system in relation to clinical and radiological variables.

Methods

This cross-sectional study was approved by the Committee of Institutional Review Board of Zagazig University Faculty of Medicine. The radiological examinations for all patients were funded by the Egyptian National Health Insurance system. All the cases were performed between 1 September 2019 and 1 September 1 2020. All study participants provided written informed consent to be involved in the study before any data collection. No author received funding from outside the university.

Inclusion and exclusion criteria

All patients included in this study were suffering from low back pain either with or without sciatica; included patients should not be younger than 18 years old or older than 80 years old. Exclusion criteria for the study included: (1) patients with history of prior operative or interventional procedure in the spine, (2) patients with history of malignancy, (3) patients with spondylolisthesis detected by dynamic plain radiography of the spine, (4) patients with scoliosis, wedge fractures or deformed vertebral bodies, (5) patients with massive spinal haemangiomas, (6) history of congenital spinal defects, (7) history of recent nephrolithiasis with referred pain to the back, (8) pregnant ladies, and (9) patients on rheumatological or connective tissue disorders.

Clinical evaluation

Clinical history taking was performed to all patients involved in the study; after recording the age and gender of all patients, other questions to be answered are: (1) duration of complaint, (2) intensity of pain (VAS) to be graded on a scale from 0 to 10, (3) presence of sciatica and either unilateral or bilateral, and (4) weight of the patient and its correlation with the height and calculation of BMI.

Radiological interpretation

All MRI examinations were interpreted independently by two consultants of radiology with more than 10 years of experience with inter-observer agreement of 95% to report the same data for all patients included in the study. Data recorded from each film included type of disc pathology, either bulge or herniated, presence of annular tear, grading of Modic end plate changes, presence of Schmorl's nodes, neural canal stenosis and facet arthropathy.

The final questionnaire included answers to the following radiological findings:

- How many disc pathologies are present?
- Disc pathologies are either disc bulge or herniation
- Other parameters were recorded:
  - Annular disc tears?
  - Modic changes?
  - Schmorl's nodes?
  - Neural canal stenosis?
  - Facet joints (either normal, effusion or sclerosis).
  - Multifidus muscle score (MS) in each side of each level.

MS interpretation and Equation formula

Interpretation of MF by MRI was conducted by measuring the degree of wasting and fatty infiltration and the bilaterality of changes. Regarding the MS, it was recorded as the highest score for each side (right and left) in the lowest three levels (L3/4, L4/5 and L5/S1).

The scores are measured as follows: (1) grade 0: < 10% fatty infiltration, (2) grade 1: 10:50% fatty infiltration, and (3) grade 2: > 50% fatty infiltration [7].

MS was calculated by the summation of degree of MF degeneration, with minimum score of 0 and maximum of 6. Score of 6 means that maximum MF degeneration grading is 2 in at least one side for the lowest three levels. We mentioned the influence of other vertebral degenerative pathologies including facet arthropathies, neural canal stenosis and Modic end plate changes. We defined disc pathology as disc bulge and herniation.

By building a module of a univariate and multivariate linear regression analysis for the parameters affecting MF degeneration score as a dependent variable, the main factors affecting MF degeneration are age, body mass index (BMI), duration of complaint in years, the presence of sciatica and visual analogue scale (VAS) score. For scoring of sciatica, score of 0 means "no sciatica", score of 1 means "unilateral sciatica" and score 2 means "bilateral sciatica".

The equation for MS could be calculated as follows:

$$\mathrm{MS} = 1.154 + (0.017 \times \mathrm{Age}) + (0.184 \times \mathrm{duration\ years}) + (0.081 \times \mathrm{Sciatica}) + (0.287 \times \mathrm{VAS}).$$

Statistical analysis

Data were fed to the computer and analysed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp).The Kolmogorov–Smirnov was used to verify the normality of distribution of variables. Comparisons between groups for categorical variables were assessed using chi-square test (Monte Carlo). Student's t test was used to compare two groups for normally distributed quantitative variables, while ANOVA was used for comparing the four studied groups. Kruskal–Wallis test was used to compare different groups for abnormally distributed quantitative variables. Mann–Whitney test was used to compare between two groups for not normally distributed quantitative variables. Bland–Altman plot and one-sample t test (between the difference and zero) (if significant then there is fixed bias) was used for agreement. The significance of the obtained results was judged at the 5% level (Figs. 1, 2).

