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ORIGINAL ARTICLE

CT measurement of trunk muscle areas in patients with chronic low back pain

Müzeyyen Kamaz, Demet Kıreşi, Hasan Oğuz, Dilek Emlik, Funda Levendoğlu

PURPOSE
The objective of this study was to determine the cross-sectional area changes of the paraspinal, isolated multifidus, quadratus lumborum, psoas, and the gluteus maximus muscles with CT in patients with chronic low back pain.

MATERIALS AND METHODS
In this study, we evaluated 36 patients with chronic low back pain and 34 healthy volunteers. The mean age of the patients was 43.2±6.9 years (range, 30–58 years) and the mean age of control group was 44.4±6.9 years (range, 31–61 years). We defined pain that lasts more then one year as chronic pain. Female patients were selected for standardization. All patients were housewives. None of the patients or controls engaged in physical activity other than routine housework. We used a visual analog scale and the Oswestry Pain Questionnaire for clinical evaluation. We made CT cross-sections of the paraspinal muscles at the upper and lower endplates of L4, and of the gluteus maximus at the head of the interfoveal level.

RESULTS
In the patient group the multifidus, psoas, and quadratus lumborum cross-sectional areas were smaller than in the control group, and the *P* values were $P=0.002$, $P=0.042$, and $P=0.047$, respectively, at the L4 endplate. At the L4 endplate level, cross-sectional areas of the multifidus and paravertebral muscles in the patient group were smaller than in the control group, and the difference was statistically significant ($P=0.001$, $P=0.010$, respectively). We did not find any significant difference between the patient and the control groups in gluteus maximus cross-sectional area.

CONCLUSION
Chronic low back pain caused atrophy of the paraspinal, isolated multifidus, quadratus lumborum, psoas, and the gluteus maximus muscles to varying degrees, which was most prominent in the multifidus. Atrophy was noted in all of the studied muscles, except the gluteus maximus. The reliability of CT in measuring the cross-sectional areas of the back muscles was acceptable.

Key words: • back pain • computed tomography • muscle • cross-sectional area measurement

From the Departments of Physical Medicine and Rehabilitation (M.K., H.O., F.L.), and Radiology (D.K. ✉ *drdemet25@hotmail.com*, D.E.), Selçuk University School of Medicine, Konya, Turkey.

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Low back pain is the second leading cause of manpower loss in many countries, following headache, and it is a condition that decreases productivity. It may be seen in 80% of the general population during any period of life (1–3). Low back pain progresses in an undulating pattern, and 10% of all low back pain is chronic. In 90% of acute low back pain, the symptoms resolve in 2–4 weeks; however, in a study by Papageourgiu et al. (4) it was reported that 69% of cases showed a second attack of pain within the first year. The reason for these recurrences is unclear. An important cause is considered to be the instability of the moving segment of the lumbar vertebrae (5).

In recent years, numerous data regarding the size and properties of muscles in patients with low back pain have been published. The lumbar muscles of patients and healthy subjects have undergone microscopic assessment, and structural changes have been shown in the muscles of patients with back pain (6–8).

The most important function of the trunk muscles is to support the vertebrae. The extensor muscles of the lower back are important in the dynamic control of the moving segments. The synergistic contractions of the multifidus and deep abdominal muscles function as a dynamic corset for the lumbar vertebrae (9). Many studies have shown that the multifidus is the most important muscle for lumbar segmental stability (9, 10). It has been proven that the quadratus lumborum muscle acts synergistically on the lumbar vertebrae, along with the deep erector spinae and the psoas muscles (11). This muscle contributes to the maintenance of the stability of the lumbar spine and pelvis on the frontal, horizontal, and sagittal planes, acting together with the iliolumbar ligament, deep erector spinae, psoas major, and the pelvic muscles. The psoas major muscle functions to keep the body erect in all 3 planes, together with the deep erector spinae, multifidus, and quadratus lumborum muscles. Contraction of the psoas muscle assists lumbar stability. The gluteus maximus, which is the primary extensor muscle of the pelvis, contributes to the stability of the back through the thoracolumbar fascia (11).

