

Ipsilateral atrophy of paraspinal and psoas muscle in unilateral back pain patients with monosegmental degenerative disc disease

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Objectives: The aim of this study was to assess the cross-sectional area (CSA) of both paraspinal and psoas muscles in patients with unilateral back pain using MRI and to correlate it with outcome measures.

Methods: 40 patients, all with informed consent, with a minimum of 3 months of unilateral back pain with or without sciatica and one-level disc disease on MRI of the lumbosacral spine were included. Patients were evaluated with self-report measures regarding pain (visual analogue score) and disability (Oswestry disability index). The CSA of multifidus, erector spinae, quadratus lumborum and psoas was measured at the disc level of pathology and the two adjacent disc levels, bilaterally. Comparison of CSAs of muscles between the affected vs symptomless side was carried out with Student's *t*-test and correlations were conducted with Spearman's test.

Results: The maximum relative muscle atrophy (% decrease in CSA on symptomatic side) independent of the level was 13.1% for multifidus, 21.8% for erector spinae, 24.8% for quadratus lumborum and 17.1% for psoas. There was significant difference ($p < 0.05$) between sides (symptomatic and asymptomatic) in CSA of multifidus, erector spinae, quadratus lumborum and psoas. However, no statistically significant correlation was found between the duration of symptoms (average 15.5 months), patient's pain (average VAS 5.3) or disability (average ODI 25.2) and the relative muscle atrophy.

Conclusion: In patients with long-standing unilateral back pain due to monosegmental degenerative disc disease, selective multifidus, erector spinae, quadratus lumborum and psoas atrophy develops on the symptomatic side. Radiologists and clinicians should evaluate spinal muscle atrophy of patients with persistent unilateral back pain.

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Paraspinal and trunk muscles play an important role in the kinetics and balance of the lumbar spine. They are considered as dynamic stabilisers applying their working force by providing stability to the spine–pelvis complex and motion to the spinal units. In addition, psoas is a significant hip flexor. Any decrease in the cross-sectional diameter (CSA) of these muscles could lead to loss of proper biomechanics and may be accompanied by the appearance of back pain [1–5]. Some authors have proposed that pain leads to a sedentary lifestyle and, furthermore, this creates extra muscle atrophy and pain, thus beginning a vicious cycle [6, 7].

In athletes with regular physical training, an increase in CSA of the paraspinal and trunk muscles has been demonstrated that reflects the improvement of muscle force and endurance [8]. In contrast, prolonged bed rest results in selective atrophy of the multifidus muscle whereas trunk muscles increase their CSA. The latter is probably the effect of shortening of muscle fibres or overactivity during bed rest [9].

Many studies on paraspinal musculature have focused on the multifidus muscle because of its unique and segmental innervation [10]. A multifidus bundle's unisegmental innervation always arises purely from the root exiting below the spinous process from which the fascicles originate, whereas in the other paraspinal muscles innervation is multisegmental. Several studies have demonstrated atrophy of multifidus following trauma, disc herniation or spinal nerve lesion by electromyographic, histological or radiographic measurements [1, 11, 12]. None of these studies focused on monosegmental degenerative disc disease.

This study aims to examine the CSA of all muscles around the lumbar spine in patients with persistent unilateral back pain caused by monosegmental degenerative disc disease and correlate this with their symptoms and period of pain.

Methods and material

During the period 2005–7, 40 consecutive patients with low back pain (LBP), all military personnel, who visited the outpatient clinic of the orthopaedic department entered the retrospective study. They were selected from a total of 2140 patients who presented to the

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military hospital's low back service. Inclusion criteria were unilateral LBP continuously for at least 3 months, one-level degenerative disc disease (loss of disc height and signal intensity) of the lumbar spine without disc material extrusion in the canal (simple disc bulging or protrusion was included) as shown in the MRI (Figure 1a). Unilateral back pain was defined on the basis of patient report of pain localisation on one side of the back with or without sciatica (buttock pain with or without lower limb radicular pain). A positive discogram (at high pressure) for unilateral back pain at the index level and negative discogram at the level above (the level below was routinely not tested to avoid confusion) were set as inclusion criteria.

