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Research Article

Association of the Cross-Sectional Area, Muscularity, and Muscle-Fat Ratio of the Paraspinal Muscles with Chronic Low Back Pain

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Abstract

Background: It is now a well-established fact that paraspinal muscle integrity plays a critical role in low back pain. We aimed to determine the association of the cross-sectional area (CSA), muscle disc ratio (muscularity), and muscle-fat ratio of the paraspinal muscles with chronic low back pain (CLBP) of varied pathologies and the effect of ageing and body mass index (BMI).
Methods: Fifty patients with CLBP (Group A) and 25 healthy controls (Group B) were enrolled. The Group A was further subgrouped into lumbar spondylosis, mechanical back pain, and lumbar disc herniation. All participants were subjected to magnetic resonance imaging of lumbar spine.
Results: The CSAs of the muscles did not differ significantly between the two groups except for multifidus ($P < 0.05$) and psoas ($P < 0.001$) at L1-L2 and psoas ($P < 0.001$) at L2-L3. There was a significant difference in CSA of the disc at L3-L4, L4-L5, and L5-S1 ($P < 0.05$), muscle-fat ratio ($P < 0.01$), and muscularity of multifidus and psoas ($P < 0.05$) from L1 to L5 levels. There was no correlation between age and BMI and the CSA. Ageing led to fatty infiltration in both groups. The CSAs of muscles and discs were comparable ($P > 0.05$) among subgroups except at a few spinal levels. Muscularity among the subgroups varied at different levels. The muscle-fat ratio was comparable ($P > 0.05$).
Conclusion: Muscularity and composition, rather than overall CSA of important spinal stabilizers, were found to be associated with CLBP. Age and BMI had no correlation with the CSA of paraspinal muscles. Various disc and muscle parameters did not differ much among common lumbar pathologies.

Keywords: Low Back Pain; Paraspinal Muscles; Magnetic Resonance Imaging; Intervertebral Disc

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Background

Low back pain (LBP) is recognized as a multifactorial symptom and is a common cause of morbidity and disability in society (1). The pathophysiology of LBP is poorly understood, and the majority of the time, there is a lack of an association between investigative findings and clinical symptoms (2). Recent studies have attempted to find the relationships between morphological changes in the lumbar paraspinal musculature (e.g., atrophy, fat replacement) and LBP, and have tried to identify discrete pain-generating tissues or clinically relevant structural changes related to pain in various lumbar pathologies (3-8).

Various muscle parameters and their correlation with LBP have been evaluated in the past (5, 9-16). Patients with chronic LBP have been reported to have smaller paraspinal muscles and more fatty infiltration than healthy asymptomatic subjects (13-15). However, findings reported in the scientific literature remain inconsistent, and one needs to be aware of other potential factors that may influence or lead to such paraspinal muscle variations before judging the mass signifying risk or presence of pathology (2, 4, 6, 12, 13). Further research is needed to clarify determinants of paraspinal muscle variations and their relation with the onset and progression of back pain problems and lumbar pathology.

The aim of the present study was to determine the association of the cross-sectional area, muscularity, and muscle-fat ratio of the paraspinal muscles with LBP, the effect of ageing and BMI on these parameters, and whether various spinal pathologies affect paraspinal muscle differently.

Methods

Ethical Statement: The study was approved by the Institutional Review Board of the hospital. Informed consent was obtained from the participants (IRB approval No.: Endst.No. Surg/Dean/17.2369-77).

Study Design: This prospective study was conducted at a tertiary care center in the Department of Orthopedics in collaboration with the Department of Radiodiagnosis from March 2017 to March 2018. Fifty patients of either sex aged between 18 and 50 years, with LBP for a minimum of 3 consecutive months, and who gave consent to participate in the study were enrolled as the study group (Group A). Patients included in this study were cases of lumbar spondylosis (lumbar canal stenosis, degenerative disc disease), mechanical back pain, and lumbar disc herniation. The study group (Group A) was further sub-grouped into A_1 [lumbar spondylosis (LS); n = 11], A_2 [mechanical back pain (MBP); n = 13], and A_3 [lumbar disc herniation (LDH); n = 26]. Patients with gross deformity of the spine, such as scoliosis or spondylolisthesis, fracture of the spine, tumors, and infections of the spine, and a history of hip or pelvic disorder were excluded from the study. Twenty-five healthy volunteers with no history of back pain were also enrolled as the control group (Group B).

Each participating patient and control was thoroughly examined clinically and was subjected to MRI. The technique of MRI sequences and imaging used in this research was as per the institutional protocol published previously (8). Measurement was done using on-screen calipers using the free open-source measurement software OsiriX (version 5.1.2) (17). The following parameters were measured on axial T2-weighted MR images at L1-2, L2-3, L3-L4, L4-L5, and L5-S1 intervertebral disc levels: (i) Width (maximum width was taken) and depth (anteroposterior diameter of the trunk at mid-sagittal section) of trunk dimensions, (ii) The cross-sectional area of the lumbar muscles [Erector Spinae (ES), Multifidus (MM), Psoas major (PS), Quadratus Lumborum (QL), Rectus Abdominis (RA), and Obliques (OBL)], (iii) Cross-sectional area of the disc, (iv) Muscle disc ratio (muscularity), (v) Muscle-fat ratio (MM + ES combined).

Definitions of Measurement Parameters: The definitions and methods of measurement of the trunk (width and depth), cross-sectional areas (CSAs) of muscles, and disc have been previously published (8). The muscle-disc ratio is the ratio of the CSA of muscle at a particular disc level in relation to the CSA of the disc at the same level. It is used to determine muscularity. Muscle-fat ratio is the ratio of muscle mean hyperintensity in relation to the subcutaneous fat mean hyperintensity at a particular disc level. We used the method of analysis as described by Bostrom et al. (18).

Statistical Analysis: The measurements were entered in a Microsoft Excel spreadsheet. Statistical analysis was performed using the SPSS software (version 20.0; IBM Corp., Armonk, NY, USA). Normally distributed variables are presented as means and standard deviations. Kolmogorov-Smirnov test was used in SPSS for assessment of normality of data. For normally distributed data, a t-test was employed for analysis. Mann-Whitney and chi-square tests were employed for categorical and ordinal data, respectively. Correlation between variables was assessed using Pearson's coefficient of correlation.

Results

Comparison between Chronic Low Back Pain (CLBP) Patients (Group A) and Asymptomatic Volunteers (Group B)

Table 1 shows the demographic profile of the cohort. Demographic parameters of both groups were comparable, and there was no significant difference.

The patients with LBP (Group A) presented with a mean duration of symptoms of 11.93 ± 12.62 months. Paraspinal tenderness was present in 23 patients (46%), but paraspinal muscle spasm was present in 94% of the patients. Sensory deficit was present in 9 (18%) patients, and only 4 (4%) had a motor deficit.