There are 2 main findings in the degeneration of muscles: decrease in the size of the muscle and increase in the amount of fat deposits (12). Recent research has shown prominent atrophy in the multifidus muscles in patients with chronic low back pain (CLBP) (13). Non-use of the muscles due to low back pain and immobilization causes atrophy, both in the flexor and extensor muscles. The morphological changes in the muscles may be shown in a non-invasive way by computed tomography (CT) (8, 13, 14). Magnetic resonance imaging (MRI) (15–17) and ultrasound (18) are also used for the same purpose. The findings gathered from direct and objective examination of muscles will contribute to the explanation of the pathogenesis of low back pain, as well as its diagnosis and treatment (12, 13, 19, 20). In studies performed to date, the structural changes of only small muscle

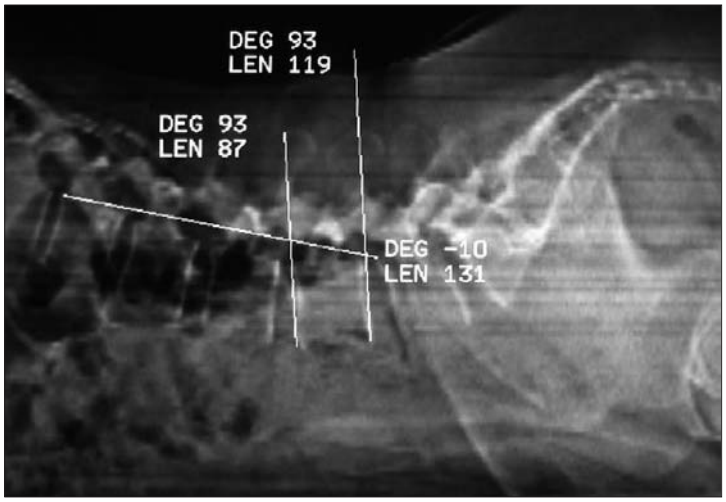

Figure 1. Lateral scanogram shows angle measurement in order to determine the angle of lordosis.

groups, such as the multifidus and the paraspinal muscles, have undergone evaluation by CT (8, 13, 14) and MRI (15–17). In order to explain the effect of CLBP on muscles, more muscle groups should be investigated. In the present study, we aimed to evaluate changes in the muscles that provide lumbar stability, including the multifidus, paraspinal muscles, psoas major muscle, quadratus lumborum, and gluteus maximus, in patients with CLBP and in healthy controls by examining their CT images.

Materials and methods

Atrophy of the paraspinal muscles (multifidus, iliocostalis, longissimus), isolated multifidus, quadratus lumborum, psoas major, and gluteus maximus in patients with CLBP and in healthy volunteers was investigated by measuring muscle area in CT images.

The study included 44 female patients with CLBP and 42 volunteers without low back or leg pain, who presented to the Physical Medicine and Rehabilitation Department of our hospital between March 2002 and December 2002. Pain lasting for more than a year was accepted as chronic pain. In all, 16 cases (8 from the patient group and 8 from the control group) were excluded because their lordosis angle did not fit the predetermined criteria. The study was conducted with the remaining 36 CLBP patients and 34 controls. The patient group and the control group were chosen among housewives in order to facilitate the statistical analysis of the degree of physical activity. Apart from daily housework, none of the subjects from either group participated in any other physical activity such as sports. Detailed histories were obtained and detailed physical examinations were performed on all patients, including radiation of the pain and any accompanying systemic diseases. Complete blood count, erythrocyte sedimentation rate, brucella titration analysis, and other studies, when needed, were measured in all subjects. The age of the subjects in both groups was between 30 and 60 years.

In order to determine the angle of lordosis, each patient laid on her back with a pillow under the small of the back and the lordosis angle was brought to a minimum. Antecedent studies (12) were considered as the basis for the method of determining the angle of lordosis and a line was drawn between the dorsal upper ends of L1 and L5. The angle between this line and the line traversing the L4's upper and lower endplates was measured. Cases that did not fit the criteria of lordosis angle, which was determined as 82° ± 5° at the upper level of L4 and 85° ± 5° at the lower level of L4, were excluded from the study (Fig. 1).

