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ORIGINAL ARTICLE

MRI features of the psoas major muscle in patients with low back pain

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Abstract
Purpose The purpose was to investigate the changes of the psoas major muscles (PM) cross-sectional area (CSA) and fat infiltration in the PM and to investigate the association between the morphology of the PM and expression of the degenerative changes of lumbar spine in patients with low back pain (LBP).
Methods T2-weighted scans for measurements of the CSA and analysis of fat infiltration were performed on 42 patients and 49 controls using a 1.5 Tesla MR system. For a quantitative analysis of fat tissue infiltration a 4-grade visual scale was used.
Results Patients had bigger CSA of the PM than controls at the levels of L3/L4 and L4/L5 intervertebral disc ($P < 0.05$). Patients with apparent degenerative changes of the lumbar spine had smaller CSA of the PM compared to the patients without apparent changes at the levels of L3/L4 and L4/L5 ($P < 0.05$). At the levels of L4/L5 and L5/S1 patients with present Modic changes in the lumbar vertebral bodies showed smaller CSA of the PM compared to the patients without Modic changes ($P < 0.05$). However, CSA of the PM in the patients with degenerative changes of lumbar spine and Modic changes was still bigger than the one of the controls. At all analyzed levels correlation between CSAs of the PM and fat infiltration of the lumbar paraspinal muscles was negative.
Conclusion Results suggest increased activity of the PM in LBP patients but PM also remains active regardless of the presence of degenerative and Modic changes of the lumbar spine.

Keywords Psoas major muscle · Low back pain · MRI · Disc degeneration · Modic changes

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Introduction

During the process of degeneration, intervertebral disc undergoes complex biochemical changes which decreases the ability of the disc to maintain hydration under load and alters disc height and the mechanics of the rest of the spinal column, possibly adversely affecting the behavior of other spinal structures such as muscles, ligaments and joints [1]. Over a period, changes regarding their volume can occur in the muscles, with a possible infiltration of nonmuscle (fat) tissue within the muscle, which can be analyzed on MR images. The most significant changes occur in the lumbar paraspinal muscles (LPM) with significant atrophic changes in the form of reduction of the muscles cross-sectional area (CSA) as well as in the form of fatty atrophy [2, 3]. In addition, the process of intervertebral disc degeneration alters the psoas major muscle (PM) morphology. The PM originates from the bodies of the lumbar vertebrae, inserts on the lesser trochanter of the femur [4], and is generally considered as an active postural muscle [5–7]. Some authors described atrophic changes of the PM with regard to unilateral lumbar disc herniation [8], and unilateral back pain [9, 10]. Moreover, smaller PM of the patients with

chronic low back pain (LBP) compared to the volunteers was described [11]. Nevertheless, no difference in CSA of the PM between chronic LBP patients and healthy control subjects was shown [12].

Since there are opposite results showing changes of the PM regarding chronic LBP the purpose of this study was to investigate if the PM had undergone any changes in patients with LBP syndrome considering its morphological and biomechanical association with the lumbar spine.

Another goal of this study was to investigate the association between the morphology of the PM and expression of the degenerative changes of lumbar spine in patients with LBP syndrome.

Materials and methods

Subjects

In this study 91 patients from Department of Radiology were included. The participants for the control group ($n = 49$, 25 female and 24 male, age range 18–84 years) were selected successively among the patients that had MRI examination of the abdomen and without history of LBP or sciatica. Participants with apparent MRI signs of degenerative changes of the lumbar intervertebral discs on the sagittal MRI scans as well as participants with systemic disease were excluded from the control group.

The patients included in the study group ($n = 42$, 24 female and 18 male, age range 19–78 years) had a chronic LBP and had no symptoms of radiculopathy (negative Lasègue's sign). Patients with profound scoliosis of the lumbar spine were excluded from the study due to expected significant differences between left and right PM. Patients completed Roland-Morris and Oswestry index questionnaires. Subsequently, the patients were grouped with regard to the presence of degenerative changes of the intervertebral discs (disc height reduction and loss of signal intensity on T2-weighted images) and Modic changes of the lumbar spine and were analyzed separately of the control group. Body mass index (BMI) was calculated for all participants. Patients gave their informed consent prior to data collection. The study was approved by the local ethics committees of the School of Medicine and the Clinical Hospital Center.