Results

At L3/4 and L4/5 levels

- There is a statistically significant correlation between age, duration of complaint and VAS score with the degree of MS degeneration in each of L3/4 and L4/5 levels.
- There is a significant correlation between the number of disc pathologies in the three levels (L3/4, L4/5 and L5/S1 levels) and degree of MS degeneration at L3/4 and L4-5 levels.
- There is no significant relation between MS degeneration at either L3-4 or L4/5 level and either BMI or sciatica.
- Regarding the presence of Schmorl's nodes and facet pathology, there are statistically significant correlations between each of them and the degree of MS at either L3-4 or L4-5 levels. The data are represented in Tables 1 and 2.

At L5/S1 level

- Unlike the upper levels, there is no statistically significant correlation ($p = 0.496$) between age and degree of MS degeneration at L5-S1 level.
- Like the upper levels, the duration of complaint and VAS score are significantly correlated with MS degeneration. There is no significant relation between MS degeneration at either L3-4 or L4/5 level and either BMI or sciatica. Regarding the presence of Schmorl's nodes and facet pathology, there are statistically significant correlations between each of them and the degree of MS at either L3-4 or L4-5 levels.
- All patients had facet pathologies at L5-S1 level, 33 of them has facet effusion and 51 had facet joint sclerosis; among patients with facet effusion, 22 had grade II MS degeneration (66.7%), and among patients with facet joint sclerosis 48 (94.1%) had grade II MS degeneration. The data are represented in Tables 1 and 2.

For a univariate and multivariate linear regression analysis for the parameters affecting multifidus muscle degeneration score in cases with MS ≥ 4, we found that age and duration by years and VAS score were correlated with MS in a univariate model. In the multivariate model, only VAS score was correlated with the MS (Tables 3, 4) (Figs. 4, 5).

The agreement between MS measured by manual summation and MS calculated by the equation was measured with a mean difference of 0.004 ± 1.55 (Fig. 3).

Regarding the distribution of the studied cases according to differences between the manual summation and MS calculated by the equation, in 60 cases (71.4%) it was < 1, in 14 cases (16.7%) it was < 2, and in 10 cases (11.9%) it was ≤ 3 (Figs. 4, 5).

Discussion

The multifidus muscle plays an important role in stabilizing the joints within the spine. It is located just superficially to the spine itself; the multifidus muscle spans three joint segments and works to stabilize these joints at each level [2, 3, 8].

The stiffness and stability make each vertebra work more effectively and reduce the degeneration of the joint structures caused by friction from normal physical activity [8, 9].

Wilke et al. found that the actions of the multifidi account for more than two-thirds of the stiffness of the spine. In comparison with all lumbar muscles, the MF are short, with a high cross-sectional area and short muscle fibres [10].

A number of prior investigations have described the MF atrophy and replacement by fat after low back injury, a pathologic process that is closely correlated with LBP. Kjaer et al. evaluated the lumbar magnetic resonance imaging (MRI) results for 412 adult and 442 adolescent subjects in a cross-sectional study of MF atrophy [11].

This study supposed that there are many factors affecting MF degeneration, including age, BMI, duration of complaint in years, the presence of sciatica and VAS score. Most of the studies in the literature described the degree of MS affection in relation to VAS score and duration of complaint in years. We proposed a new method to assess the degree of MF degeneration and chose the