The study was approved by the ethics committee of our hospital. All the included patients were informed about the study and each signed an informed consent form.

The criteria for exclusion were previous lumber surgery, lumbar lordosis exceeding 10°, presence of neuromuscular or joint disease, signs of systemic disease, carcinoma or organ diseases, and exercising the lumbar muscles within the previous 3 months.

The weight and height of each subject was recorded prior to the study. The body mass index (BMI) was calculated according to the following formula: weight (kg)/square of height (m^2).

To determine the degree of pain, a 10-cm visual analogous scale (VAS) was used, whereas the Oswestry Pain Questionnaire was used to find out how much the pain affected the ability to perform daily activities.

Cross-sectional area (CSA) of the paraspinal and psoas muscles are best visualized in imaging sections through the level of L4 (20); therefore, transaxial sections from the upper and lower plates of L4 were obtained in order to determine the CSA of the paraspinal, quadratus lumborum, and the psoas muscles. On the repeated trial imaging studies, it was determined that the CSA of the gluteus maximus muscle was best visualized in sections going through the interfoveol line. The imaging position was standardized because the position of the joint and the size of the muscle may affect the CSA of the muscles. All the patients were placed in the prone position while CT were performed in order to avoid the compression of back muscles, and the hips were placed in the neutral position. The lumbar lordosis was minimized by placing a pillow under the small of the back. All the patients were asked to remain motionless and flaccid during the imaging process. CT (Picker PQS 2000) was performed at 130 kWe and 175 mA, and the sections were 5 mm thick. Measurement of the area of the muscles was made by calculating the mean of the bilateral areas of the paraspinal (multifidus, longissimus, iliocostalis), isolated multifidus, psoas, quadratus lumborum, and gluteus maximus muscles (Fig. 2). These measurements were made by an expert radiologist (D.K.) who was blind to the clinical findings of the patients. Furthermore, measurements of 10 randomly selected patients were repeated by a second radiologist (D.E.). The measurements by both radiologists were compared and the accuracy coefficient was found to be 0.68–0.99.

Statistical evaluation

Statistical analyses of the findings were performed with the SPSS for Windows v.10.0 software program. The relationships between the variables gathered by clinical and radiological measurements in the patient group were compared by the Pearson's correlation test. The differences between patient and the control group data were compared by the Student's t test because all

