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FULL PAPER

MRI assessment of paraspinal muscles in patients with acute and chronic unilateral low back pain

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Objective: To investigate the changes in paraspinal muscle cross-sectional area (CSA) and composition, using the digital data from lumbar spine MRIs of patients with acute and chronic low back pain (LBP).
Methods: In total, 178 patients with unilateral LBP who had lumbar MRI examination were recruited. The data were obtained by a retrospective documentation audit. The CSAs and mean signal intensities of the bilateral paraspinal muscles [psoas major (PM), quadratus lumborum, multifidus (MF) and erector spinae (ES)] were measured, and the percentage of fat infiltration was calculated. The data between the painful side and non-painful side were compared, and between-group comparisons were tested. 42 patients with chronic unilateral LBP could indicate the problem level, and the CSA and mean signal intensity of the MF muscle were analysed at the problem level, and one vertebral above and one vertebral level below the problem level.
Results: The CSAs of the PM and ES muscles were significantly decreased in the acute LBP group, while in the chronic LBP group, significant reduction in CSA was found in the MF and ES muscles on the painful side compared with the non-painful side. The mean signal intensity and fat content of the ES muscle on the painful side in the chronic LBP group was significantly higher than that on the painful side in the acute LBP group. The significant decrease of CSA in the MF muscle was found at multiple levels on the painful side.
Conclusion: The present findings show that there is selective ipsilateral atrophy of paraspinal muscles, specific to the symptomatic side, in patients with acute and chronic LBP. The reduction of the muscle CSA and increased fatty infiltration occurred synchronously, and the extent of change is significantly greater in chronic LBP in the ES muscle. Atrophy of the MF muscle appears to be at multiple levels but side specific in relation to symptoms in patients with chronic LBP, and the decreased muscle CSA may occur prior to fatty infiltration.
Advances in knowledge: There are specific paraspinal muscles undergoing atrophy and fatty infiltration in patients with acute and chronic LBP on the symptomatic side. The CSA of the MF muscle decreased at multiple levels on the symptomatic side in patients with chronic unilateral LBP, which may occur prior to fatty infiltration.

INTRODUCTION

Low back pain (LBP) is a common disease in adults. In the United States, there were 43–60% patients suffering from LBP in the previous 3 months.[1] The aetiology of LBP is comprehensive, and most patients with acute LBP tend to recover from pain within 8–10 weeks with or without rehabilitation intervention.[2] For patients with chronic LBP (defined as sustained back pain over a period of 3 months), intensive rehabilitation has proven effective.[3] The local paraspinal stabilizing muscles of the back have drawn more and more attention, and specific muscle strengthening exercises have been reported to decrease the pain and improve the stability of the spine.[4–7]

Atrophy of the paraspinal muscles has been frequently demonstrated in patients with LBP,[8–10] and in patients with unilateral LBP, decreased cross-sectional area (CSA) of the multifidus (MF) and psoas major (PM) muscles has been reported on the painful side compared with the non-painful side.[11] The CSA of paraspinal muscles has been associated to some degree with the muscle's capacity to generate force since force is proportional to the CSA of the muscle. The paraspinal muscles are considered as dynamic stabilizers by providing stability to the motion of spinal units. Muscle force imbalance may lead to kinetic instability of the spine. Another degenerative change in the paraspinal muscles of LBP is increased fat deposition. Intramuscular fatty infiltration has been reported in the

Table 1. Participant demographics (mean ± standard deviation)

Demographics	Acute LBP group	Chronic LBP group	p-value
Gender (male/female)	39/37	44/58	0.850
Age (years)	44.63 ± 12.42	45.23 ± 10.89	0.732
Height (m)	1.67 ± 0.19	1.66 ± 0.11	0.691
Weight (kg)	55.36 ± 6.59	57.01 ± 7.26	0.708
Body mass index (kg m^{-2})	19.15 ± 4.21	20.37 ± 3.65	0.862
Left/right	47/29	60/42	0.721

LBP, low back pain.

paraspinal muscles of LBP by using MRI assessment,[12] and it suggests that fat infiltration is strongly associated with LBP in adults.[13] MRI is useful for evaluating the muscle CSA and composition quantitatively because of its good soft-tissue contrast and it being radiation free. Currently, little is known about the differences in the paraspinal muscle CSA and composition between acute and chronic LBP. Many investigations on the paraspinal muscles of patients with LBP have focused on the MF muscle because of its unique segmental innervations;[11,14,15] few of these studies focused on multisegmental changes of the MF muscle of patients with unilateral LBP.