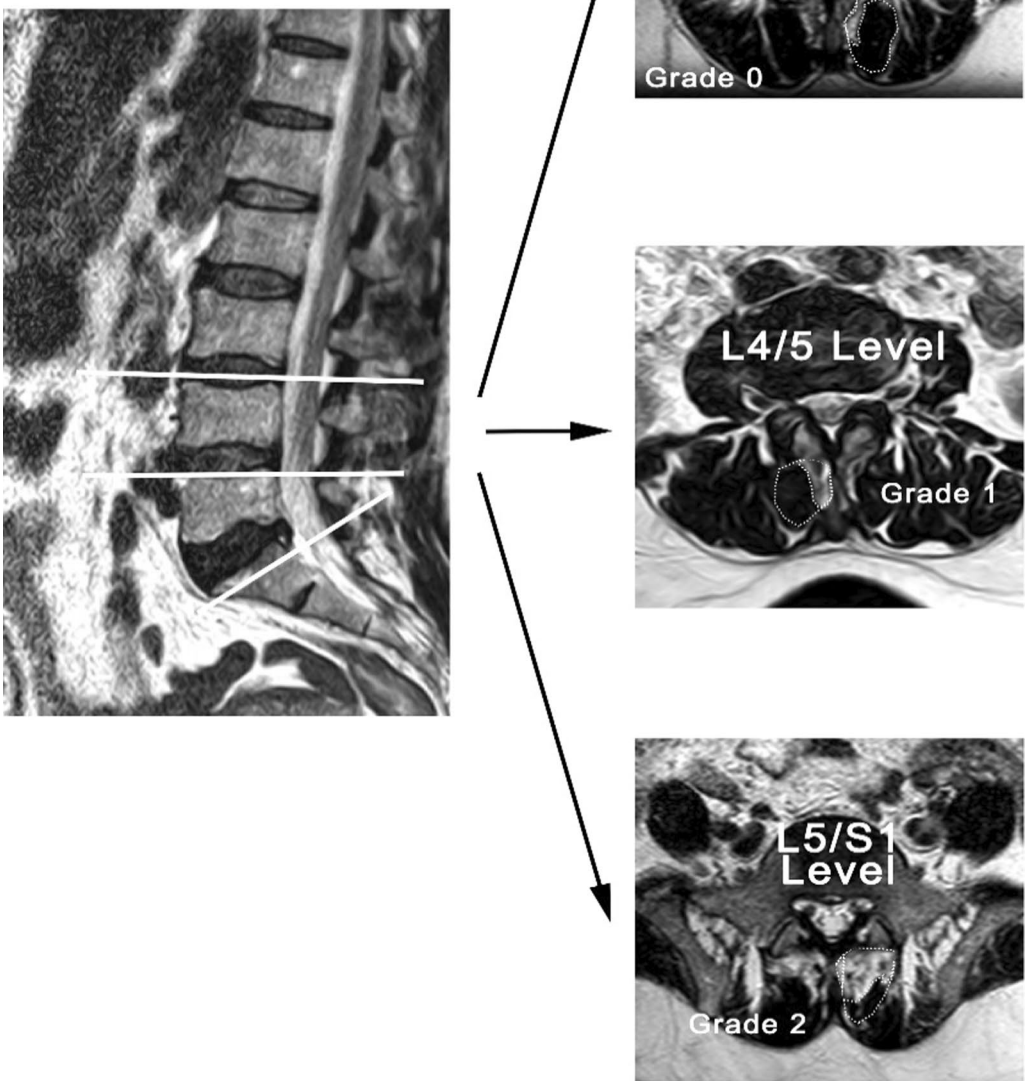
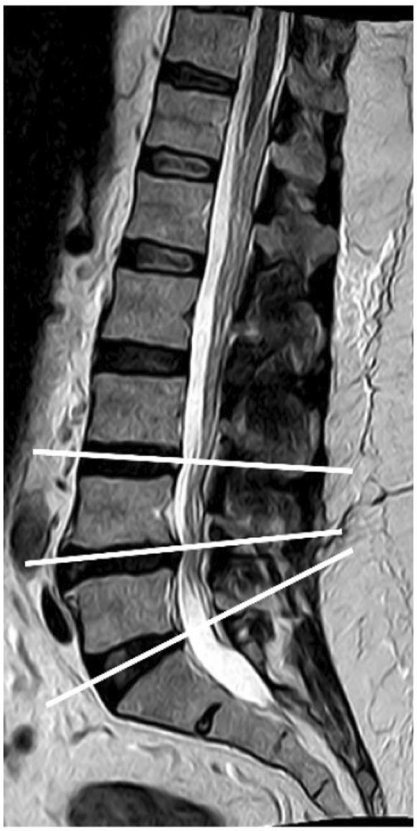


