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Quantification Threshold Pixel Technique of Magnetic Resonance Imaging in Paraspinal Muscles Atrophy among Discopathy Patients

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Abstract

Purpose: To evaluate the relationship between lumbosacral discopathy status and paraspinal atrophic changes (Cross-sectional area (CSA) and fatty infiltration (FI)) among different age groups. **Materials and Methods:** We retrospectively evaluated 200 patients with confirmed discopathy who were examined by lumbosacral Magnetic Resonance Imaging (MRI) at the two main governmental hospitals in Gaza Strip. Using ImageJ software and quantification threshold technique, we measured the CSA and FI of paraspinal muscles {multifidus (MF) & erector spinae (ES)}. The interpretation of MRI images was performed by two radiologists with a good inter-observer agreement between the radiological discopathy findings. **Results:** The highest percentage and severity of discopathy were noticed at the level of L4/5 (89.5%), followed by L5/S1 (14.5%). The FI is increased towards lower levels of L3/4 to L5/S1. No correlation was found between discopathy level, the severity of discopathy, and CSA of MF & ES muscles. In contrast, a correlation was observed between FI of MF & ES muscles, discopathy level, and severity. Also, the results illustrated no significant relation was observed between CSA of MF & ES muscles and age groups ($P > 0.05$), while a significant correlation was reported between FI and age groups ($P < 0.05$). **Conclusion:** The MRI quantification threshold pixel technique for paraspinal muscles reflected the atrophic changes like CSA and FI in discopathy patients.

Keywords

Paraspinal Muscles, Cross-Sectional Area, Fatty Infiltration, Multifidus, Erector Spinae, Discopathy

1. Introduction

Magnetic resonance imaging (MRI) is an excellent noninvasive tool to assess the lumbosacral spine pathology and adjacent muscles changes. The posterior paraspinal muscles (multifidus (MF) & erector spinae (ES) muscles) play an essential role in spinal stability and flexibility, and weakness of those muscles is a major cause of recurrent Low Back Pain (LBP) [1]. The evaluation of paraspinal muscle morphology and fatty infiltration (FI) has attracted a wide spectrum of attention in the literature recently to assess the relationship between Cross-Sectional Area (CSA) and FI of MF & ES muscles, discopathy, and LBP [2]-[8]. However, there remain discrepancies in literature due to variable imaging modalities used. In the past, a visual qualitative approach, which was assessed by a scoring system (the Mercuri score), was applied to standard T1-weighted spin-echo sequences to assess FI. This score is visually applied by the radiologist and ranges from 1 (normal muscle appearance) to 4 (severe involvement, more than 60% fatty degeneration) [9] [10]. Likewise, the reliability of measurements of lumbar multifidus FI was assessed, using the Goutallier classification system (GCS) (0 - 4 grading scale) [11], which was initially established to assess fatty degeneration in rotator cuff injuries. Although such studies have reported good intra-rater (ICC or kappa 0.71 - 0.93) and inter-rater reliability (ICC or kappa 0.58 - 0.85) [12] [13], these techniques don't allow accurate measurements and can't be utilized to evaluate changes over time. Hence, quantitative MRI measurements of paraspinal muscles composition using the threshold pixel quantification technique have been developed. This technique is accomplished by isolating pixels within the selected muscle region of interest (ROI) that represents fat by the threshold method or manual segmentation. The signal intensity (SI) of each fat pixel from an MRI image can be given a bright-gray scale value [14] [15]. Hence, FI in the muscles, which is considered a bad sign and a strong indicator of muscle weakness, could be quantified [16]. The main advantage of threshold quantification techniques with MRI is its ability to provide a more detailed overview of FI progression [17], which indicates atrophic muscle changes in several spine conditions, such as disc herniation [2] [18] [19] [20]. The purpose of the current study is to investigate the correlation between the lumbosacral discopathy status (L3/4, L4/5, and L5/S1) and age group with the paraspinal atrophic changes (CSA & FI).

2. Method and Materials

2.1. Study Population and Sample

This analytical cross-sectional retrospective study included 200 discopathy patients (95 female and 105 male) with non-probability consecutive sampling, which selected the MRI departments at two main governmental hospitals in Gaza Strip; Al-Shifa Medical Complex and European Gaza Hospital (EGH). The inclusion criteria were patients aged 18 - 80 years and with a confirmed discopathy diagnosis. Patients with lumbosacral spine congenital anomalies, fractures, infections, vertebral metastasis, and pregnancy were excluded to avoid bias due to CSA & FI changes.

2.2. Study Period and Ethical Considerations

The timeframe for this study was from April 2020 to April 2021. The study was conducted after getting ethical and administrative approval from Al-Azhar Gaza-University, Helsinki committee, ministry of health, and human resources development administration, respectively.