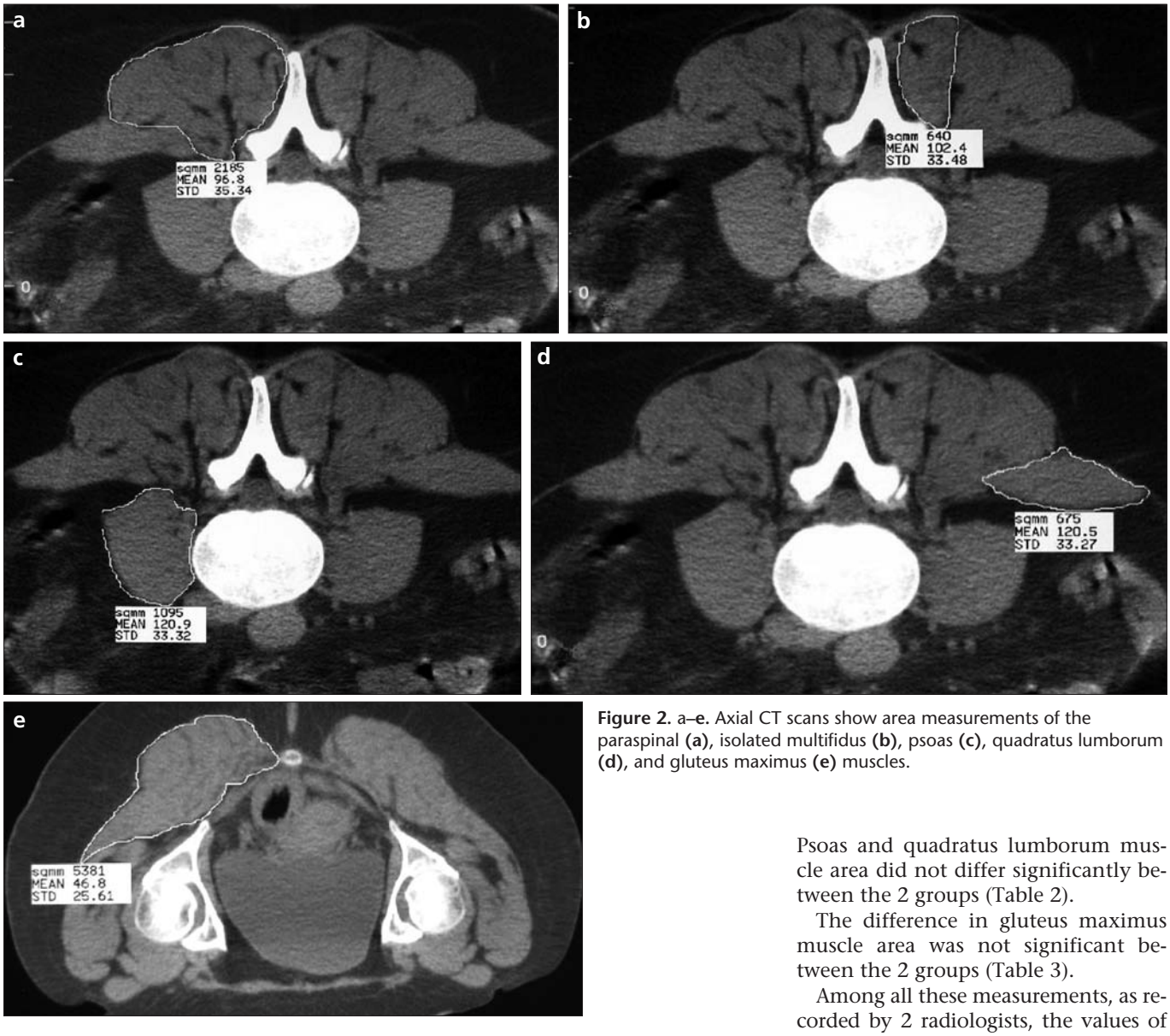

Figure 2. a–**e.** Axial CT scans show area measurements of the paraspinal **(a)**, isolated multifidus **(b)**, psoas **(c)**, quadratus lumborum **(d)**, and gluteus maximus **(e)** muscles.

data corresponded to the Gaussian distribution. Statistical significance was accepted as $P < 0.05$.

Results

The study included 36 patients with CLBP and 34 controls (who presented to the hospital for reasons other than low back or leg pain). The average age of the patient group was 43.2±6.9 years, whereas the average age of the control group was 44.4±7.7 years. The patient and the control groups were similar in terms of age and BMI distribution. Mean BMI was 28.6±2.6 in the patient group and 28.5±3.6 in the control group.

The mean CSA values of the multifidus, psoas, quadratus lumborum, and gluteus maximus muscles at the level of the L4 upper and lower plates in the patient and the control groups, and the *P* and t values according to Student's t test are presented in Tables 1–3.

In sections that traversed the level of the L4 upper plate the area measurements of the multifidus, psoas, and quadratus lumborum muscles were significantly lower in the patient group than in the control group (P=0.002, P=0.042, and P=0.047, respectively). Paraspinal muscle area did not differ significantly between the 2 groups (Table 1).

In sections that traversed the level of L4 lower plate, the area measurements of the multifidus and paraspinal muscles were significantly lower in the patient group than in the control group (P=0.001 and P=0.010, respectively). Psoas and quadratus lumborum muscle area did not differ significantly between the 2 groups (Table 2).

The difference in gluteus maximus muscle area was not significant between the 2 groups (Table 3).