The overall objective of the present study was to investigate the changes in the paraspinal muscle CSA and composition, using the digital data from lumbar spine MRIs of patients with acute and chronic LBP.

METHODS AND MATERIALS

Subjects

In total, 178 patients with unilateral LBP who had lumbar MRI examination between 1 January 2012 and 31 August 2013 at the Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, China were recruited in this study. Inclusion criteria were patients at the age of 18–65 years, with the symptoms of unilateral LBP or referral to one lower limb. Exclusion criteria included: (1) a history of back surgery; (2) a history of spinal fracture or injuries; (3) primary or metastatic spinal tumour; (4) ankylosing spondylitis or infectious diseases; (5) deformities of the spine, such as spondylolisthesis; (6) other systemic diseases, such as diabetes mellitus and renal disorder; (7) patients who had received lumbar muscle training in the past year. Acute LBP was defined as onset no more than 3 months and chronic LBP was defined as lasting more than 3 months. The patients' heights and body weights were documented, and their body mass indexes (BMIs) were determined. BMI was calculated as weight/(height)^2 (in kilogrammes per square metre). There were no significant differences between the acute and chronic LBP groups for gender, age, height, weight, BMI and the symptomatic side (Table 1). The study plan was approved by the Ethics Committee of the Sun Yat-sen Memorial Hospital.

Imaging procedures

T_2 weighted images were acquired using a 3-T MRI-scanner (Philips Achieva®; Philips Healthcare, Best, Netherlands) with the repetition time 2500 ms and echo time 60 ms. Slice thickness was 5 mm. The matrix was 332 × 266 and the field of view was 200 mm. The patients were placed supine with a pillow positioned underneath the knees, the hips and knees were slightly flexed, and the neutral positions of the patients were maintained in order to avoid lordosis of the lumbar spine. The MRI scans showed four images per spinal level. Axial slice at the level of L4 upper endplate was selected to calculate the muscle CSA because the paraspinal muscles were demonstrated to be at their maximal CSAs at L3–L4 level.[12,16] For those patients with chronic unilateral LBP, the level indicated by the symptom of documentation was measured, together with one vertebra above and one below for MF muscle analysis.

Data analysis

The axial images were analysed using Onis and ImageJ software (Wayne Rasband, National Institutes of Health, Bethesda, MD). The CSAs and mean signal intensities of the bilateral paraspinal muscles [PM, quadratus lumborum (QL), MF and erector spinae (ES)] were measured by constructing polygon points around the outer margins of individual muscles (Figure 1). After setting the threshold of the image, the percentage of fat infiltration was calculated by tracing the outline of an individual muscle by ImageJ software.

Measurement reliability

All measurements were conducted by the same person. Intratester reliability was assessed by repeated evaluation of 10 of all the images per group. An intraclass correlation coefficient (ICC) was calculated to assess the intrarater reliability of the measurements.

Statistical analysis

Statistical analysis was performed using SPSS® v. 15 (SPSS Inc., Chicago, IL) with statistical significance set at $p < 0.05$. The data between the painful side and the non-painful side were compared using paired samples t-test. Between-group comparisons were tested using independent samples t-tests.

RESULTS

Changes in muscle cross-sectional area

In the acute LBP group, the mean CSAs of four muscles were all decreased on the painful side compared with those of the

Figure 1. The individual paraspinal muscles were outlined by constructing polygon points. m1, m2: psoas major; m3, m4: quadratus lumborum; m5, m6: multifidus; m7, m8: erector spinae.