Cases with a history of long-lasting back pain syndrome at a different site, lumbar spine surgery, scoliosis, spondylolysis, spondylolisthesis, multisegmental degenerative disc disease, lumbar facet joint disease, bilateral back pain symptoms, central LBP, polyneuropathy, myopathy, absence from work for more than 3 months and body mass index more than 30 were excluded. Facet arthropathy and other spinal pathology exclusion were based on both clinical and radiological findings. Also, patients with negative discograms at the index level or positive discograms in the disc above the level of pathology with a normal MRI signal (three patients) were excluded.

The study in human participants was approved by the local ethical committee.

Prior to the study, all patients had undergone systematic treatment with rest for a brief time, anti-inflammatories and physical therapy involving several modalities (ultrasound, transcutaneous electrical nerve stimulation

(TENS) unit), but no specific exercises except for walking. The patients' lifestyles did not involve sport activities during the time of their symptoms but they were still working full-time for the army, even though they were exempted from strenuous military exercises. Selective nerve root blocks for the 24 patients with radicular pain provided partial relief of their symptoms. All patients filled in the Oswestry disability index (ODI) questionnaire (Greek version) [13] and the visual analogue score (VAS) to detect the ability for daily activities and pain level at the time of MRI scan. ODI score is the sum of points from answers to 10 questions on disability, each of them receiving 0–10 points (0 means no disability and 100 equals the highest disability). VAS consists of marking the degree of any pain on a horizontal line 100 mm long (range from 0 = no pain to 100 = maximum pain). The radiological measurements were carried out on a MRI scan of the lumbar spine performed at the time of inclusion in the study.

MRI technique and CSA measurement

All patients had a lumbar spine MRI at the time of presentation. Imaging was performed by using a 1.5 T superconducting magnet (General Electric Signa High Definition Magnetic Resonance (HDMR), GE Healthcare, Buckinghamshire, UK) and an 8 channel phased array coil. The patients were placed supine with a pillow positioned underneath their knees, ensuring that the patient was lying symmetrically with weight evenly distributed across both sides. The imaging protocol was standardised in the following fashion: (a) T_1 weighted