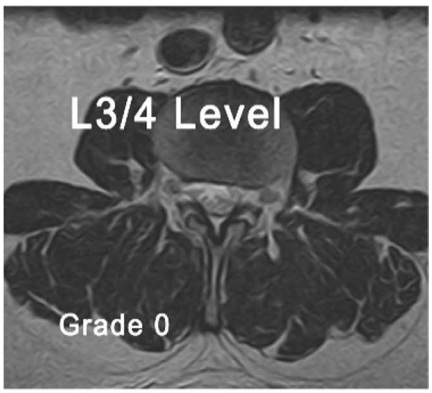
Fig. 1 Lumbosacral MRI, of a 28-year-old man with 3 years history of LBP without sciatica, BMI = 29, there is disc bulge at L3/4 down to L5/S1 level. No neural canal stenosis. Average VAS score = 4. Axial cuts revealed grade 0 MS degeneration at L3/4 level, grade 1 MS degeneration at L4/5 level and grade 2 MS degeneration at L5/S1 level, MS = 3. MS = 1.154 + (0.017*Age) + (0.184* duration years) + (0.081* Sciatica) + (0.287* VAS). According to MS equation, the expected MS = 3.3

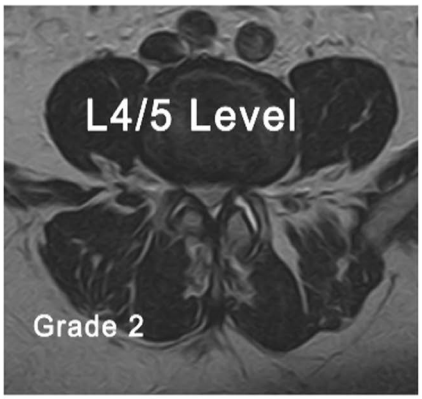
lowest three lumbar levels from L3/4 down to L5/S1 level. The multifidus score was calculated by summation of degree of multifidus muscle degeneration at those lowest three levels (L3/4, L4/5 and L5/S1), with a minimum score of 0 and maximum of 6.

The present study mentioned the influence of other vertebral degenerative pathologies including facet arthropathies, neural canal stenosis and Modic end plate changes and defined disc pathology as disc bulge or herniation.

Kader et al. performed a retrospective study of 78 patients with LBP and either with or without leg pain.







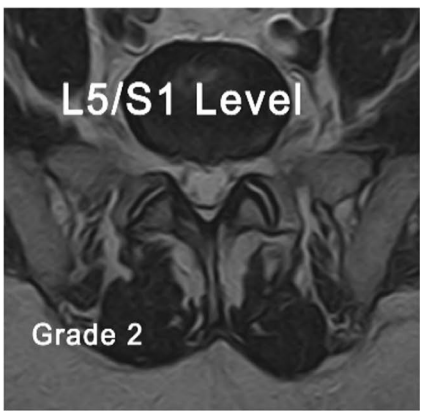


Fig. 2 Lumbosacral MRI, of a 57-year-old man with 5 years history of LBP without sciatica, BMI = 18, there is disc bulge at L4/5 and L5/S1 levels. No neural canal stenosis. Average VAS score = 5. Axial cuts revealed grade 0 MS degeneration at L3/4 level, grade 2 MS degeneration at L4/5 and L5/S1 levels, MS = 4. MS = 1.154 + (0.017*Age) + (0.184* duration years) + (0.081* Sciatica) + (0.287* VAS). According to MS equation, the expected MS = 4.5

Table 1 Distribution of the studied cases according to different parameters (n = 84)