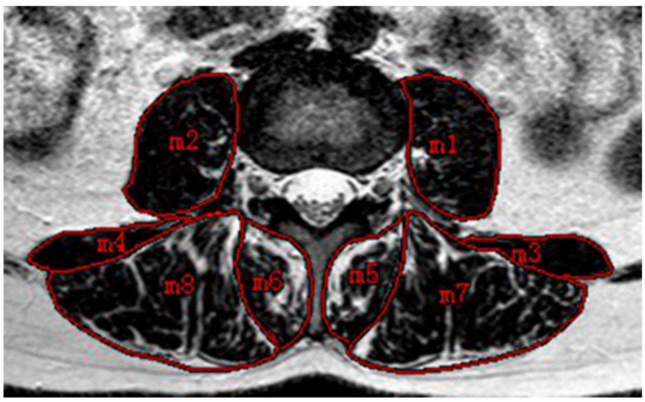
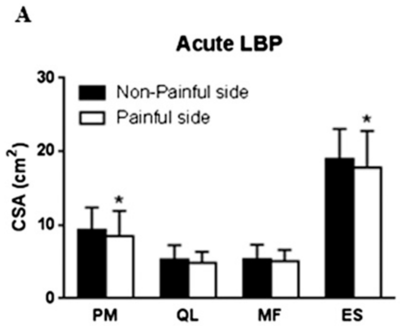


Figure 2. Changes in the muscle mean cross-sectional area (CSA) of the paraspinal muscles in the acute (a) and chronic low back pain (LBP) (b) groups. Values are mean ± standard deviation. *Significant differences compared with the non-painful side. ES, erector spinae; MF, multifidus; PM, psoas major; QL, quadratus lumborum.

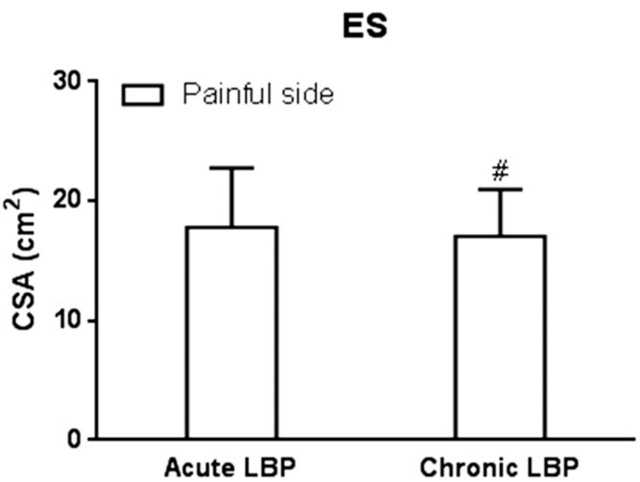


non-painful side. Among these muscles, the CSAs of the PM and ES muscles were significantly decreased (PM, $p = 0.042$; ES, $p = 0.023$) (Figure 2a). In the chronic LBP group, significant reduction in the mean CSA was found in the MF and ES muscles on the painful side compared with the non-painful side (MF, $p = 0.016$; ES, $p = 0.046$); however, there was no significant difference between the bilateral muscles' CSA in the PS and QL muscles (Figure 2b). The mean CSA of ES of the painful side in the chronic LBP group was significantly smaller than that of the painful side in the acute LBP group (Figure 3). Figure 4 demonstrated the paraspinal muscles of one of the patients with acute LBP, the CSAs of the PM and ES muscles were decreased on the right painful side.

Changes in mean signal intensity

The signal intensity was measured to indicate the paraspinal muscle composition. A consistent result was found in the changes of muscle mean signal intensity compared with that of the muscle CSA. The mean signal intensities of the PM and ES muscles on the painful side were significantly higher than those on the non-painful side in the acute LBP group (PM, $p = 0.049$; ES, $p = 0.045$), whereas there was no significant change in the QL and MF muscles (Figure 5a). In the chronic group, the mean signal intensity was significantly higher in the MF and ES muscles on the painful side than on the non-painful side (MF, $p = 0.046$; ES, $p = 0.023$), and there was no significant increase of mean signal intensity in the PM and QL muscles (Figure 5b). The mean signal intensity of the ES muscle on the painful side in the chronic LBP group was significantly higher than that on the painful side in the acute LBP group ($p < 0.05$).

Figure 3. Comparison of the mean cross-sectional area (CSA) of the erector spinae (ES) muscle on the painful side in the acute and chronic low back pain (LBP) groups. Values are mean ± standard deviation. #Significant differences compared with the acute LBP group.