Table 1. Demographic profile of the study population

Parameter	Frequency (percent)		P-value[#]
	Group A (n = 50)	Group B (n = 25)	
Age (years)			0.578
18-30	17 (34)	9 (36)	
31-40	17 (34)	8 (32)	
41-50	16 (32)	8 (32)	
Mean age	36.24 ± 9.07	35.57 ± 8.87	
Range	(18-50)	(18-50)	
Male	25 (50)	10 (40)	0.413[*]
Female	25 (50)	15 (60)	
Height (m)	1.65 ± 0.060 (1.52-1.75)	1.66 ± 0.069 (1.51-1.77)	0.491
Weight (kg)	68.04 ± 10.93 (46-94)	70.48 ± 9.39 (52-84)	0.344
BMI (kg/m^2)	24.94 ± 3.27 (19.1-32.6)	24.60 ± 2.26 (20.57-30.427)	0.644
Occupation			-
Farmer	7 (14)	2 (8)	
Laborer	4 (8)	2 (8)	
Businessman	5 (10)	3 (12)	
Housewife	16 (32)	4 (16)	
Nurse	3 (6)	2 (8)	
Doctors	4 (8)	5 (20)	
Student	4 (8)	6 (24)	
Police	3 (6)	0 (0)	
Teacher	4 (8)	1 (4)	

BMI: Body mass index
[*]Calculated with chi-square test, [#]Calculated with independent t-test

Table 2 shows the comparison of trunk width and depth, cross-sectional area of discs, and muscle-fat ratio between patients and the control population. Trunk width and trunk depth were comparable. There was a statistically significant difference in CSA of lumbar disc at L3-L4 (P = 0.020), L4-L5 (P = 0.010), and L5-S1 (P = 0.020), and the CSA of discs in controls was smaller at these levels. There was a statistically significant difference (P < 0.010) at all lumbar disc levels in the muscle-fat ratio.

Comparison of the mean cross-sectional area of lumbar muscles between group A and group B showed no statistically significant differences in the CSA of the majority of paraspinal muscles and all the levels except for the CSA of MM (P = 0.004 and P = 0.002 for the right and left sides, respectively) and PS (P = 0.001) at L1-L2, the CSA of bilateral PS (P = 0.001) and QL of the right side (P = 0.003) at L2-L3, and the CSA of PS of the right side (P = 0.034) at the L3-L4 disc levels.

MRI measurements of muscle disc ratio (muscle area: disc area) between the two groups showed a statistically significant difference in the ratio of CSA of multifidus muscle with disc at all levels (P < 0.050) except at L5-S1.

The ratio of CSA of ES muscle with the disc was comparable at almost all levels except the left side at the L3-L4 level (P = 0.040) and the right side at the L4-L5 level (P = 0.030).

Table 2. Magnetic resonance imaging measurements of trunk width and depth, cross-sectional area, and muscle-fat ratio at L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 disc levels between Group A and Group B

Measurement		Mean ± SD (Range)			95% CI	
		Group A (n = 50)	Group B (n = 25)	P-value[*]	LOWER	UPPER
Trunk width	L1-L2	307.27 ± 38.98 (232.90-414.00)	295.31 ± 32.43 (192.6-344.50)	0.190	-6.077	30.003
	L2-L3	313.75 ± 40.01 (230.10-417.50)	302.19 ± 33.37 (188.0-347.20)	0.218	-6.969	30.091
	L3-L4	318.82 ± 36.75 (227.60-414.50)	315.81 ± 39.11 (171.0-366.10)	0.745	-15.320	21.335
	L4-L5	317.89 ± 36.40 (214.80-403.00)	317.55 ± 35.86 (190.9-366.30)	0.970	-17.346	18.018
	L5-S1	321.12 ± 33.15 (246.30-400.50)	323.87 ± 38.17 (179.0-371.02)	0.749	-19.778	14.279
Trunk depth	L1-L2	202.54 ± 40.20 (138.10-368.40)	199.07 ± 29.48 (129.8-281.80)	0.703	-14.597	21.545
	L2-L3	195.89 ± 31.22 (127.50-281.20)	201.15 ± 30.85 (131.6-287.30)	0.492	-20.441	9.924
	L3-L4	190.99 ± 33.17 (122.10-284.50)	197.12 ± 38.44 (102.3-301.80)	0.477	-23.207	10.955
	L4-L5	195.19 ± 33.29 (122.40-286.40)	197.08 ± 38.51 (117.2-311.40)	0.826	-19.030	15.233
	L5-S1	199.46 ± 35.19 (133.40-287.70)	193.70 ± 36.50 (108.6-301.90)	0.511	-11.632	23.151
CSA OF DISC (cm^2)	L1-L2	13.69 ± 2.58 (9.47-20.44)	13.06 ± 2.15 (10.28-17.66)	0.295	-0.562	1.826
	L2-L3	15.25 ± 2.77 (10.86-23.31)	14.33 ± 3.00 (10.97-22.78)	0.192	-0.472	2.310
	L3-L4	16.25 ± 2.61 (12.06-23.01)	14.68 ± 2.97 (11.13-22.18)	0.022	0.231	2.903
	L4-L5	16.89 ± 2.70 (12.14-23.22)	15.13 ± 3.19 (11.10-22.87)	0.015	0.352	3.155
	L5-S1	15.86 ± 2.89 (11.39-26.18)	14.28 ± 2.91 (11.59-21.59)	0.029	0.165	2.989
Muscle: Fat Ratio	L1-L2	0.21 ± 0.07 (0.10-0.42)	0.12 ± 0.05 (0.08-0.27)	0.001	0.064	0.129
	L2-L3	0.19 ± 0.07 (0.09-0.36)	0.13 ± 0.06 (0.09-0.30)	0.001	0.027	0.089
	L3-L4	0.19 ± 0.08 (0.09-0.52)	0.14 ± 0.05 (0.09-0.36)	0.004	0.018	0.087
	L4-L5	0.21 ± 0.09 (0.10-0.54)	0.16 ± 0.06 (0.10-0.37)	0.016	0.009	0.087
	L5-S1	0.22 ± 0.07 (0.12-0.40)	0.17 ± 0.05 (0.09-0.29)	0.001	0.024	0.085

P-value calculated with independent t-test

There was a statistically significant difference in the ratio of CSA of PS and disc at the L1-L2 (P = 0.001 for both sides), L2-L3 (P = 0.005 for the right side; P = 0.001 for the left side), L3-L4 (P = 0.001 for the right side; P = 0.008 for the left side), and L4-L5 (P = 0.004 for the right side; P = 0.014 for the left side) level. The ratio of CSA of QL with the disc was found to be statistically significant at the L3-L4 (P = 0.003 for the right side; P = 0.006 for the left side), L4-L5 (P = 0.018 for the right side; P = 0.024 for the left side), and the right side of the L1-L2 (P = 0.030) and L2-L3 (P = 0.002) levels.