Magnetic resonance imaging

MRI examinations were performed using a 1.5 Tesla MR system Magnetom Avanto (Siemens Healthcare, 0, Germany). Measurements were obtained on transverse oblique MR images parallel to the referent intervertebral disc at L3/L4, L4/L5, and L5/S1 levels of the lumbar spine, (Fig. 1a). MR images were used to analyze muscle size and morphology. For measurements of the cross-sectional area (CSA) and analysis of fat infiltration of the left and right PM, and fat infiltration of the left and right LPM (multifidus and erector spinae) T2-weighted FSE images (TR 5200 ms/TE 105 ms; field of view, 200 × 200 mm; matrix, 250 × 384; section thickness, 3 mm; number of excitations, 2) were obtained. MR scans were analyzed using ISSA (VAMS, Zagreb, Croatia) software for image analysis. The circumferences of the PM and intervertebral discs were traced using electronic caliper and the CSAs were calculated (Fig. 1b). In order to reduce the influence of body constitution and gender to measured anatomical variables we used relative (the ratio between CSA of the PM and of the corresponding intervertebral disc) instead of an absolute CSA of the PM. For quantitative analysis of non-muscular (fat) tissue infiltration we used a 4-grade visual scale adapted from studies performed by Ropponen et al. [13] and Kjaer et al. [14]: Grade 0 = no apparent non-muscular tissue, Grade 1 = minor deposits of non-muscular tissue (<25 %), Grade 2 = moderate infiltration of non-muscular tissue (25–50 %), and Grade 3 = severe infiltration of non-muscular tissue (>50 %). The non-muscular tissue was identified as higher intensity pixels within the muscle CSA, while the lower intensity pixels represented muscle tissue (Fig. 2). All measurements were independently performed by two radiologists.

Statistics

Statistica 8.1. (StatSoft Inc., Tulsa, SAD) and MedCalc 7.5. (MedCalc, Maraikerke, Belgium) computer software were used for statistical analysis. In preliminary research MedCalc 7.5. (MedCalc, Maraikerke, Belgium) computer software was used to calculate sample size and to determine the necessary number of examinees per group. Inter-rater reliability was determined using the Cohen' Kappa and correlation coefficients. Testing for normality of the distribution of the data was performed with Kolmogorov–Smirnov (KS) test. For normally distributed data we used the arithmetic mean and standard deviation, and for data that were not distributed normally median and 5–95th percentiles were used. One-way ANOVA, Mann–Whitney test, Chi-square and Spearman's tests were used to make comparisons between the groups. Differences were considered significant at the level of $P < 0.05$.

Results

As shown in Table 1, there were no statistically significant differences in average ages between controls and patients ($P = 0.231$). In both groups, females and males were equally distributed ($P = 0.559$). Moreover, there were no

