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Original Article

Paraspinal Muscles Cross-Section Area and Fat Infiltration in Chronic Versus Acute Low Back Pain Patients and their Association with Disc Herniation

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Abstract

Background: Low back pain is an important health problem and is one of the main symptoms in lumbar disc pathology. It is not known whether paraspinal muscular weakness is a cause or a result of low back pain.

Objectives: The current study was performed in order to investigate paraspinal muscles Cross-Section Area (CSA) and Fat Infiltration (FI) in chronic versus acute Low Back Pain (LBP) patients and their association with disc herniation.

Methods: 76 acute and 76 chronic LBP adult subjects who were candidates for magnetic resonance imaging in a referral hospital in Isfahan, Iran, were evaluated in terms of demographics, their pain and disability severity, FI (signal intensity index) of paraspinal muscles in five lumbar levels, CSA of paraspinal muscles in five lumbar levels and disk herniation degree in five lumbar levels.

Results: Overweight patients: 34 (45.9 %); obese: 12 (16.2 %); ODI score: 25.2 (6.7) and mean VAS score was: 6.44 (1.2). The longer the pain persisted, the higher its severity was felt. Similar numbers were found for females. Females had higher pain scores and higher FI in paraspinal muscles. Accordingly, FI was higher, and CSA was lower in chronic LBP than acute LBP (P <0.05). Women had smaller, and fattier paraspinal muscles (P <0.05).

Conclusion: Chronic LBP is associated with a decreased muscle volume in paraspinal muscles. Regular physical activity routines, weight loss meal plans, physiotherapy and corrective training programs might prevent chronicity of LBP, increase paraspinal CSA, decrease paraspinal FI, attenuate back pain severity and hence improve patients' quality of life.

Keywords: Lumbar Spine, Muscle Fat Replacement, Muscular Atrophy, Magnetic Resonance Imaging, Paraspinal Muscle, Low Back Pain

1. Background

Low Back Pain (LBP) is a health issue of paramount importance. It is the most common cause of activity limitation in people younger than 45 years of age, the second most frequent reason for physician visits, the fifth most frequent cause of admissions to hospitals and the third most common reason for implementing surgical procedures. With an annual prevalence of 15-45% in different cities, it is estimated that approximately 70-85% of all people have back pain at some point in their life, resulting in a great economic burden on societies both directly (diagnosis, treatment, rehabilitation, etc.) and indirectly (via the numerous working days lost). The causality of LBP is not completely understood.[1,2] In recent years, studies have shown an association between LBP and paraspinal muscular weakness.[3] The strength of the trunk flexor and extensor muscles by means of a cable tensiometer was measured and generalized weakness of the trunk muscle in patients with low back pain was found.[4] Biomechanical studies have shown that the multifidus muscle is a major contributor to lumbar segmental stability.[5,6] It is widely accepted that dysfunction of multifidus muscles has an important effect on etiology and recurrence of low back pain. However, it is not known whether muscular weakness is a cause or a result of low back pain.[7,8]

Two distinct paraspinal muscle abnormalities may be seen with lumbar disc pathology: a decrease in the size of muscles (atrophy) and/or replacement of muscle fibers by fat (fatty degeneration).[7] Several investigators have assessed structural changes of the paraspinal muscles in patients with low back pain by using imaging techniques such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Ultrasound (US).[2,8-12] CT and MRI have been used to assess the amount of fat deposits of paraspinal muscles in patients with low back pain by using histograms and a semi-quantitative visual grading method. In the recent quantification studies using MRI,

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fatty degeneration in paraspinal muscles was evaluated with proton MR Spectroscopy (MRS).[13]

Typically, lumbar muscle size Cross-Sectional Area (CSA) is measured by outlining fascial muscle borders on axial images.[14] However, CSA measures may be distorted by replacement of muscle with adipose or connective tissue.[15,16] The CSA of the multifidus muscle has been shown to be larger in male subjects, and age was not related to multifidus size.[17] The size of the multifidus muscle has also been documented in people with acute and chronic Low Back Pain (LBP). In patients with acute unilateral LBP, studies employing ultrasound imaging demonstrated a decrease in the CSA of the multifidus muscle ipsilateral to painful symptoms,[18,19] and the atrophy was predominantly isolated to one vertebral level (L5). Multifidus muscle atrophy has been quantified in MRI and CT studies in terms of both decreased muscle size and alterations in muscle consistency (due to fatty deposits or fibrous/connective tissue infiltration).

2. Objectives

This study was conducted in order to investigate paraspinal muscles CSA and FI in chronic versus acute LBP patients and their association with disc herniation.