2.3. Lumbosacral MRI Imaging

MRI scans were conducted with a 1.5-Tesla MR device using a spine coil (Philips Intera; Siemens-MAGNETOM) with patients in the neutral supine position. A routine assessment was carried out with T2-weighted turbo spin-echo (TSE) sagittal, T1-weighted TSE sagittal, and T2-weighted TSE axial images. T2-weighted TSE. Imaging parameters for scan were: TR: 3650 ms; TE: 120 ms; slice thickness = 3 mm; NAS or Average = 4. Axial slices were performed parallel to L3/4, L4/5, and L5/S1 intervertebral disc space without overlapping the slice boxes. Also, were used for muscle area measurements and to determine the degree of FI.

2.4. Paraspinal Muscles Measurements and Quantification Yields

Quantitative measurements and yields for the MF & ES muscles were taken by ImageJ software (version 1.52 National Institutes of Health). The process was picked up by one of the investigators, who expert in ImageJ quantitative thresholding pixel filter analysis. The expert investigator manually drew the border of the MF & ES muscles at L3/4, L4/5L, and L5/S1 on the six axial slices with coverage of the upper and lower disc recess using ImageJ software. The mean of FI SI among each slice was calculated based on higher SI equated to more fat inside the ROI. CSA measurements of the MF & ES muscles were taken, with the area measurement in (cm^2) by margins of each muscle to be measured within the ROI to exclude the fatty areas in the periphery and to ensure the muscles' size. Besides, FI was assessed by manually adjusting a threshold signal within the total muscle CSA to only include pixels in the muscular adipose tissue area (See **Figure 1**).

2.5. ImageJ Software Validity and Intra-Rater Reliability

Based on the previous studies [2] [15] [21] [22] the ImageJ software threshold filter has an excellent intra-reader and inter-reader for FI of the muscles. Likewise, functional CSA measurements, using a manual thresholding technique,

Figure 1. Illustrates the MRI axial T2-weighted image adjacent to the quantification technique in which the naked eye has limitations to detect paraspinal muscles size and composition (a). Muscles are divided manually into 4 ROIs by ImageJ software to estimate the CSA of the muscles; the ROIs (1 & 3) represents the CSA for multifidus muscles, while ROIs (2 & 4) represents the CSA for erector spinae muscles; (b). Posterior paraspinal muscles are coded in red color pixels via threshold filter to estimate the fatty infiltration among the ROIs; (c). Results of Quantification yields and setting threshold filter (Area of muscles is representative of CSA and Area% is representative of fatty infiltration for the corresponding ROIs; (1 & 3) represents multifidus muscles, and (2 & 4) represents erector spinae muscles.

have reported intra-rater ICCs varying between 0.81 and 0.99 [23] [24] [25].

2.6. MRI Radiological Finding for Discopathy

Patients fulfilling the aforementioned inclusion criteria were retrospectively evaluated for discopathy by two expert radiologists. The Inter-observer agreement for radiological finding of discopathy was good (kappa = 0.84 [95% confidence interval (CI) 0.73 - 0.95]). Radiological findings were focused on determining the involvement, types, side, location, and severity/size of the intervertebral discopathy. The location and severity/size of the intervertebral discopathy are based on the reference stander guidelines according to Arrotegui (2019) [26] and Fotinopoulos *et al*. (2018) [27].

2.7. Statistical Analysis

Data were analyzed using the Statistical Package of Social Sciences (SPSS) system (Version 25). Descriptive statistics in the form of frequencies and percentages were employed. Also, means and standard deviations were calculated for each muscle of interest. KAPPA agreement was used to determine the agreement between two radiologists in MRI radiological findings. Spearman correlation analysis and one-way ANOVA tests were applied. The confidence intervals (CI) were reported as 95%, and a P-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Characteristics of Discopathy Participants (Table 1)

The mean age in our study was 45.7 ± (13.6), with 74 patients (37%) in themiddle age group (41 - 55 y), 73 patients (36.5%) in the young age (18 - 40 y), and 53 patients (26.5%) patients in the old age group (56 - 80). Most of the participants were male, [105 (52.5%) vs 95 female (47.5%), and the highest percentage of Body mass index (BMI) categories was in the obese category, 84 (42%). Most

Table 1. Characteristics of discopathy participants.

No. of Patients (n = 200)	Variables
Age	
Mean ± (SD)	45.7 ± (13.6)
Age groups	
Young age (18 - 40 y)	73 (36.5%)
Middle age (41 - 55 y)	74 (37%)
Old age (56 - 80 y)	53(26.5%)
Gender	
Male	105 (52.5%)
Female	95 (47.5%)
Body mass index	
Normal weight	59 (29.5%)
Overweight	57 (28.5%)
Obese	84 (42%)
Discopathy complain	
LBP only	18 (9%)
Radiated pain only	16 (8%)
LBP with radiated pain	166 (83%)
Radiculopathy sides	
No radical pain	18 (9%)
Right side	46 (23%)
Left side	72 (36%)
Both sides	64 (32%)
LBP classification	
Acute LBP (Less than 6 weeks)	26 (13%)
Sub-acute LBP (6 to 12 weeks)	20 (10%)
Chronic LBP (More than 12 weeks)	154 (77%)

participants, 105 (52.5%), were suffering from LBP with radiated pain. The radiated pain was mostly on the left side, 72 patients (36%), whereas 46 patients (23%) had radiated pain to the right side. The majority of patients, 154 (77%), had chronic LBP (more than 12 weeks).