The ratio of CSA of OBL with disc was found to be statistically non-significant (P > 0.050) at all levels. Obliques were not measurable at the L5-S1 level. The ratio of the sum of all the muscle's CSAs with the CSAs of the disc was statistically significant at the L2-L3 (P = 0.040 for both sides), L3-L4 (P = 0.009 for the right side; P = 0.020 for the left side), and L4-L5 (P = 0.005 for the right side; P = 0.010 for the left side) level.

Table 3 shows the correlation between age and cross-sectional area of muscles in both the study and control populations. There was no correlation between age and cross-sectional area of muscles in either group except a moderate negative correlation (r = -0.426) with ES of the left side at the L2-L3 level (P = 0.034) in the control (group B) population and a weakly positive correlation (r = 0.318) with RA muscle of the left side at the L3-L4 level (P = 0.024) in the study group (group A).

Table 4 shows the correlation between age and muscle-fat ratio in both the study and control populations. There was a weak positive correlation between age and muscle-fat ratio in group A at L2-L3 (r = 0.358; P = 0.010) and L3-L4 (r = 0.436; P = 0.002). There was also a weak positive correlation at L2-L3 (r = 0.457; P = 0.021), a strong positive correlation at L4-L5 (r = 0.510; P = 0.009), and a weak positive correlation (r = 0.435) at L3-L4 (P = 0.029) in group B.

Table 5 shows the correlation between BMI and muscle area in both the study and control populations. There was no significant correlation between BMI and muscle cross-sectional area except for a weak positive correlation (r = 0.332) with QL muscle of the left side (P = 0.019), a weak positive correlation with bilateral OBL (r = 0.303, P = 0.032 for the right side; r = 0.279, P = 0.050 for the left side) at the L1-L2 level, and a weak positive correlation with bilateral RA at L2-L3 (r = 0.300, P = 0.036 for the right side; r = 0.434, P = 0.002 for the left side), a weak positive correlation with bilateral RA at L3-L4 (r = 0.323, P = 0.022 for the right side; r = 0.308, P = 0.030 for the left side), and with bilateral QL at L4-L5 (r = 0.393, P = 0.005 for the right side; r = 0.369, P = 0.008 for the left side) in Group A.

Table 3. Correlation between age and cross-sectional area of muscles in study and control populations

Level	Correlation between age and CSAs of muscle area					
			Group A (n = 50)		Group B (n = 25)	
			r value*	P-value*	r value*	P-value*
L1-L2	Multifidus	Right	0.031	0.833	-0.167	0.426
		Left	0.003	0.983	-0.343	0.093
	Erector Spinae	Right	0.097	0.504	-0.387	0.056
		Left	0.033	0.821	-0.351	0.085
	Psoas	Right	0.006	0.968	-0.228	0.274
		Left	-0.099	0.494	-0.278	0.178
	Quadratus Lumborum	Right	0.138	0.340	0.065	0.756
		Left	0.141	0.327	0.129	0.537
	Rectus Abdominis	Right	0.118	0.414	-0.281	0.195
		Left	-0.008	0.957	-0.248	0.254
	Obliques	Right	0.246	0.086	-0.380	0.061
		Left	0.122	0.400	-0.212	0.310
L2-L3	Multifidus	Right	0.018	0.903	-0.301	0.144
		Left	-0.023	0.874	-0.013	0.950
	Erector Spinae	Right	0.116	0.421	-0.324	0.114
		Left	0.068	0.638	-0.426*	0.034
	Psoas	Right	-0.117	0.420	-0.072	0.732
		Left	-0.167	0.246	-0.043	0.839
	Quadratus Lumborum	Right	0.006	0.965	0.108	0.608
		Left	0.006	0.965	0.170	0.417
	Rectus Abdominis	Right	0.018	0.905	0.104	0.635
		Left	0.019	0.898	-0.016	0.941
	Obliques	Right	0.146	0.311	-0.361	0.076
		Left	0.124	0.393	-0.267	0.197
L3-L4	Multifidus	Right	-0.046	0.753	-0.015	0.945
		Left	0.064	0.660	-0.014	0.947
	Erector Spinae	Right	0.004	0.980	-0.251	0.227
		Left	0	0.999	-0.321	0.118
	Psoas	Right	-0.148	0.306	-0.353	0.083
		Left	-0.174	0.227	-0.315	0.126
	Quadratus Lumborum	Right	0.048	0.744	-0.064	0.760
		Left	-0.032	0.828	-0.054	0.798
	Rectus Abdominis	Right	0.254	0.076	-0.010	0.964
		Left	0.318	0.024	-0.026	0.913
	Obliques	Right	0.116	0.424	-0.202	0.333
		Left	-0.099	0.494	-0.172	0.411
L4-L5	Multifidus	Right	-0.090	0.535	-0.201	0.335
		Left	-0.101	0.487	-0.161	0.442
	Erector Spinae	Right	-0.010	0.943	-0.238	0.251
		Left	-0.040	0.780	-0.380	0.061
	Psoas	Right	-0.112	0.440	-0.222	0.285
		Left	-0.193	0.180	-0.165	0.430
	Quadratus Lumborum	Right	0.181	0.209	0.100	0.666
		Left	0.260	0.069	0.034	0.884
	Rectus Abdominis	Right	0.165	0.272	0.221	0.311
		Left	0.143	0.345	0.226	0.301
L5-S1	Multifidus	Right	0.124	0.392	-0.352	0.084
		Left	0.141	0.328	-0.255	0.219
	Erector Spinae	Right	-0.074	0.610	0.061	0.773
		Left	-0.079	0.583	0.016	0.941
	Psoas	Right	-0.138	0.339	-0.163	0.437
		Left	-0.227	0.113	-0.209	0.316
	Quadratus Lumborum	Right	0.003	0.983	-0.094	0.661
		Left	-0.002	0.988	0.072	0.738

*r value (correlation) and P-value calculated with bivariate (Pearson's) analysis

Table 4. Correlation between age and muscle-fat ratio in study and control populations at each lumbar disc level

Level	Correlation between age and Muscle-fat ratio			
	Group A (n = 50)		Group B (n = 25)	
	r value#	P-value#	r value#	P-value#
L1-L2	0.219*	0.127	0.364*	0.073
L2-L3	0.358*	0.011	0.457*	0.021
L3-L4	0.436**	0.002	0.510**	0.009
L4-L5	0.062	0.671	0.435*	0.029
L5-S1	0.134	0.352	0.215	0.302

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).
#r value (correlation) and p-value calculated from bivariate (Pearson's) analysis

There was a weak positive correlation (r = 0.451) with QL of the right side at the L4-L5 level (P = 0.040) and a moderately positive correlation (r = 0.415) with QL of the left side at L5-S1 (P = 0.044) in controls (Group B).