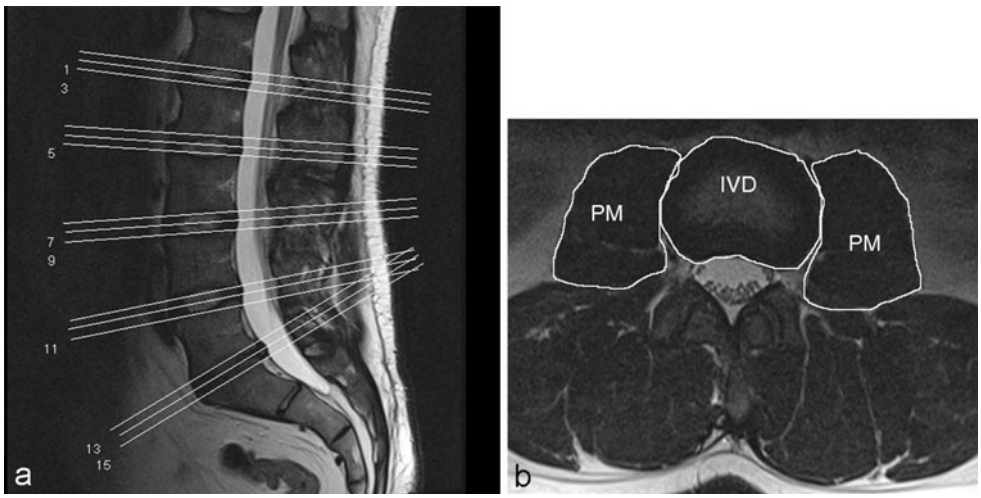

Fig. 1 Transverse oblique MR images parallel to the referent intervertebral discs of the lumbar spine (**a**). The circumferences of the psoas major muscle (PM) and intervertebral discs (IVD) on the T2-weighted modified axial scan (**b**)

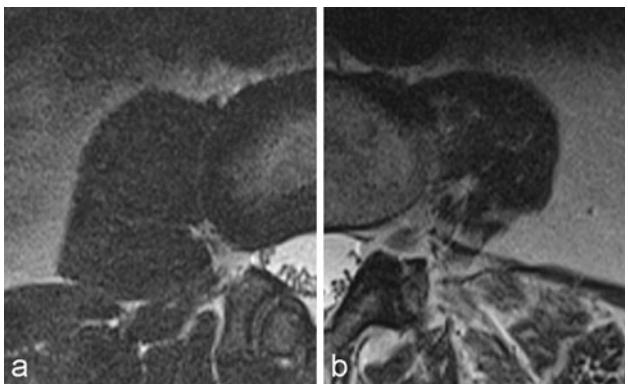

Fig. 2 Non-muscle tissue infiltration in the psoas major muscle seen on axial T2-weighted MRI scans. Grade 0 = no apparent non-muscle tissue (**a**), Grade 1 = minor deposits of non-muscle tissue (<25 %) (**b**)

significant differences between controls and patients with regard to the BMI ($P = 0.967$) (Table 1).

Differences in relative CSAs and fat infiltration of the PM between LBP patients and controls

Difference in CSAs between the left and right PM at the levels of L3/L4, L4/L5, and L5/S1 intervertebral discs was analyzed (Table 2). Detailed analysis showed no significant differences in CSAs between the left and right PM at all analyzed levels in the patients as well as in the controls group. We compared CSAs of the PM between patients and controls using the mean value of both sides at the same level for each examinee (Table 3). Detailed analysis showed significantly bigger CSA of the PM of the patients than controls at the levels of L3/L4 ($P < 0.05$) and L4/L5 ($P < 0.05$). The difference at the level of L5/S1 intervertebral disc was not statistically significant ($P = 0.247$).

More than 80 % of control subjects as well as patients showed no detectable fat infiltration (Grade 0) in both PM. Minor deposits of fat tissue (Grade 1) were found in 16.7 % of controls and 15.3 % of patients, whilst moderate and severe infiltrations (Grade 2 and 3) were not found in any examined subject (Table 4). Results are presented together for the left and right muscles. No statistically significant differences of the fat infiltration in PM between controls and patients were found ($P = 0.802$).

Analysis of the relative CSAs of the PM in the patients group with regard to the presence of degenerative changes of lumbar intervertebral discs

At the level of L3/L4 and L4/L5 intervertebral discs a significant difference of the CSAs of the PM was found

Table 1 Distribution of the examinees with regard to the age, gender, and BMI

	Age (years)		Gender		BMI (kg/m^2)	
	Mean ± SD	95 % CI	Female	Male	Mean ± SD	95 % CI
Control	55.1 ± 17.1	50.2–60.0	25	24	26.6 ± 5.2	25.1–28.1
Patients	51.1 ± 14.5	46.5–55.6	24	18	26.6 ± 4.4	25.3–28.0
P value	0.231*		0.559**		0.967*	

SD Standard deviation, *CI* Confidence interval, *BMI* Body mass index

* One-way ANOVA

** Chi-square test

Table 2 Relative CSAs of the left and right psoas major muscles in controls and patients at the level of L3/L4, L4/L5, and L5/S1 intervertebral disc