	No. (%)
Age (years)	
Mean ± SD.	45.05 ± 12.53
Median (Min. – Max.)	43 (23–70)
BMI (kg/m^2)	
< 18.5 (Underweight)	4 (4.8%)
18.5–24.9 (Normal)	22 (26.2%)
25–29.9 (Overweight)	32 (38.1%)
30–34.9 (Obese)	20 (23.8%)
> 35 (Extremely obese)	6 (7.1%)
Mean ± SD	26.77 ± 4.70
Median (Min.—Max.)	27 (16–38)
Duration of compilation (years)	
Mean ± SD.	4.39 ± 1.96
Median (Min.—Max.)	4 (1–10)
Right sciatica	
No	36 (42.9%)
Yes	48 (57.1%)
Left sciatica	
No	46 (54.8%)
Yes	38 (45.2%)
Sciatica	
No	26 (31%)
Unilateral	30 (35.7%)
Bilateral	28 (33.3%)
VAS	
Mean ± SD.	4.25 ± 1.26
Median (Min. – Max.)	4.0 (2.0–8.0)

Table 2 Distribution of the studied cases according to multifidus muscle degeneration score measured by manual calculation (n = 84)

Multifidus muscle degeneration score	No. (%)
1	2(2.4%)
2	7(8.3%)
3	25(29.8%)
4	18(21.4%)
5	16(19%)
6	16(19%)
Mean ± SD.	4 ± 1.3
Median (Min.–Max.)	4(1–6)

They assessed the correlation between MRI changes in the MF and leg pain. It was reported that MF atrophy was present in 80% of the patients with LBP and that there was a significant correlation between MF atrophy and referred leg pain [7].

Table 3 Univariate and multivariate linear regression analysis for the parameters affecting multifidus muscle degeneration score

	Univariate		Multivariate	
	r	*P*	*P*	B (95% CI)
Age (years)	0.371	0.001*	0.136	0.017(0.04–2.27)
BMI (kg/m^2)	0.104	0.347	–	–
Duration (years)	0.497	< 0.001*	0.028*	0.184(-0.01–0.04)
Sciatica	0.254	0.020*	0.629	0.081(0.02–0.35)
VAS	0.463	< 0.001*	0.015*	0.287(0.06–0.52)
			$P < 0.001$*/$r^2 = 0.339$	

B: Unstandardized coefficients, r: Pearson coefficient, R^2 Coefficient of determination

CI confidence interval

*Statistically significant at $P \leq 0.05$

All variables with $P < 0.05$ were included in the multivariate

Equation: MS= 1.154+ (0.017 × Age) + (0.184 × duration years) + (0.081 × Sciatica) + (0.287 × VAS)

Duration and VAS included in the multivariate

Table 4 Univariate and multivariate linear regression analysis for the parameters affecting multifidus muscle degeneration score (4 + 5 + 6)

	Univariate	[a]Multivariate		
	P	OR (95%C.I)	*P*	OR (95% CI)
Age (years)	0.017*	1.048 (1.009–1.090)	0.181	1.030 (0.986–1.076)
BMI (kg/m^2)	0.875	1.008 (0.918–1.106)	–	–
Duration (years)	0.002*	1.578 (1.175–2.121)	0.125	1.300 (0.930–1.816)
Sciatica	0.236	1.762 (0.690–4.496)	–	–
VAS	0.002*	2.003 (1.286–3.121)	0.042*	1.689 (1.020–2.798)

B: Unstandardized coefficients, r: Pearson coefficient, R^2 Coefficient of determination

CI confidence interval

*Statistically significant at $P \leq 0.05$

[a] All variables with $P < 0.05$ were included in the multivariate

In a systematic review made by Fortin and Macedo, on 11 studies to evaluate paraspinal muscle morphology in patients with LBP and control patient, they concluded that the results of most studies suggest that multifidus and paraspinal muscle groups are smaller in patients with chronic LBP than in control patients who are healthy and all pooled estimates were statistically significant. In addition, they showed that patients with chronic LBP appear to have more multifidus muscle atrophy at L5 than L4 [1].