3. Methods

In this study, 76 adult patients with acute LBP and 76 adult patients with chronic LBP and candidates for MRI, referred to Rajaee Hospital in Isfahan in 1402, who met the inclusion criteria, were included.

Subjects with low back pain with an indication of MRI, were assigned to either acute (<12 weeks = 76 patients) or chronic (≥12 weeks= 76 patients) groups. The exclusion criteria in this study included professional athletes, morbidly obese patients, patients with a self-reported history of high lipid profile, previous lumbar injection, surgery or trauma, systemic inflammatory disease, neurological disorders, neoplasms, and scoliosis, conditions causing muscular atrophy and neuromuscular.

Images were reviewed by a board-certified radiologist for the presence of signal alterations within the paravertebral musculature in fat-suppressed T2W sequences. Patients underwent routine diagnostic MRI of the lumbar spine 1.5-T MR system (Siemens Magnetom Vision Plus, Erlangen, Germany). According to spine nomenclature and classification (Fardon et al., 2001), lumbar disc pathologies were defined based on MRI findings (no discopathy, protrusion, extrusion). The muscle CSA was measured by contouring multifidus, erector spine and psoas major muscles, using the default software for the mentioned system. Chemical shift MRI was performed in axial plane with sagittal cross-references made to the relevant mid-intervertebral disk at the L1-L2, L2-L3, L3–L4, L4–L5, and L5–S1 levels of the lumbar spine using a double-echo fast low-angle shot (FLASH) sequence: TR:128 msec, double TE:2.7 and 5.3 ms, flip angle 90º, slice thickness 6 mm, intersection gap 0.4 mm, matrix 143 × 256, FOV 300 mm, acquisition 1 A region of interest (ROI) was positioned in the center of the each muscle at the five levels of lumbar intervertebral discs. CSF was chosen as the reference.

The double-echo sequence was performed during a single breath-hold in 20 seconds. Corresponding in-phase and opposed-phase images were obtained from the same anatomical position. Quantitative parameter of signal change between in-phase and opposed-phase images were calculated from the measured Signal Intensity Index (SII), as described in previous reports:

Signal intensity index (SII) of the muscle:

$$\frac{("SIin - SIout)}{SIin} \times 100$$

Measured outcomes: Demographics (age; sex) and morphometries (weight; height; BMI). Pain and disability scores: VAS and ODI. Fatty infiltration index of paraspinal muscles in 5 lumbar levels (signal intensity index, a.k.a "SII"). The CSA of paraspinal muscles in five lumbar levels. Disk herniation degree in 5 lumbar levels.

3.1. Statistical Analysis

To report quantitative variables, mean and Standard Deviation (SD) indicators were used. The k-S test was used to check the normality of data distribution. Chi-square test, Fisher's exact test, independent samples t-test and mann-whitney test were also used to analyze the data. All statistical analyses were performed with SPSS ver. 25 (SPSS, Chicago, IL, USA) software. *P* value < 0.05 was considered to indicate a statistically significant difference.

4. Results

In order to carry out this study, 76 acute and 76 chronic LBP patients were included. Statistical analysis revealed that our male and female subjects had higher BMI measures in both groups than that of what has been reported from Iranian healthy subjects which was 22.8 ± 4.6 for men and 23.6 ± 6.6 for women.

5. Discussion

This study investigated the changes in the paraspinal muscle CSA and fatty infiltration in patients with acute and chronic LBP using MRI assessment at the same level. The repeatability of measurement for the muscle CSA, the mean signal intensity and fatty infiltration was acceptable, indicating that the evaluations were reliable. The results of the present study are in agreement with that of previous studies.[20] Another investigation suggested that the atrophic change in the MF muscle was probably related to the degenerative changes of the lumbar discs.[21]