3.2. MRI Radiological Finding and Quantification Yields of Paraspinal Muscles (CSA & FI) for Discopathy Participants (Table 2)

The discopathy involvement was predominant at the lower three levels, with the highest percentage (89.5%) at L4/5, followed by L5/S1, (67%), then L3/4 (40.5%). The highest percentage of disc bulge was at L4/5 (70%), followed by L5/S1 (45%) and L3/4, (31.5%). In contrast, the highest percentage of disc herniation was at L5/S1 (9.5%), followed by L4/5 (8.5%) then L3/4 (20.5%). Regarding the affected

Table 2. Demonstrates of MRI radiological finding and quantification yields of paraspinal muscles (CSA & FI) for discopathypar-ticipants.

MRI radiological finding by disc level for discopathy					
Discopathy status	**L1/2**	**L2/3**	**L3/4**	**L4/5**	**L5/S1**
	(N%)	**(N%)**	**(N%)**	**(N%)**	**(N%)**
Discopathy involvement					
Yes	10 (5%)	27 (13.5%)	81 (40.5%)	179 (89.5%)	134 (67%)
No	190 (95%)	173 (86.5%)	119 (59.5%)	21 (10.5%)	66 (33%)
Discopathy types					
No Discopathy	190 (95%)	173 (86.5%)	119 (59.5%)	21 (10.5%)	66 (33%)
Disc protrusion	1 (0.5%)	2 (1%)	12 (6%)	10 (5%)	19 (9.5%)
Disc herniation	2 (1%)	1 (0.5%)	5 (20.5%)	17 (8.5%)	19 (9.5%)
Disc bulge	4 (2%)	229 (11%)	63 (31.5%)	140 (70%)	90 (45%)
Disc cephalic migration	1 (0.5%)	0 (0%)	1 (0.5%)	3 (1.5%)	2 (1%)
Disc caudal migration	2 (1%)	1 (0.5%)	0 (0%)	9 (4.5%)	3 (1.5%)
Disc sequestration	0 (0%)	1 (0.5%)	0 (0%)	0 (0%)	1 (0.5%)
Discopathy affected side					
No disc	190 (95%)	173 (86.5%)	119 (59.5%)	21 (10.5%)	66 (33%)
Right side/Asymmetric	5 (2.5%)	5 (2.5%)	19 (9.5%)	29 (14.5%)	30 (15%)
Left side/Asymmetric	1 (0.5%)	9 (4.5%)	16 (8%)	58 (29%)	39 (19.5%)
Both side/diffuse	1 (0.5%)	12 (6%)	35 (17.5%)	85 (42%)	39 (19.5%)
Central/Focal	3 (1.5%)	1 (0.5%)	7 (3.5%)	7 (3.5%)	30 (15%)
Discopathy location					
No disc	190 (95%)	173 (86.5%)	119 (59.5%)	21 (10.5%)	66 (33%)
central zone	3 (1.5%)	1 (0.5%)	8 (4%)	10 (9.5%)	29 (14.5%)
Subarticular zone	3 (1.5%)	2 (1%)	5 (2.5%)	16 (8%)	18 (9%)
Foramina	0 (0%)	9 (4.5%)	35 (17.5%)	105 (52.5%)	47 (23.5%)
Extra-foramina	4 (2%)	15 (7.5%)	33 (15.5%)	48 (24%)	40 (20%)
Discopathy size/severity					
Normal	190 (95%)	173 (86.5%)	119 (59.5%)	21 (10.5%)	66 (33%)
Grade 1 (Mild)	4 (2%)	13 (6.5%)	39 (19.5%)	78 (39%)	67 (33.5%)
Grade 2 (Moderate)	2 (1%)	9 (4.5%)	26 (13%)	72 (36%)	46 (23%)
Grade 3 (Sever)	4 (2%)	5 (2.5%)	16 (8%)	29 (14.5%)	21 (10.5%)
Quantification yields of discopathy paraspinal muscles					
Paraspinal muscles	**L1/2**	**L2/3**	**L3/4**	**L4/5**	**L5/S1**
	Mean ± (SD)	**Mean ± (SD)**	**Mean ± (SD)**	**Mean ± (SD)**	**Mean ± (SD)**
Multifidus muscles					
CSA (cm^2)					