	Left muscle	Right muscle	*P* value*
Controls			
L3/L4	0.50 (0.28–0.86)	0.49 (0.29–0.91)	0.918
L4/L5	0.59 (0.36–1.16)	0.55 (0.34–1.11)	0.841
L5/S1	0.57 (0.33–1.29)	0.58 (0.33–1.22)	0.962
Patients			
L3/L4	0.63 (0.40–0.98)	0.60 (0.38–1.05)	0.780
L4/L5	0.66 (0.46–1.17)	0.65 (0.43–1.00)	0.676
L5/S1	0.67 (0.35–1.07)	0.67 (0.33–1.09)	0.496

Values are presented as median and 5–95th percentiles

Relative CSAs of the psoas major muscles are presented as the ratio between absolute CSA of the psoas major muscle and CSA of the corresponding intervertebral disc

CSA Cross-sectional area

* Mann–Whitney test

Table 3 The differences in relative CSAs of the psoas major muscles between controls and patients at the level of L3/L4, L4/L5, and L5/S1 intervertebral disc

	Controls	Patients	*P* value*
L3/L4	0.49 (0.29–0.86)	0.61 (0.40–1.02)	<0.05
L4/L5	0.58 (0.34–1.17)	0.66 (0.45–1.14)	<0.05
L5/S1	0.57 (0.33–1.29)	0.67 (0.33–1.08)	0.247

Values are presented as median and 5–95th percentiles

Relative CSAs of the psoas major muscles are presented as the ratio between absolute CSA of the psoas major muscle and CSA of the corresponding intervertebral disc

CSA Cross-sectional area

* Mann–Whitney test

Table 4 Frequencies (%) of the fat infiltration in psoas major muscle with regard to the group and grade

	Grade 0	Grade 1	Grade 2	Grade 3	All
Control	70 (83.3)	14 (16.7)	0	0	84 (100)
Patients	83 (84.7)	15 (15.3)	0	0	98 (100)
P value*	0.802				

In purpose of quantitative analysis of non-muscle (fat) tissue infiltration a 4-grade visual scale was used (Grade 0 = no apparent non-muscle tissue, Grade 1 = minor deposits of non-muscle tissue (<25 %), Grade 2 = moderate infiltration of non-muscle tissue (25–50 %), and Grade 3 = severe infiltration of non-muscle tissue (>50 %)

* Chi-square test

($P < 0.05$). Our results showed significantly smaller CSAs of the muscle in patients with degenerative changes present on the lumbar intervertebral discs compared to the patients without apparent degenerative changes at these levels. At the level of L5/S1 intervertebral disc there were no differences in CSA of the PM ($P = 0.499$) (Table 5).

Analysis of the relative CSAs of the PM in the patients group with regard to the presence of Modic changes in the lumbar vertebral bodies

At the level of L3/L4 intervertebral disc no significant difference in the CSAs of the PM between groups was found ($P = 0.088$). However, at the levels of L4/L5 and L5/S1 intervertebral discs, patients with present Modic changes in the lumbar vertebral bodies showed significantly smaller CSAs of the PM compared to the patients without Modic changes ($P < 0.05$) (Table 5).

Correlation between relative CSAs of the PM and fat infiltration of the LPM in the patients group

At all analyzed levels correlation between CSAs of the PM and fat infiltration of the LPM was negative (L3/L4: $r = -0.277$, L4/L5: $r = -0.332$, L5/S1: $r = -0.39$) (Fig. 3).

Discussion

In this study we have found that LBP patients have significantly bigger CSA of the PM in comparison with control subjects. The analysis of the PM was performed at the levels of L3/L4, L4/L5, and L5/S1 intervertebral discs. Thus we covered the lowest segments of the lumbar spine, where the degenerative changes most often occur [15]. Patients have bigger CSA of the PM compared to control subject's at all analyzed levels although the differences are only significant at the levels of L3/L4 and L4/L5 intervertebral discs (Table 3). Conflicting data have been obtained with regard to the changing of CSA of the PM in case of LBP [11, 12]. Parkkola et al. [11] described smaller PM of the patients with chronic low back pain (LBP) compared to the volunteers. On the other hand, Danneels et al. [12] showed no differences in CSA of the PM between chronic LBP patients and healthy control subjects. Our results do not correspond completely with the results of Danneels et al. [12]. They conducted a comparative study between unoperated CLBP (Chronic Low Back Pain) patients and matched control subjects using computed tomography images but similarly to us, they used the muscle to bone ratios to express muscle's CSA. They found no significant differences between the CSAs of the PM of the patients and healthy controls [12]. Considering the stabilizing function of the PM together with the lumbar back muscles [16], presented hypertrophy of the PM might be the result of its increased activity during the sanation of instability associated with degenerative disorders of lumbar