Changes in fatty infiltration

The fatty infiltration was measured by the percentage of fat content in total CSA of an individual muscle. The percentages of fat content in the PM and ES muscles on the painful side were significantly higher than that on the non-painful side in the acute LBP group (PM, $p = 0.031$; ES, $p = 0.001$); However, there was no significant difference in the QL and MF muscles (Figure 6a). These results were in agreement with that in the mean signal intensity. The difference of fat content in the paraspinal muscles of the chronic LBP group is presented in Figure 6b. On the painful side, the percentages of fat content in the MF and ES muscles were significantly higher than that on the non-painful side (MF, $p = 0.035$; ES, $p < 0.001$). There was

Figure 4. The paraspinal muscles of a patient with low back pain with acute pain on the right side. The psoas major and erector spinae muscles decreased in cross-sectional area compared with that on the left side.

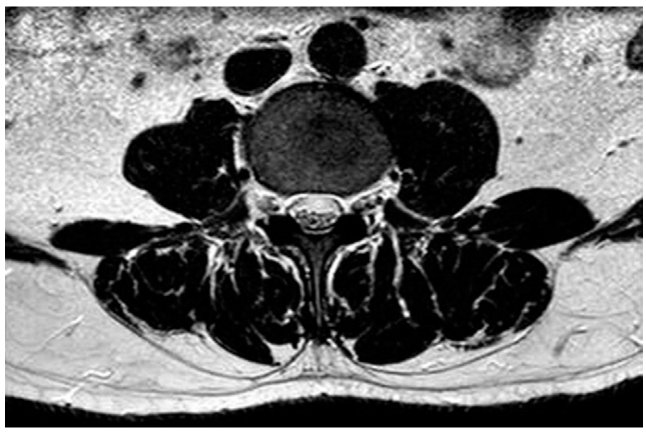
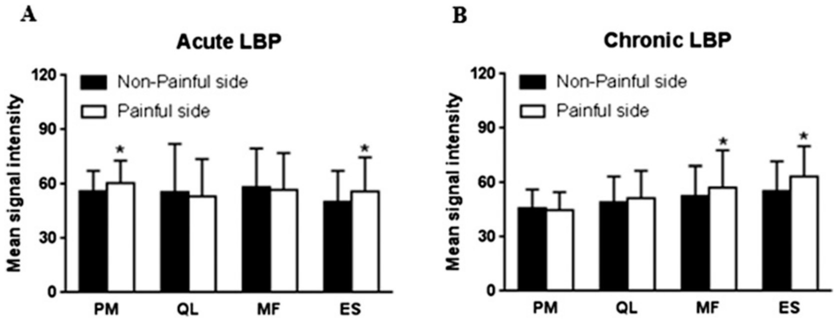


Figure 5. Changes in the mean signal intensity of the paraspinal muscles in the acute (a) and chronic low back pain (LBP) (b) groups. Values are mean ± standard deviation. *Significant differences compared with the non-painful side. ES, erector spinae; MF, multifidus; PM, psoas major; QL, quadratus lumborum.



no significant change in fat content in the QL and PM muscles between the painful and non-painful sides. The fat content of the ES muscle on the painful side was significantly higher in the chronic LBP group than that in the acute LBP group (Figure 7). A representative image of fatty infiltration in the MF and ES muscles of a patient with chronic LBP was demonstrated in Figure 8.

Changes in multifidus at multisegmental levels in patients with chronic unilateral low back pain

The clinical symptoms of 42 patients could indicate the problem level. In two of the patients, the clinically indicated level was L3/L4, in 26 L4/L5 and in 14 L5/S1. The measurements of the CSA of the MF muscle are presented in Table 2. It can be seen that the CSA of MF was significantly decreased at the problem level, and one vertebral level above and one vertebral level below the problem level on the painful side compared with that of the non-painful side. The greatest reduction of 15.94% in CSA of the MF muscle was found at the clinically indicated level. There were also smaller, but statistically significant, decreases in the CSA of the muscle at the adjacent levels, one vertebral level above and one vertebral level below, by 6.80% and 11.10%, respectively. The mean signal intensity of the MF muscle in patients with chronic unilateral LBP was significantly increased on the painful side at the problem level. As for the other two adjacent levels, the mean signal intensities had no significant change (Table 3).