Continued

Right Side	5.67 ± (2.3)	6.12 ± (1.7)	8.64 ± (4.13)	9.06 ± (2.2)	9.59 ± (3.02)
Left Side	6.09 ± (5.26)	6.35 ± (1.8)	7.14 ± (2.08)	8.69 ± (2.2)	9.19 ± (2.91)
Fatty infiltration ratio (%)					
Right Side	47.31 ± (18.1)	43.94 ± (17.6)	44.81 ± (16.6)	48.64 ± (16.4)	53.90 ± (17.09)
Left Side	48.61 ± (18.8)	44.79 ± (18.3)	45.06 ± (17.3)	48.84 ± (17.2)	54.48 ± (17.13)
Erector spinae muscles					
CSA (cm^2)					
Right Side	19.53 ± (4.6)	19.57 ± (5.1)	21.14 ± (5.9)	18.5 ± (13.6)	14.3 ± (6.89)
Left Side	19.45 ± (4.5)	19.6 ± (5.3)	19.8 ± (5.09)	17.6 ± (4.13)	13.6 ± (6.69)
Fatty infiltration ratio (%)					
Right Side	37.97 ± (14.4)	43.92 ± (17.5)	44.68 ± (15.9)	52.13 ± (16.24)	58.03 ± (17.6)
Left Side	38.43 ± (15.94)	40.19 ± (16.3)	44.31 ± (16.19)	51.83 ± (17.7)	58.42 ± (19.3)

side of discopathy, the discopathy at level L3/4 is more compressed on the right side (9.5%) than on the left side (8%). In contrast, the discopathy at level L4/5 is more compressed on the left side (29%) than on the right side (14.5%). Similarly, at level L5/S1, the discopathy is more compressed on the left side (19.5%) than on the right side (15%). On the other hand, At level L3/4, L4/5 and L5/S1 the percentage of the discopathy compression on the foramina versus extra-foramina site as follow: {**L3/4**: 17.5% vs 15.5%, **L4/5**: 52.5% vs 24%, **L5/S1**: 23.5% vs 20%}. At levels L3/4, L4/5, and L5/S1, regarding the percentage of disc size and severity, the highest percentage in grade 1 (mild), followed by grade 2 (moderate), then grade 3 (severe) {**L3/4**: 19.5%, 13%, 8%; **L4/5**: 39%, 36%, 14.5%; **L5/S1**: 33.5%, 23%, 10.5%}. Concerning the quantification yields (CSA & FI) in ES & MF muscles for discopathy participants, the CSA of MF muscles were in a direct proportionate trend from L1/2 to L5/S1 [On the right side: from 5.67 ± (2.3) to 9.59 ± (3.02); On the left side: from 6.09 ± (5.26) to 9.19 ± (2.91)]. Likewise, the FI of MF muscles increased from L1/2 to L5/S1 [On the right side: from 47.31% ± (18.1)% to 53.90% ± (17.09)%; On the left side: from 48.61% ± (18.8)% to 54.48% ± (17.13)%]. Regarding CSA of ES muscles, there is an indirect relationship trend from L1/2 to L5/S1 [On the right side: from 19.53 ± (4.6) to 14.3 ± (6.89); On the left side: from 19.45 ± (4.5) to 13.6 ± (6.69)]. In contrast, the FI of ES muscles increased from L1/2 to L5/S1 [On the right side: from 37.97% ± (14.4)% to 58.03% ± (17.6)%; On the left side: from 38.43% ± (15.94)% to 58.42% ± (19.3)%].

3.3. Associations between the MF & ES Muscles Quantification Yields (CSA & FI) and Discopathy Status (Table 3)

1) At level L3/4:

There was no statistical correlation observed between involvement, types, affect side, location, and severity/size of lumbosacral discopathy with both CSA of

Table 3. Displays the correlation of multifidus and erector spinae muscles quantification yields (CSA & fatty infiltration) with discopathy status.