Among all these measurements, as recorded by 2 radiologists, the values of the 10 randomly selected patients had a high accuracy coefficient (0.68–0.99).

Discussion

Muscle degeneration has 2 macroscopic findings: a decrease in muscle size and an increase in the amount of fat deposits, which are both easily demonstrated by CT. There is very limited data on the changes in CSA of the paraspinal muscles in patients with CLBP (21) and in patients with postoperative low back pain (1, 8, 13). In low back pain patients who have either undergone a surgical intervention or have not, excessive fat infiltration has been demonstrated in the back muscles. On the other hand, the amount of fat deposits and the CSA of muscles in patients with CLBP and in healthy controls were measured at different levels, and no statistically significant

differences were detected when the muscles were compared by age, sex, physical activity, height, and weight. Mayer et al. (1) and Laasonen et al. (22) reported the replacement of muscle tissue by fatty tissue as muscular atrophy in postoperative lumbar muscles, whereas Termote et al. (23) reported that the same situation is present in neuromuscular disease. Then again, Parkola et al. (24) found a higher amount of fat deposits in the erector spinae and the multifidus muscles of patients with CLBP than in healthy controls on MRI sections. Nonetheless, there were factors that limited the study by Termote et al. (23). In their study the paraspinal fat area was not measured in a standard way and the relationship between age, and BMI and fat deposits was not demonstrated, and these are important factors. Parkola et al. also failed to demonstrate fatty infiltration in atrophic psoas muscles. McLoughin et al. (25) reported that the percentage of total and peripheral fatty tissue was compatible with age and increase in fatty tissue; however, it was not a sign of atrophy. In a study by Dannels et al. (12), the histogram method was used in order to separate fat deposits from muscles and it was shown that the area of the muscles and the duration of symptoms were not related to fat infiltration (12, 25). These studies support the idea that fat infiltration is primarily a consequence of age and non-use of muscles. Based on these studies, we did not evaluate fat infiltration in the muscles.

All the muscles in the lumbar region contribute to the stability of the lumbar vertebrae. The multifidus muscle, which is the most important muscle for lumbar segmental stability, is the largest paraspinal muscle located at the most medial part (19). This muscle provides the segmental stability and the control of neutral zone movement. Kader et al. (19) detected atrophy in the multifidus muscle in 80% of the cases in a study in which they investigated disc degeneration and nerve compression with MRI images.

Although most previous studies have focused on the multifidus muscle, there have been studies of the other muscles that play a role in the maintenance of vertebral stability (12, 13, 16, 24, 26). In the present study, we evaluated all these muscles, as well as the gluteus maximus muscle, which is thought to contribute to the stability of the back through the thoracolumbar fascia. The CSA values of back muscles in our control group were significantly higher than those in our patient group. Based on measurements made through the L4 upper endplate, the areas of the multifidus, psoas, and quadratus lumborum muscles, and based on measurements made through the L4 lower endplate, the areas of multifidus and psoas muscles were significantly lower in the patient group than in the control group. These findings indicate that atrophy occurred predominantly in the multifidus muscles, as reported in other studies, whereas other back muscles were also affected by atrophy at different levels.

Danneels et al. (12) found atrophy in the multifidus and the paraspinal muscles at the level of the L4 lower plate in a study in which they compared the muscle areas of paraspinal (multifidus, iliocostalis longissimus), isolated multifidus, and psoas major muscles on CT sections through the L3 lower and L4 upper and lower endplates in 32 patients with CLBP and in 23 healthy individuals. Although the findings of their study seem to support our findings, there are some differences. In the above-mentioned study, there were no significant differences between the CSAs at the level of the L4 upper endplate and at L3 level, whereas in our study the multifidus, psoas, and quadratus lumborum muscles were atrophic at the L4 upper endplate level in patients with CLBP. The L3 level was not investigated in our study.