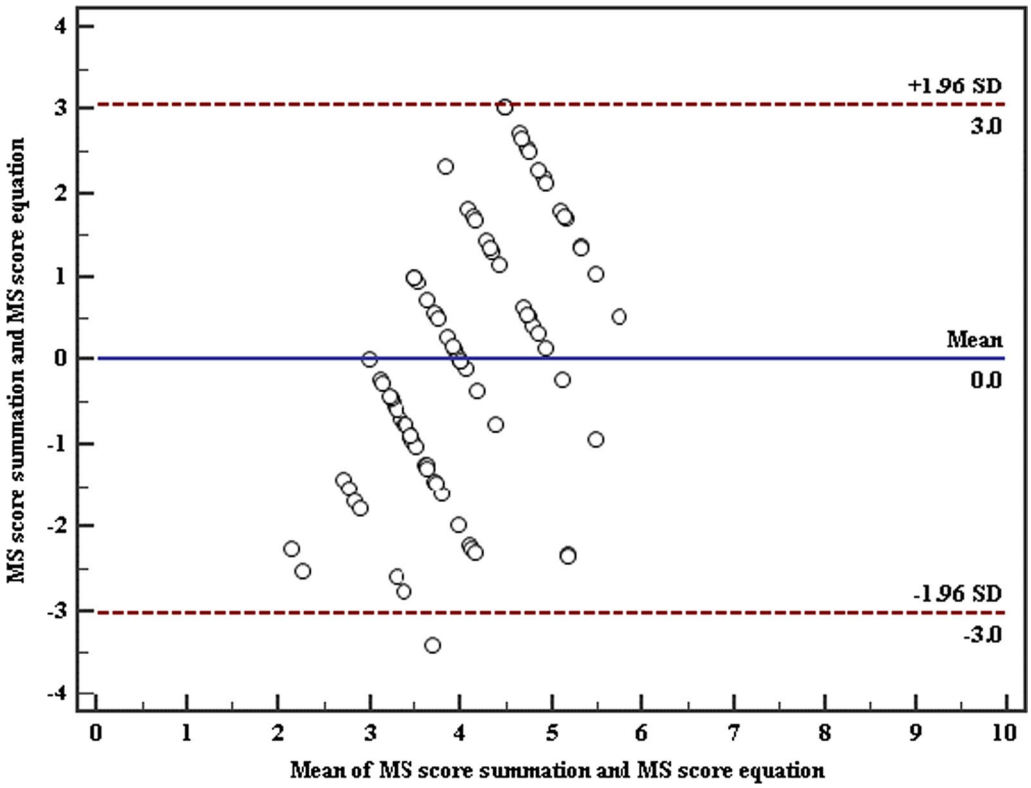


Fig. 3 Agreement between MS summation and MS equation

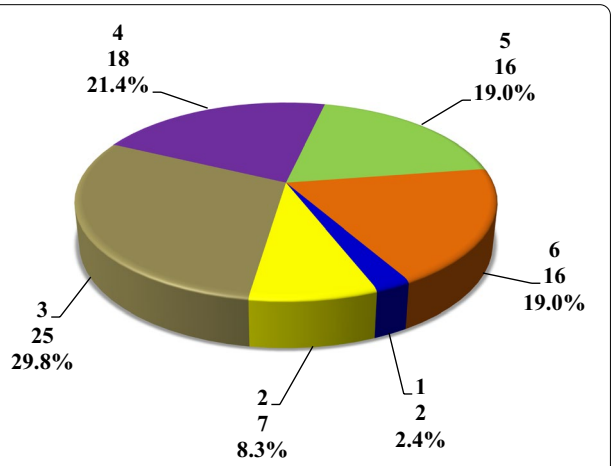


Fig. 4 Distribution of the studied cases according to multifidus muscle degeneration score (n = 84)

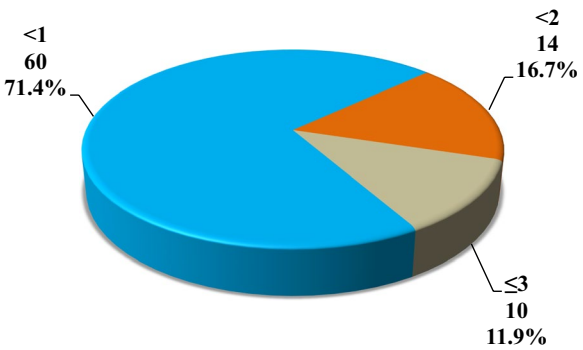


Fig. 5 Distribution of the studied cases according to difference (n = 84)

Indahl et al. noted that the injection of saline into the zygapophyseal joint in a porcine model resulted in decreased activity of the multifidus muscle. They concluded that the effect of the injection was to activate a stretch reflex in the joint capsule, which in turn excited inhibitory interneurons in the spinal cord [12].