(cm²) Muscles CSA	Discopathy involve		Discopathy types		Discopathy affect side		Discopathy location		Discopathy size/severity	
	R	p-value	R	p-value	R	p-value	R	p-value	R	p-value
L3/4										
Multifidus										
Right side	0.02	0.777	0.027	0.699	0.02	0.774	0.031	0.659	0.049	0.488
Left side	0.055	0.439	0.068	0.336	0.063	0.375	0.043	0.545	0.057	0.42
Erector spinae										
Right side	0.037	0.6	0.003	0.97	0.012	0.868	0.057	0.422	0.01	0.891
Left side	0.091	0.202	0.043	0.546	0.049	0.491	0.11	0.119	0.059	0.403
L4/5										
Multifidus										
Right side	0.068	0.338	0.103	0.147	0.137	0.052	0.174*	0.014*	0.037	0.603
Left side	0.025	0.721	0.023	0.742	0.118	0.096	0.025	0.729	0.027	0.704
Erector spinae										
Right side	0.113	0.11	0.183*	0.011*	0.135	0.056	0.124	0.08	0.04	0.575
Left side	0.095	0.181	0.124	0.081	0.098	0.167	0.077	0.28	0.037	0.604
L5/S1										
Multifidus										
Right side	0.009	0.899	0.043	0.549	0.009	0.905	0.013	0.859	0.036	0.61
Left side	0.058	0.414	0.066	0.355	0.041	0.577	0.053	0.452	0.069	0.333
Erector spinae										
Right side	0.006	0.938	0.022	0.752	0.004	0.955	0.069	0.332	0.039	0.585
Left side	0.014	0.844	0.001	0.996	0.022	0.754	0.094	0.185	0.046	0.521
(%) Fatty infiltration	**Discopathy involve**		**Discopathy types**		**Discopathy affect side**		**Discopathy location**		**Discopathy size/severity**	
	R	**p-value**	**R**	**p-value**	**R**	**p-value**	**R**	**p-value**	**R**	**p-value**
L3/4										
Multifidus										
Right side	0.109	0.124	0.143*	0.044*	0.13	0.067	0.113	0.111	0.147*	0.038*
Left side	0.129	0.068	0.135	0.057	0.158*	0.026*	0.123	0.083	0.173*	0.014*
Erector spinae										
Right side	0.133	0.06	0.166*	0.019*	0.154*	0.029*	0.163*	0.021*	0.163*	0.021*
Left side	0.065	0.359	0.091	0.198	0.089	0.209	0.076	0.287	0.089	0.209
L4/5										
Multifidus										

Continued

Right side	0.035	0.622	0.173*	0.015*	0.059	0.406	0.042	0.551	0.168*	0.018*
Left side	0.059	0.41	0.216*	0.002*	0.011	0.881	0.035	0.627	0.165*	0.019*
Erector spinae										
Right side	0.113	0.11	0.054	0.45	0.264*	0.001*	0.121	0.088	0.152*	0.032*
Left side	0.151*	0.033*	0.065	0.36	0.292*	0.001*	0.141*	0.046*	0.152*	0.032*
L5/S1										
Multifidus muscles										
Right side	0.470*	0.032*	0.198*	0.047*	0.397*	0.017*	0.244*	0.036*	0.271*	0.019*
Left side	0.397*	0.031*	0.113*	0.041*	0.378*	0.027*	0.352*	0.043*	0.391*	0.016*
Erector spinae										
Right side	0.068	0.336	0.007	0.919	0.103*	0.041*	0.004	0.958	0.214*	0.048*
Left side	0.037	0.606	0.016	0.826	0.147*	0.025*	0.002	0.978	0.221*	0.038*

*Statistical significant.

MF & ES muscles. Also, a weak positive correlation was noticed between FI and discopathy size/severity, type, and side. The right side of the ES muscles has shown a weak positive correlation between FI and discopathy size/severity (R = 0.163, P-value = 0.021), discopathy types (R = 0.166, P-value = 0.019), discopathy side (R = 0.154, P-value = 0.029), and with discopathy locations (R = 0.163, P-value = 0.021).

2) At level L4/5:

A weak positive correlation was reported on the right side of the ES muscle with discopathy types (R = 0.183, P-value = 0.010), whereas no correlation was seen on the left side. Furthermore, a weak positive correlation was shown on the right side of the MF with discopathy location (R = 0.174, P-value = 0.014), whereas no correlation was obvious on the left side. On the other hand, a weak positive correlation between FI and discopathy size/severity on the right and the left side of the L4/5 MF muscles (R = 0.168, P-value = 0.018, and R = 0.165, P-value = 0.019, respectively). Similarly, a weak positive correlation between FI and discopathy types on the right and left sides (R = 0.173, P-value = 0.015, and R = 0.216, P-value = 0.002, respectively). Furthermore, the right and left sides of the ES muscles were noted to have a weak positive correlation between FI and discopathy size/severity. However, the right and left sides of the ES muscles had a moderate positive correlation between FI and discopathy side.

3) At level L5/S1:

No statistical correlation was reported between involvement, types, affect side, location, and severity/size of lumbosacral discopathy with CSA of both sides of the MF & ES muscles. However, a moderate positive correlation was observed between the right and left MF sides, and FI with discopathy involvement (R = 0.470, P-value = 0.032, and R = 0.397, P-value = 0.031, respectively). While there was a weak positive correlation between the right and left MF side and FI with

Table 4. Demonstrates the relation of MF & ES muscles quantification yields (CSA & FI) and age group.