Comparison among Subgroups of the Study Group

There was no significant difference in the demographic parameters among the subgroups of group A. These subgroups were also comparable to the controls (Group B). Trunk width and trunk depth, cross-sectional area of the discs, and muscle-fat ratio at all lumbar discs were comparable (P > 0.050).

MRI measurements of the cross-sectional area of muscle among the subgroups were analyzed. The CSAs of muscles were comparable and found to be statistically non-significant (P > 0.050) except a significant difference in regard to quadratus lumborum of the right side between lumbar spondylosis and LDH (P_3 = 0.040); bilateral oblique muscle between lumbar spondylosis and LDH (P_3 = 0.024 for right side, P_3 = 0.006 for left side) at L1-L2; multifidus of the left side between lumbar spondylosis and MBP (P_1 = 0.005) at L2-L3; multifidus of the right side between lumbar spondylosis and MBP (P_1 = 0.013) between MBP and LDH (P_2 = 0.049) and rectus abdominis of the right side between lumbar spondylosis and MBP (P_1 = 0.029) L3-L4; erector spinae of the left side between lumbar spondylosis and MBP (P_1 = 0.009), and between lumbar spondylosis and LDH (P_3 = 0.035) at L4-L5; and the left side of the multifidus between MBP and LDH (P_2 = 0.023) and with regard to erector spinae of the left side between lumbar spondylosis and MBP (P_3 = 0.018) at L5-S1.

MRI measurements of muscle disc ratio (muscle area: disc area) among the subgroups were analyzed. The ratio of MM with the disc was statistically significantly different at the L2-L3 level on the left side between lumbar spondylosis and MBP (P_1 = 0.002) and between MBP and LDH (P_2 = 0.053); at the L3-L4 level on the right side between lumbar spondylosis and MBP (P_1 = 0.005) and between MBP and LDH (P_2 = 0.012); on the left side between MBP and LDH (P_2 = 0.014); at the L4-L5 level on the left side between MBP and LDH (P_2 = 0.059); and at the L5-S1 level on the right side between MBP and LDH (P_2 < 0.005).

Table 5. Correlation between age and cross-sectional area of muscles in study and control populations

Level	Correlation between BMI and muscle area					
			Group A (n = 50)		Group B (n = 25)	
			r value#	P-value#	r value#	P-value#
L1-L2	Multifidus	Right	0.121	0.403	-0.022	0.916
		Left	0.220	0.125	-0.289	0.161
	Erector Spinae	Right	0.172	0.232	-0.150	0.474
		Left	0.196	0.173	-0.126	0.548
	Psoas	Right	-0.024	0.871	-0.094	0.653
		Left	-0.028	0.847	-0.163	0.437
	Quadratus Lumborum	Right	-0.095	0.512	0.283	0.170
		Left	0.332*	0.019	0.364	0.073
	Rectus Abdominis	Right	0.256	0.072	-0.193	0.378
		Left	0.013	0.931	-0.063	0.774
	Obliques	Right	0.303*	0.032	-0.134	0.522
		Left	0.279*	0.050	0.100	0.635
L2-L3	Multifidus	Right	0.043	0.769	-0.270	0.192
		Left	0.091	0.530	0.049	0.814
	Erector Spinae	Right	0.152	0.291	-0.124	0.554
		Left	0.137	0.342	-0.212	0.308
	Psoas	Right	-0.046	0.752	0.084	0.691
		Left	-0.041	0.776	0.088	0.677
	Quadratus Lumborum	Right	-0.164	0.254	0.335	0.102
		Left	0.080	0.582	0.315	0.125
	Rectus Abdominis	Right	0.300*	0.036	0.351	0.100
		Left	0.434**	0.002	0.229	0.293
	Obliques	Right	0.228	0.112	-0.118	0.574
		Left	0.255	0.074	0.038	0.859
L3-L4	Multifidus	Right	-0.116	0.422	-0.078	0.710
		Left	0.146	0.313	-0.070	0.740
	Erector Spinae	Right	0.083	0.565	-0.021	0.922
		Left	0.042	0.774	0	0.999
	Psoas	Right	0.015	0.916	0.089	0.673
		Left	0.013	0.929	0.132	0.530
	Quadratus Lumborum	Right	-0.123	0.405	0.383	0.059
		Left	-0.119	0.415	0.278	0.179
	Rectus Abdominis	Right	0.323*	0.022	0.209	0.363
		Left	0.308*	0.030	0.205	0.372
	Obliques	Right	0.261	0.067	0.019	0.926
		Left	0.266	0.062	0.086	0.684
L4-L5	Multifidus	Right	0.234	0.102	-0.062	0.768
		Left	0.042	0.774	-0.132	0.529
	Erector Spinae	Right	0.126	0.384	-0.016	0.939
		Left	0.130	0.369	-0.191	0.360
	Psoas	Right	0.035	0.809	0.114	0.587
		Left	-0.081	0.575	0.176	0.399
	Quadratus Lumborum	Right	0.393**	0.005	0.451*	0.040
		Left	0.369**	0.008	0.345	0.126
	Rectus Abdominis	Right	0.262	0.078	0.335	0.118
		Left	0.202	0.178	0.348	0.104
L5-S1	Multifidus	Right	0.135	0.349	-0.223	0.285
		Left	0.188	0.190	-0.183	0.382
	Erector Spinae	Right	-0.078	0.590	-0.125	0.552
		Left	-0.185	0.199	-0.219	0.294
	Psoas	Right	-0.022	0.881	-0.004	0.986
		Left	-0.147	0.307	-0.019	0.928
	Quadratus Lumborum	Right	0.195	0.176	0.394*	0.057
		Left	0.263	0.065	0.415*	0.044

#r value (correlation) and P-value calculated from bivariate (Pearson) analysis

The muscle disc ratio of ES at all lumbar discs was comparable and found to be statistically non-significant ($P > 0.050$) except for a statistically significant difference at L4-L5 on the right side between MBP and LDH ($P_2 = 0.030$).

The muscle disc ratio of PS at all lumbar discs was comparable and found to be statistically non-significant ($P > 0.050$) except for a statistically significant difference at L1-L2 on the left side between lumbar spondylosis and LDH ($P_3 = 0.050$), at L2-L3 on the right side between MBP and LDH ($P_2 = 0.060$), and at L3-L4 on the left side between MBP and LDH ($P_2 = 0.050$).

The muscle disc ratio of QL at all lumbar discs was comparable and found to be statistically non-significant ($P > 0.050$) except for a statistically significant difference at L1-L2 on the right side between lumbar spondylosis and LDH ($P_3 = 0.013$) and at L3-L4 on the left side between MBP and LDH ($P_2 = 0.020$).