Gibbons et al. (16) compared the CSA of the paraspinal, quadratus lumborum, and psoas major 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. However, they detected degenerative changes in the muscles. We suggest that the very low number of subjects in that study (n=13) may have been the reason

Table 1. Area measurements (cm^2) of the multifidus, psoas, paraspinal, and quadratus lumborum muscles in sections that traversed the level of the L4 upper endplate

Muscles	Patients group (n=36)	Control group (n=34)	t	*P*
MF	3.07±0.89	3.80±1.06	3.147	0.002*
PA	17.66±2.61	18.60±2.61	1.504	0.137
PS	5.60±1.74	6.45±1.69	2.072	0.042*
QL	3.15±0.94	3.63±1.05	2.024	0.047*

*$P < 0.05$ PA: paraspinal muscle QL: quadratus lumborum muscle
PS: psoas muscle MF: multifidus muscle

Table 2. Area measurements (cm^2) of the multifidus, psoas, paraspinal, and quadratus lumborum muscles, in sections that traversed the level of the L4 lower plate

Muscles	Patients group n=36	Control group n=34	t	*P*
MF	4.59±1.13	5.65±1.33	3.620	0.001*
PA	17.89±2.71	19.60±2.68	2.662	0.010*
PS	7.29±1.99	7.85±1.81	1.228	0.224
QL	3.77±1.25	3.98±1.17	0.710	0.480

*$P < 0.05$ PA: paraspinal muscle QL: quadratus lumborum muscle
PS: psoas muscle MF: multifidus muscle

Table 3. Area measurements (cm^2) of the gluteus maximus muscle in sections that traversed the interfoveal level

Muscles	Patients group n=36	Control group n=34	t	*P*
GM	49.31±6.85	48.17±7.31	0.673	0.503

GM: gluteus maximus muscle

that significant differences were not found.

Dangaria and Naesh (26) evaluated the CSA of the psoas muscle in 25 discopathy patients with signs of unilateral sciatic nerve compression on MRI and in 15 healthy individuals, and observed atrophy on the side of compression. Moreover, they concluded that this atrophy was related to the duration of symptoms. In our study, the psoas muscle was also found to be atrophic, but atrophy was not related to the side with symptoms. The reason for this may have been because the symptoms changed sides over time in patients with CLBP, and both sides were affected in most of the patients.

The non-primary muscles of the back, such as the latissimus dorsi and gluteus maximus, contribute to the stability and movement of the back through the thoracolumbar fascia (11); therefore, we examined the gluteus maximus muscle as well. However, we did not detect any significant difference in area measurements between the patients with CLBP and the control group. The reasons that atrophy did not develop in the gluteus maximus of patients with CLBP could be explained by the large area of the muscle, individual differences, and less immobilization than in the primary back muscles during periods of pain.

Non-use due to low back pain may cause atrophy, both in the extensor and in the flexor muscles (24). In our study, there was atrophy in the psoas, which is a flexor muscle, and in the paraspinal and multifidus muscles, which are extensors. CLBP causes atrophy of different muscles to varying degrees. This situation may be due to the inhibition of segmental reflexes in the related muscles (12).

The mechanism of atrophy in the muscles of the lumbosacral region in patients with CLBP is not well understood; however, it is accepted that inflammation and pain in the lumbar vertebrae limit movement of the muscles of this region, especially the multifidus muscle, which leads to atrophy of these muscles. It is suggested that changes occur in the multifidus muscle as a result of reflex inhibition and disturbance of coordination of the trunk muscles in both the subacute and chronic phases (12). The possible mechanism responsible for decreasing muscle size is attributed to direct inhibition or inhibition of long arch reflexes due to pain. Reflex inhibition due to pain continues even when patients do not experience pain, and this is characterized by fatigue during the pain-free period (27).

In conclusion, atrophy develops in the paraspinal, psoas, and quadratus lumborum muscles, and is especially prominent in the multifidus muscle of patients with CLBP to varying degrees. Muscle atrophy is not related to age, BMI, or the level of pain. Atrophy was not observed in the gluteus maximus, which has a partial effect on back movement. The detection of atrophy in the paravertebral muscles of patients with CLBP necessitates the use of exercise programs for the related muscles in the treatment of low back pain.

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