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 good, indicating that the evaluations were reliable. The results of the present study are in agreement with that of others that there are selective atrophic changes occurred in the PM and MF muscles on the symptomatic side in unilateral LBP.[11] A reduction of muscle CSA in acute LBP may due to disuse because of the pain at the acute stage. Hides et al[17] demonstrated unilateral muscle atrophy in the MF muscle in acute LBP, and the atrophic change isolated to one vertebral level. The authors suggested that it might be an inhibition along a long-loop reflex to protect impaired muscles at the symptomatic level. In patients with chronic LBP, the decreased CSAs of the paraspinal muscles have been repeatedly reported.[8,11,15] One explanation could be pain as an inhibitor for the stabilizing muscles on the painful side and compensatory hypertrophy could happen on the non-painful side, which caused imbalance of the paraspinal muscles. Another investigation suggested that the atrophic change in the MF muscle was probably related to the degenerative changes of the lumbar discs.[16] However, our results show side-related atrophy of the MF muscle, indicating that the process is not a general deconditioning of the stabilizing muscles. To further investigate the morphological change of the MF muscle, which is

Figure 6. Changes in percentage of fat content of the paraspinal muscles in the acute (a) and chronic low back pain (LBP) (b) groups. Values are mean ± standard deviation. *Significant differences compared with the non-painful side. ES, erector spinae; MF, multifidus; PM, psoas major; QL, quadratus lumborum.

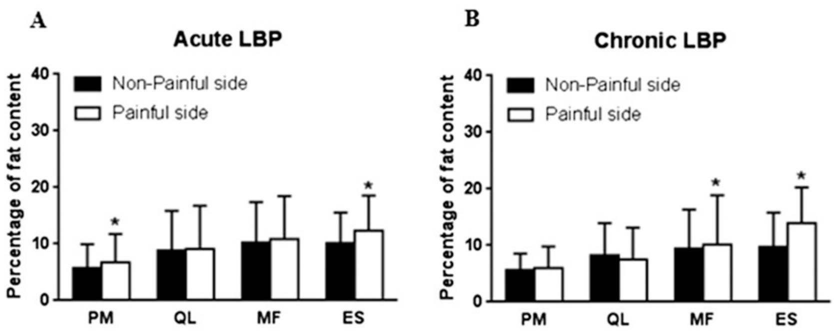
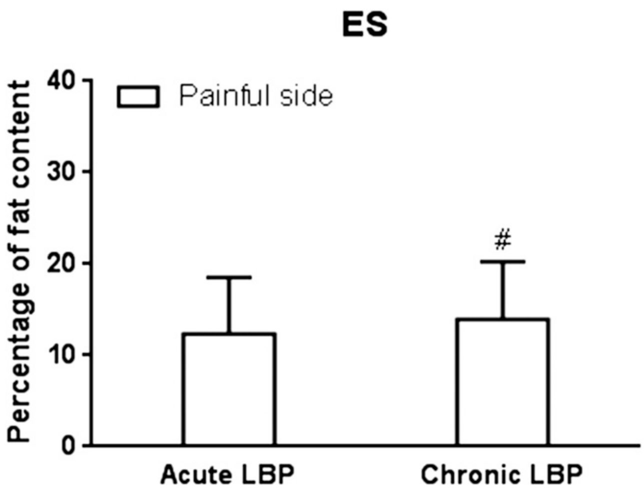


Figure 7. Comparison of fat content of the erector spinae (ES) muscle on the painful side in the acute and chronic low back pain (LBP) groups. Values are mean ± standard deviation. #Significant differences compared with the acute LBP group.



one of the most important lumbar stabilizer muscles, we compared the CSA of the MF muscle at three consecutive vertebral levels and found that atrophy occurred at all vertebral levels with the greatest reduction at the problem level. Severe and extensive atrophy in the MF muscle has been found to be associated with radiculopathy.[18] In the patients with chronic unilateral LBP, nerve root compression or irritation may exist and induce denervation of the muscle. Atrophy of the MF muscle was considered to be related to denervation by a nerve root or dorsal ramus injury.[19] For the patients with chronic LBP, even without radicular symptoms, denervation of the MF muscle may also occur, and dorsal ramus injury can cause atrophy of the MF muscle at multiple spinal levels. What's more, the decreased CSA of the MF muscle at the problem level may lead to local muscle weakness and unstable of the spine, then unstability of the adjacent vertebral levels make the muscle more vulnerable to atrophy.