The muscle disc ratio of OBL in all lumbar discs was comparable and found to be statistically non-significant ($P > 0.050$) except for a statistically significant difference at L1-L2 on the left side between lumbar spondylosis and LDH ($P_3 = 0.035$). The muscle disc ratio of all the muscles combined at all lumbar discs was comparable and found to be statistically non-significant ($P > 0.050$) except for a statistically significant difference at L3-L4 on the left side between MBP and LDH ($P_2 = 0.040$) and L4-L5 between MBP and LDH ($P_2 = 0.017$ for the right side; $P_2 = 0.030$ for the left side).

Comparison between Subgroups of Group A and Group B

Trunk width and trunk depth were comparable. There was a statistically significant ($P < 0.050$) difference between LDH and group B at lower lumbar levels (L3-L4, L4-L5, and L5-S1). There was a statistically significant difference ($P < 0.050$) between all the subgroups of group A and group B in terms of the muscle-fat ratio.

There was no statistically significant ($P > 0.050$) difference between the CSA of muscles between subgroups and asymptomatic individuals except for MM and PS at the L1-L2 level ($P < 0.050$) between all subgroups and group B; for MM between group A1 (LS) and Group B and for PS between all subgroups and group B at L2-L3.

The ratio of MM with disc was significantly different from L1-S1 between LDH and group B ($P < 0.050$) and between LS and group B ($P < 0.050$) from L1-L4. The ratio of ES with disc was statistically significant different from L1 to S1 between LDH (A3) and Group B ($P < 0.050$). The ratio of PS with disc was significantly different from L1-S1 between LDH and group B ($P < 0.050$) and between LS and group B at the L2-L3 and L3-L4 levels. The QL disc ratio was significantly different from L2-L5 ($P < 0.050$), the OBL disc ratio from L3-L5 ($P < 0.050$), and the combined all muscles disc ratio ($P < 0.010$) between LDH and group B.

Figure 1 shows measurements of the cross-sectional area of trunk muscles and disc on axial T2-weighted images in a 40-year-old male patient with right-side disc prolapse at L5-S1. The patient had had symptoms of LBP with radiation to the lateral aspect of the leg and foot for the last 4 months and a half. Figure 2 shows measurements of muscle disc ratio (MM+ES) on axial T2-weighted images in the same patient.

Discussion

Many studies conducted in the past have focused on the comparison of the CSA of the lumbar muscles between patients with CLBP and healthy asymptomatic subjects (5, 6, 8, 15, 19, 20). The majority of these studies focused only on parameters like CSA, fatty infiltration, alignment, or a combination of these, and the findings reported in these studies were inconsistent. A study was required to analyze the effect and interplay of various factors associated with LBP, and the present study is an attempt in this direction.

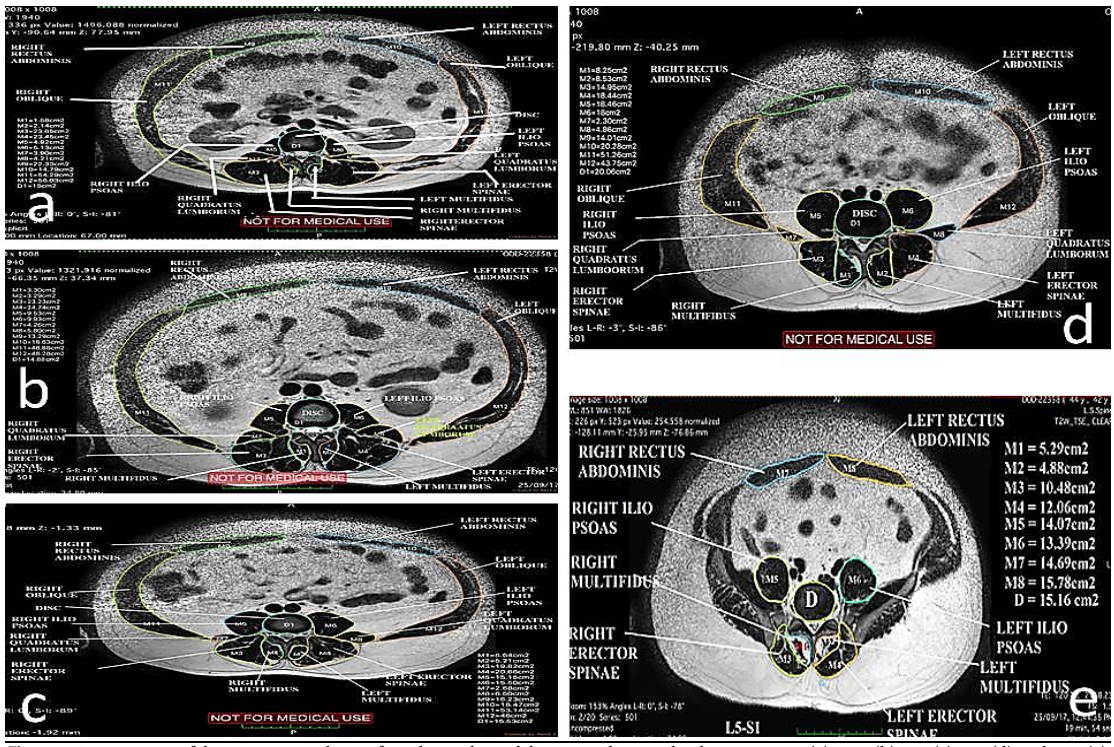

Figure 1. Measurements of the cross-sectional area of trunk muscles and disc on axial T2-weighted images at L1-2 (a), L2-L3 (b), L3-4 (c), L4-5 (d), and L5-S1 (e) lumbar disc levels in a 40-year-male patient with right sides disc prolapse at L5-S1 (The patient had had symptoms of LBP with radiation to the lateral aspect of the leg and foot for the last 4 months and a half.)