(cm^2) Muscles CSA	Young age	Middle age	Old age	F	Overall P-value
L3/4					
Multifidus					
Right side	8.67 ± (2.616)	8.14 ± (2.627)	9.29 ± (6.732)	1.209	0.301
Left side	7.76 ± (2.153)	6.75 ± (1.887)	6.83 ± (2.074)	5.314	Overall P-value = 0.006*
					Young VS Middle age = 0.009*
					Young VS Old age = 0.009*
Erector spinae					
Right side	20.32 ± (5.59)	21.18 ± (6.002)	22.22 ± (6.236)	1.598	0.205
Left side	19.62 ± (4.758)	19.57 ± (5.157)	20.41 ± (5.488)	0.492	0.612
L4/5					
Multifidus					
Right side	9.72 ± (2.183)	8.72 ± (2.103)	8.63 ± (2.343)	5.15	0.007
Left side	9.23 ± (2.191)	8.41 ± (2.065)	8.33 ± (2.326)	3.504	Over all P-value = 0.032*
					Young VS Middle age = 0.020*
					Young VS Old age = 0.020*
Erector spinae					
Right side	17.53 ± (4.024)	19.69 ± (21.67)	18.01 ± (4.978)	0.496	0.609
Left side	17.8 ± (4.284)	17.14 ± (3.637)	17.8 ± (4.605)	0.584	0.558
L5/S1					
Multifidus					
Right side	10.24 ± (2.751)	9.06 ± (3.042)	9.43 ± (3.252)	2.977	0.053
Left side	9.74 ± (2.82)	8.77 ± (2.665)	9.02 ± (3.289)	2.172	0.117
Erector spinae					
Right side	14.21 ± (4.311)	14.5 ± (9.847)	14.22 ± (4.444)	0.039	0.962
Left side	13.63 ± (4.556)	13.67 ± (9.385)	13.36 ± (4.356)	0.037	0.964

discopathy type, a moderate positive correlation was seen between the right and left MF sides and FI with discopathy affected side. A significant association was observed between FI of both sides of the MF muscles with the discopathy severity/size. A weak positive correlation was noticed between FI of the ES on the right and left side and discopathy on the affected side (R = 0.103, P-value = 0.041, and R = 0.147, P-value = 0.025, respectively). Likewise, a weak positive correlation was observed between the right and left side of ES muscles FI with discopathy severity/size. In contrast, no statistical correlation was noticed between FI of ES muscle and involvement, types, and location of lumbosacral discopathy (P-value > 0.05).

Table 5. Demonstrates the relation of MF & ES muscles quantification yields (CSA & FI) and age group.

Fatty infiltration (%)	Young age	Middle age	Old age	F	Overall P-value
L3/4 Multifidus					
Right side	36.98 ± (14.16)	45.11 ± (13.753)	55.16 ± (17.957)	22.226	Over all P-value = 0.001* Young VS Middle age = 0.004* Young VS Old age = 0.001* Middle VS Old age = 0.011*
Left side	36.4 ± (13.482)	46.14 ± (14.265)	55.49 ± (20)	22.885	Over all P-value = 0.001* Young VS Middle age = 0.001* Young VS Old age = 0.000 Middle VS Old age = 0.03
Erector spinae					
Right side	38.23 ± (14.63)	45.43 ± (15.15)	52.5 ± (15.297)	14.044	Over all P-value = 0.001* Young VS Middle age = 0.012* Young VS Old age = 0.001*
Left side	37.42 ± (13.12)	44.71 ± (16.075)	53.25 ± (15.953)	17.061	Over all P-value = 0.001* Young VS Middle age = 0.011* Young VS Old age = 0.001*
L4/5 Multifidus					
Right side	40.88 ± (13.71)	48.57 ± (13.273)	59.4 ± (18.026)	23.958	Over all P-value = 0.001* Young VS Middle age = 0.006* Young VS Old age = 0.001* Middle VS Old age = 0.001*
Left side	39.98 ± (15.11)	47.71 ± (15.085)	58.25 ± (13.613)	23.478	Over all P-value = 0.002* Young VS Middle age = 0.018* Young VS Old age = 0.011* Middle VS Old age = 0.017*
Erector spinae					
Right side	45.33 ± (14.67)	53.8 ± (16.299)	59.16 ± (14.827)	13.18	Over all P-value = 0.001* Young VS Middle age = 0.003* Young VS Old age = 0.001*
Left side	44.16 ± (15.5)	53.29 ± (17.481)	60.37 ± (16.746)	15.123	Over all P-value = 0.001* Young VS Middle age = 0.003* Young VS Old age = 0.001*

*Statistical significant.

Table 6. Demonstrates the relation of MF & ES muscles quantification yields (CSA & FI) and age group.

Fatty infiltration (%)	Young age	Middle age	Old age	F	Overall P-value
L5/S1 Multifidus					
Right side	46.06 ± (15.574)	55.35 ± (14.933)	62.7 ± (17.363)	17.445	Over all P-value = 0.001* Young VS Middle age = 0.001* Young VS Old age = 0.001* Middle VS Old age = 0.032*
Left side	46 ± (14.174)	55.86 ± (13.877)	64.22 ± (19.373)	21.366	Over all P-value = 0.001* Young VS Middle age = 0.001* Young VS Old age = 0.001* Middle VS Old age = 0.010*
Erector spinae					
Right side	52.13 ± (16.048)	59.83 ± (17.957)	63.66 ± (17.086)	7.665	Over all P-value = 0.001* Young VS Middle age = 0.020* Young VS Old age = 0.001*
Left side	51.28 ± (17.975)	59.69 ± (18.483)	66.46 ± (19.164)	10.627	Over all P-value = 0.001* Young VS Middle age = 0.019* Young VS Old age = 0.001*

*Statistical significant.