Figure 8. The fatty infiltration of the paraspinal muscles of a patient with chronic low back pain. The fat content of the multifidus and erector spinae muscles on the painful side (left) was higher than that of the right side.

Table 2. The cross-sectional area (CSA) of multifidus in patients with chronic unilateral low back pain (mean ± standard deviation)

Comparisons	One vertebral level above problem vertebral level CSA (cm^2)	Problem vertebral level CSA (cm^2)	One vertebral level below problem vertebral level CSA (cm^2)
Painful side	6.45 ± 1.95	4.64 ± 1.71	3.81 ± 1.41
Non-painful side	6.83 ± 1.93	5.33 ± 1.93	4.27 ± 1.70
Percentage difference	6.80	15.94	11.10
p-value	0.000	0.000	0.000

In the present study, the mean signal intensity was used as an indicator to evaluate the paraspinal muscle composition. The higher mean signal intensity reflects more fat content in the muscle. This method can assess the fat content in the paraspinal muscles in an objective, quantitative and reproducible manner compared with using a 4-point visual scale (0 = no apparent non-muscle tissue, 1 = minor deposits of non-muscle tissue, 2 = moderate deposits of non-muscle tissue and 3 = large areas of non-muscle tissue). It has been demonstrated that the intrarater agreement for the fat content from signal intensities of MRI images of cervical muscles is excellent (ICC, 0.94–0.98).[20] Our results demonstrated that the mean signal intensities of the PM and ES muscles on the painful side were significantly higher than that of the non-painful side in patients with acute LBP. These results were consistent with our findings of fatty infiltration that significant increased fatty infiltration was also found in the PM and ES muscles on the painful side in the acute LBP group. The results for the chronic LBP group were also in agreement between the mean signal intensity and fatty infiltration in the MF and ES muscles on the painful side. Our results confirm some previous studies results,[9,12,21] but not others.[22] The differences in methodology may lead to these controversial conclusions. The mechanisms of intramuscular fat filtration are far from clear. It has been previously suggested owing to altered differentiation of the fibroblasts after paraspinal muscle inflammation.[9] Our results demonstrated, in both the mean signal intensity and the fat content in the paraspinal muscles, that the extent of fat deposition was higher with longer duration of symptom, which might imply that the fat deposition is a process of cyclic superimposition with time. Furthermore, when attention was focused on the MF muscle, the mean signal intensity of MF in patients with chronic unilateral LBP was significantly increased on the painful side at one single problem level. It may suggest that the decreased muscle CSA may occur prior to fatty infiltration in patients with chronic LBP. Another possible explanation is that the problem levels vary between patients, and the levels above and below are therefore also varied. Large standard deviations of the mean signal intensities may account for the results. An increase in intramuscular fat may affect the

Table 3. The mean signal intensity of multifidus in patients with chronic unilateral low back pain (mean ± standard deviation)

Comparisons	One vertebral level above problem vertebral level	Problem vertebral level	One vertebral level below problem vertebral level
Painful side	57.75 ± 22.68	55.28 ± 20.17	55.88 ± 16.83
Non-painful side	56.70 ± 21.15	52.11 ± 20.96	53.31 ± 19.27
p-value	0.599	0.004	0.081

contractility of muscles for stabilizing the spine and make these patients prone to segmental instability. Specific muscle training aimed at enhancing the activity of the stabilizer muscles should be applied to prevent severe fatty infiltration of the muscles.

This study has some limitations. The data for this investigation were obtained by a retrospective documentation audit. The lack of symptoms (such as the visual analogue score) and function of the spine assessment makes it unclear whether the atrophic changes are associated with the severity of symptoms or deficits of back function.

In conclusion, the present findings show that there is selective ipsilateral atrophy of the paraspinal muscles, specific to the symptomatic side, in patients with acute and chronic LBP. The reduction of the muscle CSA and increased fatty infiltration occurred synchronously, and the decreased CSA of the MF muscle appears to be at multiple levels but side specific in relation to symptoms of chronic LBP.

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