Hodges et al. demonstrated, also in a porcine model, the rapid onset of MF atrophy within 3 days after an experimentally induced nerve root injury. After transaction of the medial branch of the L3 nerve root, the ipsilateral MF CSA adjacent to the L4, L5 and L6 spinous processes was reduced by 13%, 20% and 12%, respectively, by 72 h after injury [13].

Kader et al. used MRI in evaluating MF atrophy, which they defined as muscular replacement with fat and

fibrous tissues. They established a ranked grading scale for MF atrophy consisting of mild, moderate and severe, corresponding to atrophy in less than 10% of CSA of the MF, more than 10% and less than 50% and more than 50%, respectively [7].

In a prospective cross-sectional study made by Beneck and Kulig on 28 individuals measuring the volume of MF and erector spinae muscles at L5-S1 and MF volume at L4 and S2-3 levels, they concluded that there is no significant relation regarding the volumes of MF between painful sides and pain-free side [14].

The main question for all studies mentioned the multifidus muscle degeneration and its correlation with other discovertebral pathologies is "what comes first?", or it could be a viscous circle as MF degeneration could be a result and an aetiology at the same moment, with more study of biomechanics of the spine could revealed that the primary disc degeneration is associated with MF degeneration and this could lead us to main aim of the study which is the MS calculation which could be valuable for all patients experienced low back pain to predict the persistence of LBP is patients with mild disc pathologies and preserved disc substance hydration with early MF degeneration. Another benefit from MS calculation is that it could lead researchers to more extensive researches in role and benefit of physiotherapy in addition to traditional medications and to study the role of regenerative medicine and interventional procedures for pain relief and to predict the duration of pain relief after percutaneous injections in patients with high MS. More research is to done to measure the MF degeneration by other modalities like ultrasound or computed tomography.

Regarding the limitation of the study, (1) the age groups were narrow with small number of patients in the study, (2) the study depends on measuring the highest grade of MF degeneration in each level and did not mention the influence of unilateral sciatica or unilateral disc compression on the degree of MF degeneration, and (3) the exclusion criteria included many patients with history of operated spine lesions or other vertebral pathologies, as well as more research is needed to study the correlation between MF degeneration and degree of pain relief after interventional or surgical spinal procedures.

Conclusions

The multifidus muscles are essential stabilizers of the lumbar spine and atrophy of these muscles is closely associated with LBP, though this does not rule out other causes of LBP. In our case reports, we found that MRI served as an effective tool for evaluating and documenting changes in MF fatty atrophy in chronic LBP patients.

This study discussed the influence of other vertebral degenerative pathologies including facet arthropathies, neural canal stenosis and Modic end plate changes and proposed the multifidus score as a unique score for prediction of MF degeneration and a new way of diagnosis to assess patients under treatment and predict other discovertebral pathologies.

Abbreviations

BMI: Body mass index; LBP: Low back pain; MF: Multifidus muscle; MRI: Magnetic resonance imaging; MS: Multifidus score; VAS: Visual analogue scale.

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Author contributions

N.L. is the guarantor of integrity of the entire study. N.L, A.A.A, H.F.T and H.S. contributed to study concepts and design. N.L, A.A.B, H.F and A.A.A performed the literature research. H.F.T and H.F helped in clinical studies. N.L, A.A.B and A.A.A contributed to experimental studies/data analysis. N.L and A.A.B. performed statistical analysis. H.F.T and A.A.A prepared the manuscript. H.F and A.A.A edited the manuscript. All authors read and approved the final manuscript.

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Availability of data and material

The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Institutional review board approval was obtained. Written informed consent was obtained from all patients.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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