Table 5 Relative CSAs of the psoas major muscle in the patients group at the level of L3/L4, L4/L5, and L5/S1 intervertebral disc with regard to the presence of degenerative changes of lumbar intervertebral discs and Modic changes in the lumbar vertebral bodies

	L3/L4	L4/L5	L5/S1
Degenerative changes			
Without	0.65 (0.48–1.05) ($n = 58$)	0.85 (0.57–1.63) ($n = 14$)	0.67 (0.33–1.09) ($n = 32$)
With	0.49 (0.39–1.02) ($n = 26$)	0.64 (0.43–0.99) ($n = 70$)	0.68 (0.32–1.07) ($n = 52$)
P value*	<0.05	<0.05	0.499
Modic changes			
Without	0.66 (0.37–0.98) ($n = 34$)	0.82 (0.43–1.06) ($n = 34$)	0.83 (0.40–1.09) ($n = 34$)
With	0.58 (0.41–0.77) ($n = 50$)	0.64 (0.45–0.94) ($n = 50$)	0.63 (0.32–0.77) ($n = 50$)
P value*	0.088	<0.05	<0.05

Values are presented as median and 5–95th percentiles

Relative CSAs of the psoas major muscles are presented as the ratio between absolute CSA of the psoas major muscle and CSA of the corresponding intervertebral disc

CSA Cross-sectional area

* Mann–Whitney test

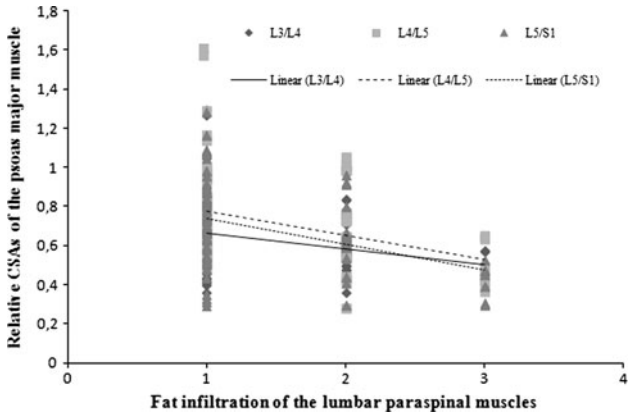

Fig. 3 Correlation between relative CSAs of the psoas major muscles and fat infiltration of the lumbar paraspinal muscles in the patients group at the levels of L3/L4, L4/L5, and L5/S1 intervertebral discs. CSAs of the psoas major muscles are presented as the ratio between absolute CSA of the psoas major muscle and CSA of the corresponding intervertebral disc. Non-muscle (fat) tissue infiltration of the lumbar paraspinal muscles is presented as a 4-grade visual scale (Grade 0 = no apparent non-muscle tissue, Grade 1 = minor deposits of non-muscle tissue (<25 %), Grade 2 = moderate infiltration of non-muscle tissue (25–50 %), and Grade 3 = severe infiltration of non-muscle tissue (>50 %). Correlation between CSAs of the psoas major muscle and fat infiltration of the lumbar paraspinal muscles was tested with Spearman's test

spine [17]. Moreover, some authors described ipsilaterally decreased CSA of the PM caused by unilateral lumbar disc herniation [8] and atrophy of the PM on the affected side in patients with unilateral back pain [9, 10]. Our results showed no differences in CSAs between the left and right PM at all analyzed levels compared to results of Ploumis et al. [10]. However, in aforementioned study only patients with monosegmental degenerative disc disease were included and only patients with symptoms of unilateral back pain were analyzed.