3.4. The Relation between Age Groups, and MF & ES Muscles Quantification Yields (CSA & FI)—(Tables 4-6)

1) At level L3/4:

There was a significant relationship between the age groups and CSA of the left MF side (P-value = 0.006). FI was noted to be significantly higher in old age in both sides of the MF and ES muscles (P-value < 0.05).

2) At level L4/5:

The CSA was significantly higher on both sides of MF muscle among young age (Right side P-value = 0.007, Left side P-value = 0.032). Regarding FI of MF and ES muscles, the results were higher on both muscles sides in old age (P-value < 0.05).

3) At level L5/S1:

There was no significant relationship between CSA on both sides of the MF & ES muscle and age groups. In contrast, there was a statistically significant relationship between FI on both sides of the MF & ES muscle and age groups (P-value = 0.001 at both sides), with a FI higher in old age.

4. Discussion

Weakness in the paravertebral muscles is accepted as one of the reasons for disc herniation [28]. This study used MRI and ImageJ software at the lumbosacral spine to extract and quantify the paraspinal muscles as anindicator of discopathy, and to assess the discopathy status at L1/2-L5/S1. The quantification yields, a useful key indicator of disease progression, depending on the pixel threshold filter, and it facilitates finding the defects [29]. The invisible or early atrophic changes cannot be distinguished by the naked eyes [30]. Hence, it is essential to utilize a precise quantification technique to get an accurate detection of paraspinal muscles' bulk size and FI ratio. In addition, the CSA & FI ratio are two markers of muscle atrophy that have been demonstrated to play a role in the development of LBP related to discopathy [31] [32] [33] [34].

In our study, the results show that the predominance of discopathy involvement is at L4/5, which is consistent with the results of Suthar *et al.* [35]. Our study also confirms that the CSA &FI ratios of MF muscles are directly proportionate to craniocaudally lengths of the intervertebral discs (L1/2 to L5/S1). This result agrees with Urrutia *et al.* study (2018) [36], which revealed that the fatty signal fraction of MS is increased in the lower lumbar levels.

On the other hand, our findings reveal the CSA of ES muscles is inversely proportionate to the craniocaudally lengths of the intervertebral discs (L1/2 to L5/S1). This is inconsistent with Urrutia *et al.*, (2018) [36], which showed a directly proportionate relationship between CSA of ES muscles and craniocaudal lengths. In contrast, the FI ratio of ES muscleincreases with craniocaudally lengths of the intervertebral discs (L1/2 to L5/S1). This result is emphasized by several publications that showed a progressive craniocaudally increase in FI from L1 to L5 [37] [38].

There was no statistically significant difference in our study between ES muscles, and discopathy status among above, below, and at predominant discopathy level. This result is inconsistent with [39] that reported disc degeneration, and the CSA of the MF muscle and the ES muscle were significantly associated at level L4/5. However, at the above and predominant level, there was a mild association between discopathy status and FI of MF and ES muscles. Nonetheless, at level L5/S1 (below predominant), there is a moderate association between discopathy status and FI of MF and ES muscles.

These results give guidance to the correlation between increasing FI ratio and discopathy level. A higher fat ratio in paraspinal muscles composition was observed below the discopathy involvement level, especially in MF muscles. The current results are very close to another study which showed that severe disc degeneration at all intervertebral levels was associated with a high-fat content of the paraspinal muscles [40].

In the same context, variations in muscle composition were observed, with greater FI on the side and at spinal levels adjacent to the disc herniation [22]. Theoretically, lumbar nerve root compression can lead to denervated atrophy of paraspinal muscles. The major cause of nerve root compression is lumber discopathy, especially disc herniation leading to multifidus atrophy, fibrosis, and increased TGF-β1 expression [41]. Also, neural denervation leading to paraspinal muscle atrophic changes is linked with chronic LBP. Atrophic changes in muscle fibers when reduced type I and II muscle fiber size and fat deposit [42].

In the current study, the results show that at the lower three vertebral levels L3/4, L4/5, and L5/S1, there is an association between the age groups and both sides of the paraspinal muscles FI ratio. However, there is no association between the age groups and CSA, except only on the left side of the MF muscle at L3/4 & L4/5. While several studies showed no association between CSA and age [2] [40] [43] others studies reported that CSA of the paraspinal muscles tended to decrease with age [44]. Our results demonstrate that the percentage of fat content in the paraspinal muscles tends to increase with age (See **Figure 2** and **Figure 3**), and this was noticed in other studies as well [38] [44].