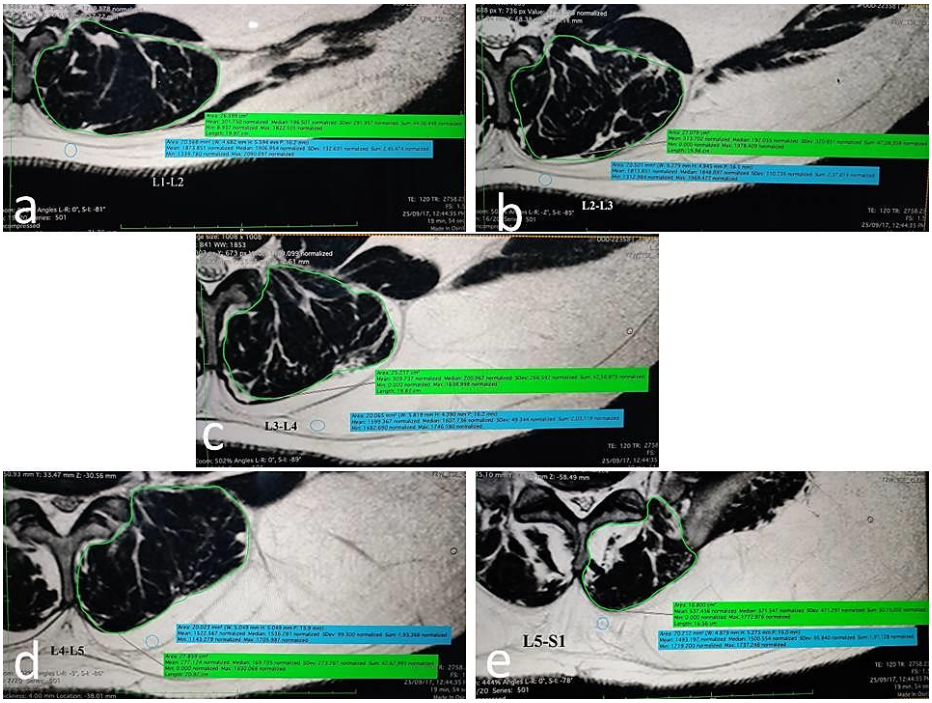

Figure 2. Measurements of muscle disc ratio (MM+ES) on axial T2-weighted images at L1-2 (a), L2-L3 (b), L3-4 (c), L4-5 (d), and L5-S1 (e) lumbar disc levels in the same patient

Differences between Chronic Low Back Pain Patients and Asymptomatic Volunteers

In the present study, we observed a generalized trend of smaller CSA of the paraspinal muscles in LBP patients, although this did not reach a statistically significant level except for a few muscles and disc levels. At the L1-L2 level, PS and MM were found to be atrophic in the patients with CLBP as compared to the control population, and the atrophy was highly statistically significant ($P < 0.005$). At the L2-L3 level, PS was also found to be atrophic, and the atrophy was highly statistically significant ($P = 0.001$). At this level, other muscles like the QL of the right side were also found to be atrophic ($P = 0.003$), and multifidus was also found to be atrophic, but atrophy was not statistically significant ($P = 0.060$). Moreover, at the L3-L4 level, PS of the right side was found to be atrophic, which was statistically significant ($P = 0.030$).

The findings of the present study substantiate the observations of the previous literature about muscle atrophy in CLBP patients compared to the control population (6, 8, 13-15). Singh et al. found the PS muscle to be atrophic at the L3-L4 disc level, but the atrophy was not statistically significant ($P = 0.070$). MM CSA's were smaller at all the measured disc levels in the study group as compared with the control group, but the difference was not statistically significant ($P > 0.050$) (8). Kader et al. reported that 80% of CLBP patients showed MM atrophy (2). Danneels et al. (15) reported that the CSA of the MM of patients with CLBP was smaller than that of the healthy control group, with similar results from the ultrasound imaging studies of Hides et al. (6). Wan et al. (21) reported atrophy of MM at the level, above the level, and below the level, with the greatest reduction at the problem level. Fortin et al. reported a mean CSA of MM (at L3-L4 = 7.21 ± 1.32 cm^2, at L5-S1 = 20.45 ± 3.04 cm^2) and ES muscle (at L3-L4 = 12.24 ± 1.68 cm^2, at L5-S1 = 11.57 ± 4.27 cm^2) (22). The majority of these studies only focused on the changes involving the multifidus muscles, but in the present study, we evaluated all the major muscles of the trunk.

Some of the reports had also addressed the changes in the other muscles at some of the lumbar levels, viz., the psoas muscle, abdominal muscles, and paraspinal muscles. Parkkola et al. noted that in patients with CLBP, the psoas muscles and the paraspinal muscles were smaller compared to those of the healthy control group (19). Gibbons et al. compared the CSA of the paraspinal, QL, and PS muscles in sections through the level of L3-L4 in patients with CLBP and in a healthy control group and did not find a significant difference between the CSAs of muscles in either group, as also observed in the present study (23). However, they detected degenerative changes in the form of fatty infiltration in the muscles (23). Kamaz et al. found measurements of the MM, PS, and QL muscles to be significantly lower at the upper L4 level in the patient group compared to the control group (5). Lee et al. found that the CSA of the ES muscle and the proportion of the area to lumbar muscles (paraspinal and PS muscles) at the L5 level in the CBP group were significantly smaller than those of the improved back pain (IBP) group ($P < 0.05$) (10). In the present study, mean values of CSA of MM, ES, and PS muscles at L3-L4, L4-L5, and L5-S1 levels in group A were smaller than those of group B, but were not statistically significant ($P > 0.050$) except for PS of the right side ($P = 0.030$).

Very few studies in the past have evaluated muscle disc ratio in CLBP patients (24-26). The muscle-to-bone ratio has been used to measure lumbar muscularity and provides an internal standard of muscularity (24-26). This has also been used in the present study to detect any sarcopenia associated with LBP. We found that muscle disc ratio with regard to MM and PS was lower in the CLBP patients (Group A) compared to asymptomatic volunteers (Group B). This was statistically significant ($P < 0.050$) at all levels (except at L5-S1), which signifies that there were more

chances of MM and PS atrophy in CLBP patients. A similar lower ratio was seen with regard to erector spinae at L3-L4 on the left side and L4-L5 on the right side. QL disc ratio was also found to be significantly ($P < 0.050$) lower at L3-L4, L4-L5, and the right side of L1-L2 and L2-L3 in CLBP patients compared to a healthy population. We also noted statistically significant ($P < 0.050$) lower combined muscle disc ratios at the L2-L3, L3-L4, and L4-L5 levels in the group A population compared to a healthy population. Kang et al. (24) reported PS: disc = 0.98 and SD = 0.23, ES: disc = 1.71 and SD = 0.46, MF: disc = 0.86 and SD = 0.30 in CLBP patients. Cooper et al. reported significant reductions of this ratio in paraspinal and PS in patients with CLBP compared to recent onset LBP (26). Contrary to the findings of the present study, Savage et al. reported that the lumbar muscularity was not significantly affected by a history of LBP (25). We are of the opinion that it may not be the overall CSA of muscle, but the muscle-disc ratio (muscularity) that is an important factor in maintaining proper spinal biomechanics, and any alteration in it may predispose individuals to LBP.

The findings of the present study correlate with those of the previous studies which reported that fatty infiltration occurs in muscles (especially MM) in CLBP patients (2, 13, 14, 19). We found a high statistically significant difference ($P < 0.001$) between the CLBP patients (Group A) and asymptomatic volunteers (Group B) with regard to the muscle-fat ratio of MM at each lumbar disc level. The muscle-fat ratio in group A was higher than in group B, which is in line with previous literature findings in which fatty infiltration was higher in CLBP patients (2, 13, 14, 19).