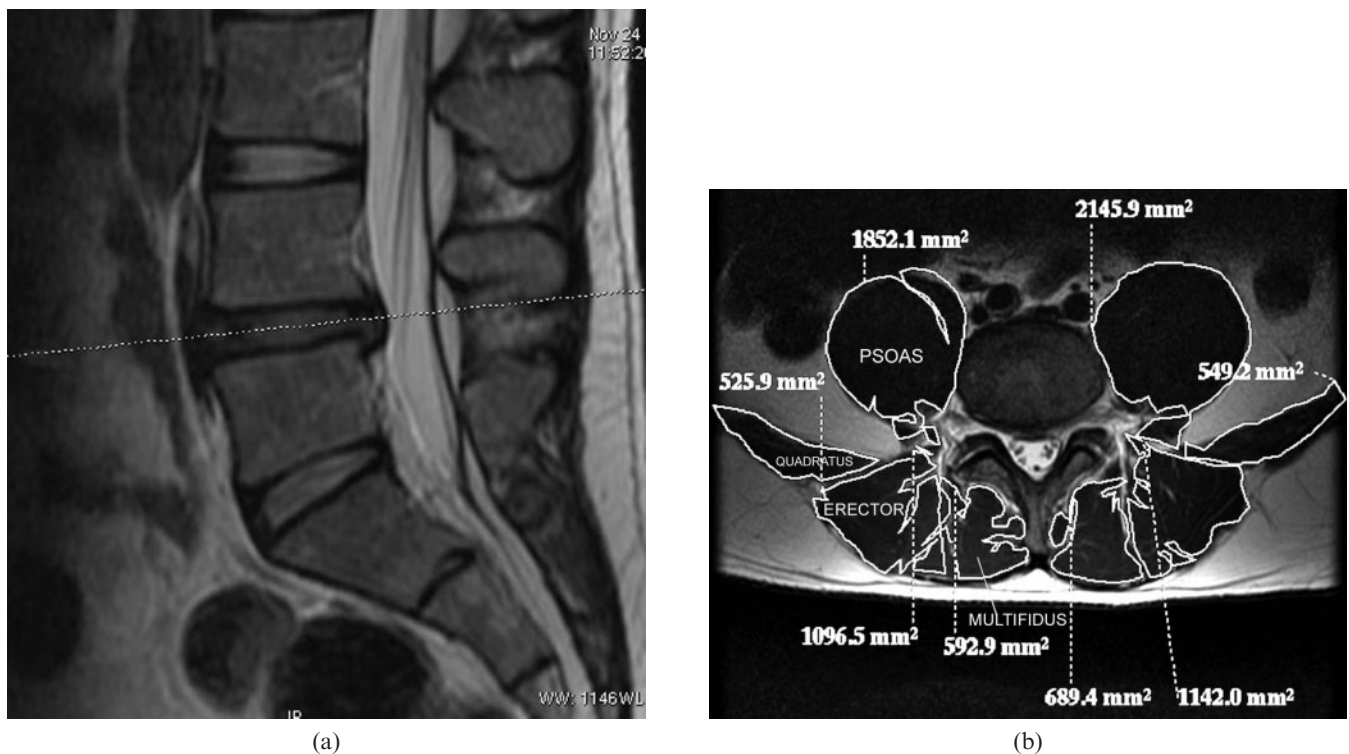


Figure 1. (a) Sagittal T_2 weighted MRI image of lumbar spine of a patient with 8 month history of right-sided back pain and occasional L5 radiculopathy on the same side. There is L4–L5 disc bulge with degeneration. (b) Transverse T_2 fast spin echo MRI image at L4–L5 level, showing mild disc bulge to the right. Measurements of paraspinal muscles' cross-sectional diameter demonstrate decreased values on the right side.

sagittal images were obtained with the following parameters: repetition time (TR)/echo time (TE), 560/12 ms; matrix, 384 × 288; sequence time, 2 min 44 s; field of view (FOV), 32 × 32 cm; number of excitations (NEX), 4; slice thickness, 4 mm; slice gap interval, 0.5 mm. (b) T_1 weighted transverse images were obtained with the following parameters: TR/TE, 600/12 ms; matrix 320 × 224; sequence time, 2 min 20 s; FOV, 20 × 20 cm; NEX, 3; slice thickness, 4 mm; slice gap interval, 0.5 mm. (c) T_2 weighted sagittal and transverse fast spin echo images were obtained with the following parameters: TR/TE, 3600/115 ms; matrix, 448 × 224; sequence time, 3 min 20 s; FOV, 32 × 32 cm for sagittal and 20 × 20 cm for transverse; slice thickness, 4 mm; slice gap interval, 0.5 mm. (d) In cases that pars interarticularis stress reaction was suspected based on low signal on T_1 weighted images about the pars and pedicle, a short tau inversion-recovery sequence was performed.

Transverse images were acquired obliquely through each disc level correcting for lordosis. The images obtained were transferred to a GE Workstation. The fascial boundary of the muscles to be measured was outlined manually on the transverse plane, with a tracker-ball driven cursor and the cross-sectional area was then automatically measured by pixel counting. All measurements were performed on the T_2 sequence. The CSA was assessed by carefully outlining the muscle mass, excluding fat and/or fibrous tissue external to muscle fascia.

For each MRI scan, measurements involved the level of pathology (Figure 1b) and two adjacent disc levels, one above and one below. In cases of L5–S1 disc pathology, adjacent levels measurements were undertaken only at the L4–L5 level. For each vertebral level at least four images were obtained, the central picture was selected and the cross-sectional area of the left and right psoas, multifidus (also includes rotators lumborum), quadratus lumborum and erector muscles (encompasses both longissimus and iliocostalis) was measured.

Measurement reliability

All measurements of cross-sectional muscle areas in MRI were taken by two radiologists (NM, IK) blinded to each other and to the side of symptoms. Measurements were performed twice and the average was used in the primary analysis.

Data analysis

Statistical analysis of data was performed with parametric methods of SPSS 10 for Windows. Relative muscle atrophy was calculated by the mathematical equation $(A - S/A) \times 100\%$, where A is the CSA of asymptomatic side and S is the CSA of symptomatic side. Student's paired t -test was used to compare CSA differences between the symptomatic and asymptomatic sides. Student's t -test was used to compare relative muscle atrophy between groups of patients with and without radiculopathy and between groups of patients with symptoms less or more than 1 year. Correlation of muscle atrophy with duration of symptoms, ODI and VAS scores was tested with Spearman's test. The

intraclass correlation coefficient (ICC) was calculated to determine inter- and intraobserver reliability as described by Winer [14]. The interobserver ICC reported was calculated from the first observation data. Reliability statistics are presented with a 95% confidence interval (95% confidence interval (CI)). A significance level of less than 0.05 was set for the p -value.