Table 1. Clinical Characteristics

Subjects	Muscle	Level	Acute LBP Mean (SD)	Chronic LBP Mean (SD)
Male	Multifidus	$L_1 – L_2$	-2.69 (3.5)	14.81 (5.7)
		$L_2 – L_3$	-4.55 (4.0)	12.84 (6.1)
		$L_3 – L_4$	-1.38 (4.2)	16.60 (6.4)
		$L_4 – L_5$	-4.87 (3.5)	12.35 (5.6)
		$L_5 – S_1$	-6.37 (5.0)	14.81 (7.5)
	Psoas major	$L_1 – L_2$	-2.22 (2.9)	12.24 (4.7)
		$L_2 – L_3$	-4.12 (3.0)	10.47 (4.7)
		$L_3 – L_4$	-3.88 (3.4)	10.97 (5.2)
		$L_4 – L_5$	-5.18 (4.1)	12.04 (6.1)
		$L_5 – S_1$	-1.15 (3.5)	13.83 (5.3)
	Erector spine	$L_1 – L_2$	-3.17 (2.3)	8.06 (3.6)
		$L_2 – L_3$	-1.71 (2.2)	9.42 (3.6)
		$L_3 – L_4$	-0.88 (2.7)	10.65 (4.1)
		$L_4 – L_5$	-4.61 (3.6)	10.71 (5.4)
		$L_5 – S_1$	-2.27 (2.7)	9.77 (4.2)
Female	Multifidus	$L_1 – L_2$	-4.18 (2.9)	12.08 (7.8)
		$L_2 – L_3$	-8.15 (4.1)	13.32 (10.5)
		$L_3 – L_4$	-3.67 (5.3)	18.29 (11.3)
		$L_4 – L_5$	-7.28 (3.3)	10.91 (8.3)
		$L_5 – S_1$	-7.67 (4.4)	10.65 (9.4)
	Psoas major	$L_1 – L_2$	-3.59 (2.5)	10.37 (6.7)
		$L_2 – L_3$	-5.48 (2.5)	8.21 (6.5)
		$L_3 – L_4$	-5.93 (2.9)	9.70 (7.6)
		$L_4 – L_5$	-7.90 (4.5)	10.98 (9.7)
		$L_5 – S_1$	-2.0.7 (3.0)	10.35 (6.4)
	Erector spine	$L_1 – L_2$	-4.18 (1.9)	6.26 (5.0)
		$L_2 – L_3$	-2.81 (2.0)	8.13 (5.2)
		$L_3 – L_4$	-1.90 (2.7)	9.51 (5.9)
		$L_4 – L_5$	-2.30 (3.3)	11.51 (7.1)
		$L_5 – S_1$	-3.26 (3.0)	8.63 (5.3)

Table 2. SII in Three Mmuscles: Chronic Versus Acute

Subjects	Muscle	Level	Acute LBP Mean (SD)		Chronic LBP Mean (SD)	
			Left	Right	Left	Right
Male	Multifidus	$L_1 – L_2$	5.96 (1.5)	5.76 (1.4)	3.39 (0.9)	3.28 (0.9)
		$L_2 – L_3$	5.39 (1.6)	5.20 (1.6)	4.32 (1.1)	3.61 (1.2)
		$L_3 – L_4$	6.06 (1.6)	5.96 (1.8)	4.30 (1.1)	3.46 (0.9)
		$L_4 – L_5$	7.23 (1.5)	7.18 (1.3)	4.58 (0.8)	4.66 (1.0)
		$L_5 – S_1$	7.79 (1.3)	7.66 (1.5)	5.36 (1.3)	5.18 (1.4)
	Psoas major	$L_1 – L_2$	Not judicable	Not judicable	Not judicable	Not judicable
		$L_2 – L_3$	6.87 (1.5)	6.89 (1.4)	6.45 (0.9)	6.33 (0.8)
		$L_3 – L_4$	8.97 (1.8)	9.43 (1.7)	6.96 (1.6)	6.78 (1.5)
		$L_4 – L_5$	13.63 (2.3)	13.40 (2.4)	11.44 (1.5)	11.14 (1.3)
		$L_5 – S_1$	12.93 (2.7)	12.67 (2.9)	9.78 (2.3)	9.73 (2.1)
Female	Multifidus	$L_1 – L_2$	3.10 (2.0)	2.94 (1.8)	3.62 (1.6)	3.66 (1.1)
		$L_2 – L_3$	4.07 (1.5)	3.85 (1.5)	3.01 (0.8)	3.79 (0.9)
		$L_3 – L_4$	4.97 (1.2)	4.79 (1.1)	4.56 (1.2)	4.27 (1.0)
		$L_4 – L_5$	5.47 (1.4)	5.25 (1.5)	4.34 (0.9)	4.28 (0.9)
		$L_5 – S_1$	5.74 (1.5)	5.80 (1.6)	4.32 (1.9)	4.51 (1.0)
	Psoas major	$L_1 – L_2$	10.30 (3.2)	10.14 (3.5)	12.53 (5.8)	11.35 (4.8)
		$L_2 – L_3$	5.86 (1.6)	5.79 (1.8)	4.64 (2.1)	4. 83(2.0)
		$L_3 – L_4$	8.02 (2.0)	8.15 (2.2)	6.30 (2.1)	6.67 (2.8)
		$L_4 – L_5$	10.45 (3.9)	10.71 (3.0)	7.58 (2.8)	7.32 (2.6)
		$L_5 – S_1$	10.39 (4.7)	10.78 (4.1)	8.01 (2.3)	6.54. (3.7)