It is assumed that fatty infiltration may negatively affect muscle contractility when muscle fibers are replaced with non-contractile tissue. Consequently, the deteriorated muscle composition may contribute to LBP recurrence (29). While some have found that patients with CLBP have more fatty infiltration than healthy controls, not all studies support this finding (15). The difference in fatty infiltration seemed to be especially evident in the multifidus muscle, where patients with CLBP have been reported to have 23.6% fat content as opposed to 14.5% in control subjects (14). Changes in CSA and morphology (especially in PS and ES) have been reported to contribute to LBP by altering biomechanics and distorting the spine-pelvis complex (30). The findings of the present study support this theory of altered biomechanics.

Correlations

a) Age with CSAs of Muscles: Shahidi et al. reported that age does not have a statistically significant effect on changes in CSA of either MM or ES muscles in individuals with lumbar spine pathology (31). In the present study, we also noted no statistically significant correlation between age and CSAs of muscles at any of the lumbar and lumbosacral levels in either of the study groups (CLBP patients and asymptomatic individuals), except that the CSA of ES of the left side at the L2-L3 level decreases as age increases (moderate negative correlation; $r = -0.426$) in the control population ($P = 0.034$), and the CSA of RA of the left side at the L3-L4 level increases with age (weakly positive correlation; $r = 0.318$) in the CLBP patients ($P = 0.024$). These findings can be explained on the basis that as the contractile component of the muscle decreases, fatty infiltration increases; thus, the CSA of the muscle may not be affected overall. Our findings are also consistent with those reported by Fortin and Macedo (16) and Crawford et al. (32). However, Bhadresha et al. (33) reported that muscle content of erector spinae and multifidus correlated negatively with increasing age in both the DDD and lumbar herniation groups at the L3-L4 level.

b) Age with Muscle-Fat Ratio: In the present study, we noted an increase in MM+ES muscle-fat ratio with increasing age at all lumbar and lumbosacral levels in patients with CLBP, but this relationship was only statistically significant at the L2-L3 level ($r = 0.358$; $P = 0.011$) and L3-L4 level ($r = 0.436$; $P = 0.002$) (Figure 3).

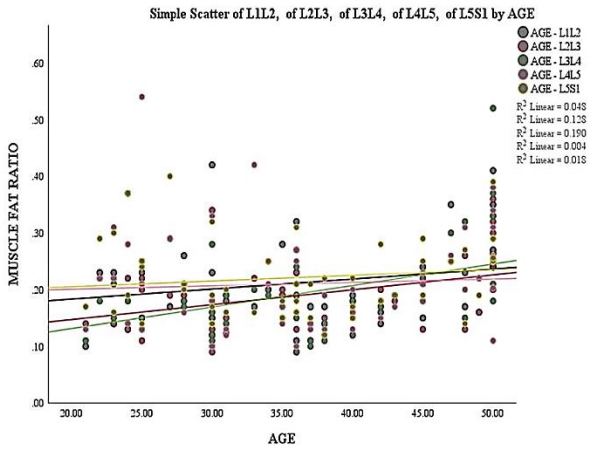

Figure 3. Scatter diagram of muscle-fat ratio of the study population (group A)

We also noted an increase in muscle-fat ratio with increasing age at all lumbar and lumbosacral levels in the control population, but this relationship was only statistically significant at the L2-L3 level ($r = 0.457$; $P = 0.021$), L3-L4 level ($r = 0.510$; $P = 0.009$), and L4-L5 level ($r = 0.435$; $P = 0.029$) (Figure 4).

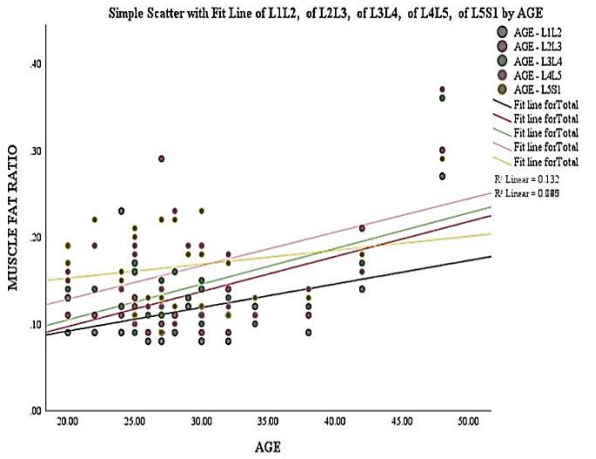

Figure 4. Scatter diagram of muscle-fat ratio of the control population (group B)

Observations of the present study reaffirm the literature findings showing that with ageing, fatty infiltration occurs in the muscle (16, 32). Crawford et al. reported an increase in fatty infiltration in the paraspinal muscles with an increase in age (32). Shahidi et al. reported that there were statistically significant increases in paraspinal muscle fat signal fraction (FSF) with age in both genders ($P < 0.0001$). The overall levels of FSF were higher in individuals with pathology across all ages compared to healthy individuals (31). Valentin et al. reported that age explained 18.1-36.0 percent of the

variance in multifidus and erector spinae (right) muscle fatty infiltrate (MFI), but they used T1-weighted MRI pixel intensity analyses contrary to the present study which used T2-weighted MRI (34). Lee et al. reported that age, disc level, and muscle type affect the degree of intramuscular fat infiltration. The extensor muscles extending from lower to upper levels are more affected (35).

c) BMI with CSAs of Muscle Area: In the present study, we noted an increase in CSA of muscle area with increasing BMI in the study population in QL of the left side (r = 0.332; P = 0.019) and bilateral OBL muscle [right side (r = 0.303; P = 0.032), left side (r = 0.279; P = 0.050)], bilateral RA at L3-L4 level [left side (r = 0.308; P = 0.030), right side (r = 0.323; P = 0.020)], and bilateral QL at L4-L5 level [right side (r = 0.393; P = 0.005), left side (r = 0.369; P = 0.008)]. We also noted an increase in CSA of muscle area with increasing BMI in the control population in the QL of the right side at the L4-L5 level (r = 0.451; P = 0.040) and the QL of the left side at the L5-S1 level (r = 0.415; P = 0.044). An increase in weight and BMI may put extra stress on the muscle, predisposing it to strain and LBP. Valentin et al. (34) reported that for multifidus volume, 81.7-84.6% of the variance was explained by age and BMI, and for erector spinae volume, 81.6-82.8% of the variance was explained by BMI in people without back pain.