Results

Patient age ranged from 20 to 45 years (mean 34.2 years, standard deviation (SD) 7.6 years). There were 32 male patients and 8 female patients. 18 patients had right-sided symptoms and 22 left-sided. Lumbosacral radicular pain concordant to disc pathology coexisted in 24 patients on the same side as back pain. There were 2 cases with pathology at L2–L3 disc, 4 cases at L3–L4, 18 at L4–L5 and 16 at L5–S1. In addition to disc degeneration ("black" desiccated disc), disc bulging was seen in 8 cases, high-intensity zone (increase of signal within posterior annulus in T_2 weighted images) in the posterior annulus in 4 and Modic changes type I (hypointensity on T_1 weighted images and hyperintensity on T_2 of endplates) in 12 cases. These 24 cases were those who presented with unilateral back pain and radicular pain. No patient showed evidence of nerve root compression on the MRI.

Patients' symptoms of unilateral back pain lasted from 3 to 48 months (mean 15.5 months, SD 14.1 months). 22 patients were symptomatic for 12 months or less and 18 had symptoms more than 1 year. At the time of inclusion in the study, the VAS score ranged from 1.5 to 8 (mean 5.3, SD 1.6), while ODI ranged from 4 to 52 (mean 25.2, SD 11.78).

The CSA of the symptomatic side was significantly smaller ($p < 0.005$) than the asymptomatic side in all measured levels and muscles. Measurements of CSA in the asymptomatic side were within the normalised values of back muscles CSA in asymptomatic patients [2].

As shown in Table 1, muscle atrophy was greater at the level below disc pathology followed by the level of pathology for all muscle groups except for multifidus, which showed more atrophy on the level above pathology. There was no statistically significant muscle atrophy difference between cases with coexisting radiculopathy and cases without radiculopathy and between cases with less than 1 year symptomatology and cases more than 1 year.

The ICC of CSA measurements was 0.92 (0.86–0.98) for intraobserver reliability and 0.89 (0.84–0.92) for interobserver reliability. There was not significant disagreement of more than 10% between any double measurement.

Correlations were not statistically significant ($p > 0.05$) between relative muscle atrophy and ODI or VAS scores or to duration of symptoms.

Discussion

This is the first study that investigates atrophy of paraspinal and psoas muscles in patients with persistent unilateral back pain with one-level disc disease and correlates them with length of symptoms, pain and disability.

Table 1. Mean (standard deviation) relative atrophy (%) of muscles in symptomatic side.

	Number of levels measured	Multifidus	Erector spinae	Quadratus lumborum	Psoas
Level above pathology	40	13.1 (10.3)	11.0 (5.7)	13.9 (13.0)	7.7 (10.5)
Level with pathology	40	10.7 (10.7)	16.3 (9.8)	19.8 (9.4)	9.8 (6.9)
Level below pathology	24	8.1 (7.2)	21.8 (16.3)	24.8 (16.4)	17.1 (10.2)

The numbers in bold show the level with maximum atrophy.

It is known that exercise and regular training increase muscle CSA and, thus, strength and endurance of young females [1, 6, 7, 15, 16]. CT measurements of patients with LBP showed decreased CSA in all muscle groups around the spine [17]. Also, patients with prolonged bed rest showed selective atrophy of multifidus and increase in the CSA of psoas and abdominal muscles [9].

Experimental disc or nerve root injury in animals showed rapid atrophy of multifidus [11]. Research in patients with disc herniation revealed unilateral atrophy (histologically and electromyographically) of the L5 band of multifidus muscle in cases of L4–L5 disc herniation [12]. Another comparative study of multifidus CSA measurement with MRI in patients with disc herniation proved atrophy only in those with radiculopathy [18]. A similar study of patients with unilateral back pain for more than 3 months showed selective atrophy of multifidus and psoas on the symptomatic side [19]. Conversely, Daneels et al [20] found reduced multifidus CSA only at L4 level in all patients with chronic LBP and Kader et al [21] showed bilateral atrophy of multifidus even in patients with single-level unilateral nerve root impingement. Several aetiologies of multifidus muscle atrophy in patients with LBP have been reported, including disuse atrophy, reflex inhibition and dorsal ramus syndrome [11, 21, 22]. Similar contradictory results of psoas CSA in patients with LBP are reported in the literature [20, 23, 24].