Only few studies analyzed infiltration of the fat tissue in the PM [13, 18]. Furthermore, some studies described significant atrophy of the LPM, and especially multifidus, in the patients with LBP [3, 9, 14, 19]. Consequently, the atrophy of the LPM might further increase the stabilizing role of the PM. In favor of that, our study showed very small atrophic changes of the PM in the form of fat infiltration. More than 80 % of our examinees, controls as well as patients, did not show any signs of detectable fat infiltration within the PM. The PM of other examinees showed minimal fat infiltration and there were no significant differences of the fat infiltration in PM between controls and patients as well (Table 4). This result corresponds to those presented by Ropponen et al. [13]. Although performed only on healthy examinees, they described none or minimal fat infiltration in the PM whilst in LPM fat infiltration reached high levels [13]. However, our findings of negative correlation between CSAs of the PM and fat infiltration of the LPM (Fig. 3) suggest opposite as smaller CSA of the PM is followed with bigger fat infiltration of the LPM.

Degenerative changes of the lumbar spine are manifested by disk space narrowing, T2-weighted signal intensity loss from the intervertebral disk, presence of fissures, fluid, vacuum changes and calcification within the intervertebral disk, ligamentous signal changes, marrow signal changes, osteophytosis, disk herniation, malalignment, and stenosis [20]. Additionally, degenerative changes of the intervertebral discs can be followed by the processes in the vertebral bodies seen in a form of the altered signal intensity on MR imaging called Modic changes. Type 1 changes are associated with active low back symptoms and segmental instability and seem to be inflammatory in origin, thus reflecting a state of active degeneration and biomechanical instability of the lumbar spine. Type 2 changes are less clearly associated with LBP, though superimposed

stress may occasionally cause their reverse conversion into type 1 changes [21].

The results of our study showed that patients with apparent degenerative changes of the lumbar intervertebral discs had smaller CSA of the PM compared to patients without degenerative changes at the levels of L3/L4 and L4/L5 intervertebral discs. Patients with present Modic changes showed smaller CSA of the PM compared to the patients without those changes at the levels of L4/L5 and L5/S1 intervertebral discs (Table 5). A possible cause of the reduction of the PM CSA might be an inactivity caused by pain. Degenerative changes, not only of the lumbar spine, are often related to pain (LBP syndrome, cervical pain syndrome). Moreover, Modic changes are strongly associated with lumbar pain [22, 23]. Furthermore, LBP patients might show avoidance behavior as a result of the fear of pain or (re)injury [24]. In the effort to reduce pain sensations patients minimize or even completely stop the movements of the painful area thereby indirectly excluding from usage of certain groups or even isolated muscles. Disuse causes atrophy of the muscles which is typical for different conditions accompanied with the inactivity. However, CSA of the PM in the patients with apparent degenerative changes of lumbar intervertebral discs as well as with present Modic changes in lumbar vertebral bodies was still bigger than one of the controls, thus indicating that PM remains active regardless of the presence of degenerative changes of the lumbar spine.

There were several limitations in our study. The Pfirrmann [25] classification might be a valuable additional assessment in our study for further analyses of our findings. In addition, increased signal on transverse T1-weighted MR images is more specific for fatty infiltration of the muscle compared to the acquired transverse T2-weighted MR images. Signal quantification of the assessed muscles, quantification with MR spectroscopy or the Dixon MRI technique might reveal more subtle fatty muscle infiltration. Therefore these techniques might reveal potential differences in muscle lipid infiltration of the PM in our study.

In conclusion, bigger CSA of the PM presented in the patients with the chronic LBP syndrome compared to the controls suggests its increased activity during the sanation of instability associated with degenerative disorders of lumbar spine. Marked degeneration of the lumbar spine in the LBP patients seen in the form of apparent degenerative changes of intervertebral discs as well as Modic changes followed by enhanced pain causes reduction of the PM CSA probably due to the decreased movement of such patients in relation to LBP patients without marked changes. Nevertheless, PM seems to remains active regardless of the presence of degenerative changes of the lumbar spine.

Conflict of interest None.

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