Comparison between Subgroups of Group A: A_1 (Lumbar Spondylosis), A_2 (Mechanical Back Pain), and A_3 (Lumbar Disc Herniation)

In the present study, there was no statistically significant difference in parameters like trunk width and trunk depth between subgroups, signifying that all the subgroups were comparable and there is no bias on measured parameters of the disc and paraspinal muscles, as it has been shown any increase in these may put extra strain on the intervertebral discs, which can accelerate the deterioration of the osteocartilaginous components of the spine, hence contributing to further lumbar back pain (36).

In the present study, we observed a general trend of CSA of muscles among subgroups of patients with LBP. Patients with LS had larger CSA > LDH > MBP, except at the L5-S1 level, where this trend was not observed. LDH subgroup patients had larger CSA at the L5-S1 level. We noted no statistically significant difference in the CSAs of muscles except for a few of the muscles at different lumbar levels. These observations make us believe that it is not the different lumbar pathologies, but the common mechanism of denervation, disuse atrophy, and reflex inhibition that are responsible for paraspinal muscle atrophy, fatty infiltration, and muscle fiber alterations (15, 29, 37, 38). Hides et al. reported that the underlying mechanism of wasting may be due to inhibition due to perceived pain via a long-loop reflex targeting the vertebral-level pathology to protect the damaged tissues (11).

We noted that there was a tendency for larger CSAs of disc in patients with lumbar spondylosis, although this difference was not statistically significant (P > 0.050).

We noted a statistically significant difference in muscle disc ratio with regard to multifidus muscle at the L2-L3 level on the left side, where it was higher in patients with lumbar spondylosis (LDH > MBP) (P_1 and P_2 < 0.050). At the L3-L4 level, the ratio was higher in MBP than other subgroups (P_1 and P_2 < 0.050). At the L4-L5 (left side), the ratio was higher in MBP patients, and at the L5-S1 level (right side), the ratio was higher in patients with LDH > MBP > lumbar spondylosis. With regard to erector spinae, we noted no statistically significant difference at any of the lumbar and lumbosacral levels except at the L4-L5 levels (right side), where the ratio was lower in patients with LDH compared to MBP (P_2 < 0.050). With regard to the psoas muscle, the muscle disc ratio was statistically significant at the L1-L2 level on the left side, where the ratio was higher in LDH patients compared to lumbar spondylosis (P_3 = 0.050). At the L3-L4 level (left side), the muscle disc ratio was lower in LDH patients compared to MBP (P_2 = 0.050). The muscle disc ratio with regard to quadratus lumborum is not statistically significant at any of the lumbar and lumbosacral levels except at the L1-L2 level on the right side, where it was similar in lumbar spondylosis and LDH (P_3 < 0.050), and at L3-L4 on the left side, where it was higher in LDH patients as compared to MBP (P_2 < 0.05). We also noted a statistically significant muscle disc ratio with regard to obliques at L1-L2 on the right side, where it was higher in patients with LDH as compared to those with lumbar spondylosis (P_3 = 0.070), at L1-L2 on the left side, where the ratio was higher in LDH patients as compared to lumbar spondylosis patients (P_3 < 0.050), and at the L3-L4 level on the left side, where the ratio was higher in patients with LDH > MBP (P_2 = 0.060). With regard to the muscle disc ratio of all the muscles combined, the ratio was not statistically significant at any of the lumbar and lumbosacral levels except at the L3-L4 level on the left side, where it was lower in patients with LDH compared to MBP (P_2 < 0.050) and at the L4-L5 level, where it was also lower in patients with LDH compared to MBP patients. These differences in the muscle disc ratio among the subgroups of patients with CLBP (Group A) may be due to the differences in the number and predominant spinal level involvement in different spinal pathologies investigated in the study.

We noted no statistically significant difference with regard to muscle-fat ratio between subgroups at any of the lumbar and lumbosacral levels. In the literature, more subcutaneous fat thickness has been reported in lumbar DDD (low back pain) than in the disc herniation group (33). Bhadresha et al. found no difference in the muscle-to-fat ratio between the DDD and disc herniation groups (33). Faur et al. reported a low correlation (R = 0.37) and significant association (ANOVA; P = 0.001; 95% CI: 2.07-8.14) between the grade of lumbar disc degeneration and the degree of LMM fatty atrophy (39).

Comparison between subgroups of CLBP patients (Group A) and Group B (asymptomatic individuals)

In the present study, there was no statistically significant difference in parameters like trunk width and trunk depth between subgroups of CLBP patients and asymptomatic individuals. It again signifies that there is no bias on measured parameters of the disc and paraspinal muscles, as a change in trunk width and depth can alter spine curvature and spine biomechanics.

There was no statistically significant (P > 0.050) difference between the CSA of muscles between subgroups and asymptomatic individuals except for a few muscles at upper lumbar levels. These findings are similar to those of the studies reporting no differences between CLBP patients and healthy individuals (8, 13, 14, 19, 40).

An important observation of the present study was the statistically significant (P < 0.050) difference of CSA of a disc between LDH and group B at lower lumbar levels (L3-L4, L4-L5, and L5-S1). These levels are the most common site of disc herniation. It needs to be clarified by studies with a larger number of participants in the future whether larger size discs are more prone to herniation.

There was a statistically significant ($P < 0.050$) difference in the muscle disc ratio between LDH and group B of all the measured muscles. This was another significant observation of the present study. This observation may be explained in two ways; one is that LDH leads to more loss of muscle mass due to pressure on the nerve roots (radiculopathy). It can also be explained on the basis of larger CSA of discs observed in the subgroup of LDH patients (A_3), hence affecting this ratio.

There was a statistically significant difference ($P < 0.050$) in the muscle-fat ratio between all the subgroups (A_1, A_2, and A_3) of CLBP patients (Group A) and asymptomatic individuals (Group B). These observations are in line with the studies in the literature reporting that CLBP is associated with more fatty infiltration in the paraspinal muscles compared to healthy individuals (13, 14, 19). It also implies that all lumbar pathologies affect muscle composition through the same pathway; it may be the degree of this fatty infiltration that varies depending on the severity of the disease.

The present study has a few limitations, as the number of patients included in the study is low, and we have evaluated the muscle-fat ratio only in the MM+ES combined. The strength of the study is that we have evaluated more parameters in CLBP and at all lumbar levels and compared these with controls. Studies in the past have evaluated only a few of the parameters, and that too at a single or a few lower lumbar levels.

Conclusion

In light of the above findings, we conclude that muscularity (muscle disc ratio) and composition (muscle-fat ratio) have a more significant associated with CLBP than the overall CSA of important spinal stabilizers (multifidus, erector spinae, and psoas). Age and BMI have no correlation with the CSA of paraspinal muscles in either patients or asymptomatic individuals. Various disc and muscle parameters do not differ much among common lumbar pathologies. Variations in a few of the parameters may be due to the severity of the predominant spinal level of involvement in the underlying disease process. Further research detailing the various possible mechanisms and remedial measures to reverse/minimize the changes in the associated parameters is required.

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgements

None.

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