In our study, atrophy of back extensors and psoas muscles on the symptomatic side of all examined levels has been demonstrated. It is known that paraspinal muscles' CSA is symmetrical in normal (without LBP) individuals between the right and left sides [25–27]. We can therefore propose that persistent unilateral back pain leads to loss of paraspinal muscle mass on the side of symptomatology. Also, the fact that all muscles (except multifidus) with multisegmental innervation have shown the maximum relative atrophy at the level below the pathological disc is likely to be explained by the adding-on effect of wasting muscle fibres caudally because of disuse or inflammation [3, 28]. Only multifidus has exhibited different results with more atrophy at the level above the disc pathology. This may be explained by the particular anatomy, *i.e.* the posterior ramus of spinal nerve that innervates multifidus segmentally can induce a reflex inhibitory mechanism and affect mainly the measurements at that level of the exiting nerve and the level above. Similar differences of multifidus innervation have been seen experimentally following nerve root and disc injury [11]. Also, the electromyographic abnormalities in multifidus following

single lumbar root injury may have broader distribution in a cephalad direction [29].

Our findings did not confirm the results of Barker et al [19] regarding correlation of decrease of muscle (only multifidus and psoas were measured) CSA with dysfunction, pain or duration of symptoms: we found no correlation with these parameters. The patients in our study had atrophy of paraspinal muscles that did not correlate with the aforementioned parameters. However, our participants had only one-level disc disease, were younger in age and their symptomatology was milder than in the cohort mentioned in that study. Perhaps the fact that our patients did not have completely sedentary lifestyles and were walking regularly, as necessitated by their military job, caused variations in the muscle atrophy pattern.

Limitations in our study were the absence of a control group. However, since the measurements were done on the asymptomatic side that showed CSA results similar to asymptomatic participants [2], they serve as a measure for comparison with the other side. The power and conclusions of the study may be reduced, as only a small number of patients with certain characteristics were included and the type and duration of previous treatment, which may be confounding factors, were not analysed. Fat and fibrous tissue next to the paraspinal muscles were eliminated by accurately circumscribing the muscle mass only.

The clinical significance of this paper is to underline the unilateral atrophy of multifidus, erector spinae, quadratus lumborum and psoas in long-lasting unilateral back pain. We showed no correlation between relative muscle atrophy and duration of symptoms or disability/pain measurements.

References

1. Hides JA, Stanton WR, McMahon S, Sims K, Richardson CA. Effect of stabilization training on multifidus muscle cross-sectional area among young elite cricketers with low back pain. *J Orthop Sports Phys Ther* 2008;38:101–8.
2. Hansen L, de Zee M, Rasmussen J, Andersen TB, Wong C, Simonsen EB. Anatomy and biomechanics of the back muscles in the lumbar spine with reference to biomechanical modeling. *Spine* 2006;31:1888–99.
3. Macintosh JE, Bogduk N. The attachments of the lumbar erector spinae. *Spine* 1991;16:783–92.
4. Hides JA, Stanton WR, Freke M, Wilson S, McMahon S, Richardson CA. MRI study of the size, symmetry and function of the trunk muscles among elite cricketers with and without low back pain. *Br J Sports Med* 2008;42:809–13.
5. Villavicencio AT, Burneikiene S, Hernandez TD, Thramann J. Back and neck pain in triathletes. *Neurosurg Focus* 2006;21:E7.