Severe and extensive atrophy in the MF muscle has been found to be associated with radiculopathy.[22]

The mechanism of fatty degeneration in skeletal muscle is not completely understood. According to the first hypothesis, fatty degeneration may be due to transformation of the fibroblasts/pre-adipocytes in response to glucocorticoid-induced inflammation. In the second hypothesis, increased secretion of cell mediators, such as pro-inflammatory cytokines, growth factors, and prostaglandins, or derivatives may stimulate the adipose tissue proliferation and degeneration.[21] Fatty degeneration in paraspinal muscles can be assessed quantitatively with several MRI methods.[5,13,22,23] In particular, advanced imaging techniques, such as MRS, have been used to evaluate and quantify the fatty degeneration of muscles such as supraspinatus or paraspinal muscles.[5,13,24] Proton MRS was used by Mengiardi et al.,[5] in order to evaluate the changes in the fat content of the multifidus and longissimus muscles in 25 patients with lumbar disc pathology. These patients had a significant increase in the fat content of the multifidus muscle when compared with that of a control group. However, there were no significant differences in the percentage of fat content for the longissimus muscles.[5] In this study, our patients had lumbar disc pathology, so we measured the signal intensity of the multifidus muscles in chemical shift MRI. Chemical shift MRI is more widely available and is much faster than MRS for the detection of lipid content of structures.

Chemical shift MRI also exploits the differences in precession velocities of fat and water protons to detect small amounts of intravoxel fat.[25] According to TE values, water and lipid molecules precess in-phase or opposed-phase. For a 1.5-T magnet, these values are 4.2 ms and 2.1 ms for the in-phase and opposed-phase, respectively. Both lipid and water signals are collected for in-phase images. In opposed-phase images, water and lipid molecules precess 180° from each other and signals are subtracted. By adding and subtracting the two complex images (images with both magnitude and phase information) from in-phase and opposed-phase imaging, selective water and fat images are generated.[25,26] A signal decrease on opposed-phased images compared with in-phase images provides a specific diagnosis of fat deposition.[25] This technique enables significant fat suppression, especially when lipid content is small. As a result, chemical shift MRI can depict smaller amounts of fat when compared with the frequency-selective method. Therefore, we chose chemical shift MRI for our study. The spleen, which is not affected by fatty degeneration, is chosen as the reference organ in differentiating adrenal adenomas from metastasis in chemical shift MRI. In vertebral and paravertebral examination, air or CSF have been previously chosen as the reference values.[26,27]

Age: Several studies have investigated the effect of age on the Cross-Sectional Area (CSA) of the lumbar paraspinal muscles in both healthy adults[9,28] and patients with lower back pain.[8,16] The majority of these studies have shown a significant effect of age on the lumbar paraspinal CSA.[8,9,28]

Exercise: Training programs, especially those focusing on core muscles such as paraspinal muscles, have been shown to be effective in decreasing low back pain in multiple studies. This emphasizes the potential role that muscular atrophy and fatty degeneration can play.

Just like any other study, this research faced some limitations. Accordingly, muscles might be in contraction while under imaging, due to being in pain. In addition, small differences in muscle size (owing to a number of factors) can result in significantly different sizes; human error in contouring and measurement also can dedicate to this limitation. Therefore, the trend of the muscle size and fat content can be more reliable than the value itself. Furthermore, unilateral pain was not considered in this study. However, there was no significant difference between the two groups regarding either the pain scores, or the CSA or FI values.

6. Conclusion

Chronic LBP is associated with a decreased muscle volume in paraspinal muscles. Regular physical activity routines, weight loss meal plans, physiotherapy and corrective training programs might prevent chronicity of LBP, increase paraspinal CSA, decrease paraspinal FI, attenuate back pain severity and hence improve patients' quality of life.

Research Highlights

What Is Already Known?

Typically, lumbar muscle size is measured by outlining fascial muscle borders on axial images. However, CSA measures may be distorted by replacement of muscle with adipose or connective tissue.

What Does This Study Add?

Chronic LBP is associated with a decreased muscle volume in paraspinal muscles.

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Author Contributions

MR contributed as the main author with the concept of planning the study. SB and KS contributed to the study design, personnel selection, and data collection. SB and KS performed the statistical analysis and helped write the manuscript. MR mentored the edition of the final version. All authors read and approved the final manuscript.

Conflict of Interest Disclosures

All authors declared that they have no conflict of interest.

Ethical Approval

This study was conducted in compliance with the principles of the Declaration of Helsinki. The current study was approved by the Isfahan University of Medical Sciences Ethics Committee with the code of IR.MUI.MED.REC.1399.150. Written consent was obtained from the families of patients to enter this study.

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