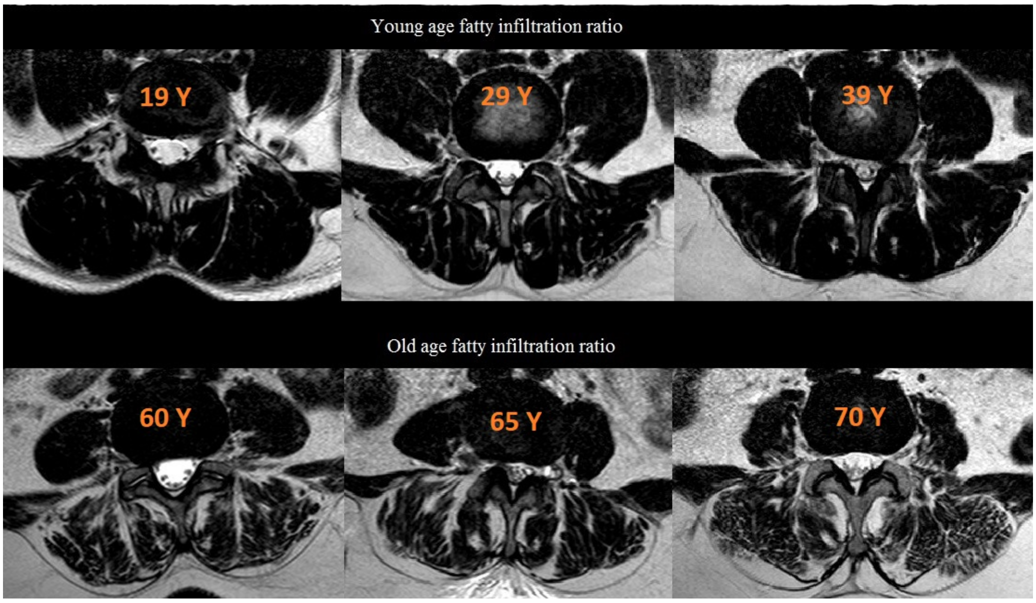

Figure 2. Illustrates the percentage of fat content in the paraspinal muscles with increasing age.

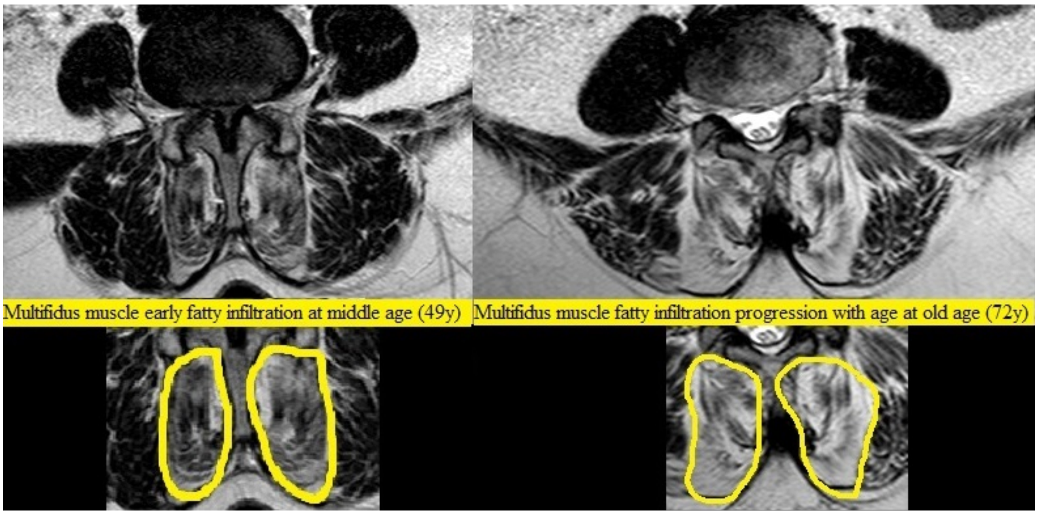

Figure 3. Illustrates the severefatty infiltration in the multifidus muscle among severe discopathy in two patients (middle vs old age).

A limitation of this study is obtaining the data by one expert investigator manually drawing the border of the MF & ES muscles at the L3/4, L4/5L, L5/S1 levels. Automated techniques, if used, could result in less rate-dependent results. Also, the CSA and FI % of MF & ES were measured using ImageJ software, which has been utilized by previous studies but is not FDA approved.

5. Conclusion

The quantification threshold pixel technique for the paraspinal muscles of lumbosacral MRI is a useful, simple, non-invasive technique to distinguish between the atrophic changes like CSA size and change of FI ratio. It does also provide more clinical data related to the diagnosis of discopathy patients. Increasing FI ratio seems to correlate with discopathy level and severity, with the higher fat ratio in paraspinal muscles composition below the discopathy involvement level.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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