6. Hodges PW. The role of the motor system in spinal pain: implications for rehabilitation of the athlete following lower back pain. *J Sci Med Sport* 2000;3:243–53.
7. Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine* 1996;21:2763–9.
8. Peltonen JE, Taimela S, Erkinntalo M, Salminen JJ, Oksanen A, Kujala UM. Back extensor and psoas muscle cross-sectional area, prior physical training, and trunk muscle strength—a longitudinal study in adolescent girls. *Eur J Appl Physiol Occup Physiol* 1998;77:66–71.
9. Hides JA, Belavy DL, Stanton W, Wilson SJ, Rittweger J, Felsenberg D, et al. Magnetic resonance imaging assessment of trunk muscles during prolonged bed rest. *Spine* 2007;32:1687–92.
10. Yoshihara K, Nakayama Y, Fujii N, Aoki T, Ito H. Atrophy of the multifidus muscle in patients with lumbar disk herniation: histochemical and electromyographic study. *Orthopedics* 2003;26:493–5.
11. Hodges P, Holm AK, Hansson T, Holm S. Rapid atrophy of the lumbar multifidus follows experimental disc or nerve root injury. *Spine* 2006;31:2926–33.
12. Mattila M, Hurme M, Alaranta H, Paljarvi L, Kalimo H, Falck B, et al. The multifidus muscle in patients with lumbar disc herniation. A histochemical and morphometric analysis of intraoperative biopsies. *Spine* 1986;11:732–8.
13. Boscaiños PJ, Sapkas G, Stilianessi E, Prouskas K, Papadakis SA. Greek versions of the Oswestry and Roland-Morris Disability Questionnaires. *Clin Orthop Relat Res* 2003;411:40–53.
14. Winer B. Statistical principles in experimental design. New York, NY: McGraw-Hill, 1971.
15. Hides JA, Stokes MJ, Saide M, Jull GA, Cooper DH. Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain. *Spine* 1994;19:165–72.
16. Rissanen A, Kalimo H, Alaranta H. Effect of intensive training on the isokinetic strength and structure of lumbar muscles in patients with chronic low back pain. *Spine* 1995;20:333–40.
17. Kamaz M, Kiresi D, Oguz H, Emlik D, Levendoglu F. CT measurement of trunk muscle areas in patients with chronic low back pain. *Diagn Interv Radiol* 2007;13:144–8.
18. Hyun JK, Lee JY, Lee SJ, Jeon JY. Asymmetric atrophy of multifidus muscle in patients with unilateral lumbosacral radiculopathy. *Spine* 2007;32:E598–602.
19. Barker KL, Shamley DR, Jackson D. Changes in the cross-sectional area of multifidus and psoas in patients with unilateral back pain: the relationship to pain and disability. *Spine* 2004;29:E515–19.
20. Danneels LA, Vanderstraeten GG, Cambier DC, Witvrouw EE, De Cuyper HJ. CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects. *Eur Spine J* 2000;9:266–72.
21. Kader DF, Wardlaw D, Smith FW. Correlation between the MRI changes in the lumbar multifidus muscles and leg pain. *Clin Radiol* 2000;55:145–9.
22. Parkkola R, Rytokoski U, Kormano M. Magnetic resonance imaging of the discs and trunk muscles in patients with chronic low back pain and healthy control subjects. *Spine* 1993;18:830–6.
23. Cooper RG, St Clair Forbes W, Jayson MI. Radiographic demonstration of paraspinal muscle wasting in patients with chronic low back pain. *Br J Rheumatol* 1992;31:389–94.
24. Dangaria TR, Naesh O. Changes in cross-sectional area of psoas major muscle in unilateral sciatica caused by disc herniation. *Spine* 1998;23:928–31.
25. Hides JA, Richardson CA, Jull GA. Magnetic resonance imaging and ultrasonography of the lumbar multifidus muscle. Comparison of two different modalities. *Spine* 1995;20:54–8.
26. Pressler JF, Heiss DG, Buford JA, Chidley JV. Between-day repeatability and symmetry of multifidus cross-sectional area measured using ultrasound imaging. *J Orthop Sports Phys Ther* 2006;36:10–18.
27. Watson T, McPherson S, Starr K. The association of nutritional status and gender with cross-sectional area of the multifidus muscle in establishing normative data. *J Man Manip Ther* 2008;16:E93–8.
28. Mannion AF, Dumas GA, Cooper RG, Espinosa FJ, Faris MW, Stevenson JM. Muscle fibre size and type distribution in thoracic and lumbar regions of erector spinae in healthy subjects without low back pain: normal values and sex differences. *J Anat* 1997;190:505–13.
29. Kottlors M, Glocker FX. Polysegmental innervation of the medial paraspinal lumbar muscles. *Eur Spine J* 2008;17:300–6.