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**Lieven A. Danneels**
**Guy G. Vanderstraeten**
**Dirk C. Cambier**
**Erik E. Witvrouw**
**Hugo J. De Cuyper**

# CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects

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L. A. Danneels (✉)
G. G. Vanderstraeten · D. C. Cambier
E. E. Witvrouw
Department of Rehabilitation Sciences
and Physical Therapy, Faculty of Medicine,
Ghent University, Belgium
e-mail: lieven.danneels@rug.ac.be,
Tel.: +32-9-2402635, Fax: +32-9-2403811

H. J. De Cuyper
Department of Physical Medicine
and Rehabilitation, Hospital Jan Palfijn –
Campus Gallifort, Antwerp, Belgium

L. Danneels
University Hospital Ghent,
Department of Rehabilitation Sciences
and Physical Therapy, De Pintelaan 185,
1B3, 9000 Ghent, Belgium

**Abstract** Increasing documentation on the size and appearance of muscles in the lumbar spine of low back pain (LBP) patients is available in the literature. However, a comparative study between unoperated chronic low back pain (CLBP) patients and matched (age, gender, physical activity, height and weight) healthy controls with regard to muscle cross-sectional area (CSA) and the amount of fat deposits at different levels has never been undertaken. Moreover, since a recent focus in the physiotherapy management of patients with LBP has been the specific training of the stabilizing muscles, there is a need for quantifying and qualifying the multifidus. A comparative study between unoperated CLBP patients and matched control subjects was conducted. Twenty-three healthy volunteers and 32 patients were studied. The muscle and fat CSAs were derived from standard computed tomography (CT) images at three different levels, using computerized image analysis techniques. The muscles studied were: the total paraspinal muscle mass, the isolated multifidus and the psoas. The results showed that only the CSA of the multifidus and only at the lowest level (lower end-plate of L4) was found to be statistically smaller in LBP patients. As regards amount of fat, in none of the three studied muscles was a significant difference found between the two groups. An aetiological relationship between atrophy of the multifidus and the occurrence of LBP can not be ruled out as a possible explanation. Alternatively, atrophy may be the consequence of LBP: after the onset of pain and possible long-loop inhibition of the multifidus a combination of reflex inhibition and substitution patterns of the trunk muscles may work together and could cause a selective atrophy of the multifidus. Since this muscle is considered important for lumbar segmental stability, the phenomenon of atrophy may be a reason for the high recurrence rate of LBP.

**Key words** Cross-sectional area · Fat deposits · Paravertebral muscles · Lumbar multifidus · Psoas

## Introduction

Low back disability has become endemic throughout Western society [1, 19,31]. Disorders of the back and lumbar spine make up the largest fraction of musculoskeletal injuries and are one of the leading causes of disability in the working years [17]. In the past, investigators have extensively focused on the bones, discs, and joints of the back. Nevertheless, the importance of the muscular system in stabilizing the lumbar spine cannot be underestimated [2], a point well illustrated by a study that provided quantitative data on the stabilizing effects of muscles on the mechanics of the spine [10]. Increasing documentation on the size and appearance of muscles in the lumbar spine of low back pain (LBP) patients is currently available in the literature. Microscopic studies of low back patients and healthy volunteers with marked atrophy of the back muscles have demonstrated structural changes in the back muscles [18, 27,30]. Fortunately, morphologic information on muscles can be obtained in a non-invasive way by computer tomography (CT) [3, 15, 16, 20,30], magnetic resonance imaging (MRI) [7, 9, 24,25], and ultrasonic imaging techniques [12,13]. Macroscopically, there are two cardinal signs of muscle degeneration, which are easily detected on CT images: a decrease in the size of the muscles and an increase in the amount of fat deposits.

There is cumulative evidence that the cross-sectional area (CSA) of the paraspinal muscles is smaller in patients with chronic LBP (CLBP) [8,24] and post-operative LBP [3, 19,30]. Chronic back pain has also been associated with more fatty infiltration in the back muscles in unoperated [9, 15,24], and operated LBP patients [19,30].

However, to the authors' knowledge, a comparative study between unoperated CLBP patients and matched (age, gender, physical activity, height and weight) healthy controls with regard to muscle CSA and the amount of fat deposits, at different levels, has never been undertaken.

Moreover, a recent focus in the physical therapy management of patients with CLBP has been the specific training of muscles surrounding the lumbar spine whose primary role is considered to be the provision of dynamic stability and segmental control to the spine [28]. Recent studies have shown that the lumbar multifidus (MF) is an important muscle for lumbar segmental stability [4, 5, 6, 10, 23,32]. Results of MF muscle biopsies of patients with a poor outcome showed muscle atrophy and an increase in frequency of pathologic changes in the MF [27]. Ultrasound imaging has been used to document muscle size of the MF and showed that, in the acute stage, the wasting of the MF can be isolated to one level [12]. Many studies have highlighted the importance of the MF; however, the authors are unaware of any studies that have quantified the size of the isolated MF and the amount of fat deposits within this muscle in CLBP patients.

In the present study the paraspinal muscles (PA) in toto (multifidus/longissimus/iliocostalis), the psoas muscle (PS) and the isolated MF are studied by means of CT at three different levels. The dimensions of these muscles are radiographically quantified in healthy subjects and patients suffering mechanical LBP to investigate the question of wasting. Not only CT measurements of muscle CSA but also the amount of fat deposits was analysed.

## Materials and methods

### Study design

After obtaining approval from the Ethical Committee of the Hospital Jan Palfijn – Campus Gallifort, Antwerp, healthy subjects and CLBP patients were entered into this study. CT images were made at three levels. CSA and fatty infiltration were determined for the back muscles as a whole (multifidus, longissimus and iliocostalis), the isolated MF muscle and the PS. All subjects signed an informed consent to participate.

### Subjects

Over a period of 3 years, all patients referred to the Department of Physical Medicine and Rehabilitation, Hospital Jan Palfijn – Campus Gallifort, Antwerp, for diagnostic evaluation and treatment were screened for the purposes of this and other studies. All patients with a history of chronic mechanical low back pain, with or without disc protrusion, were selected for the current study. Chronic pain was defined as lasting more than 1 year. Exclusion criteria were: previous lumbar surgery, the presence of a lumbar scoliosis exceeding 10°, neuromuscular or joint disease, evidence of systemic disease, carcinoma or organ diseases. Patients who had been involved in sports or fitness training for the low back muscles over the previous 3 months were also excluded. CT scans were performed in all these patients before starting an intensive rehabilitation programme. To facilitate the comparison with a normal active and working control group, the patient group was confined to all subjects between 25 and 55 years of age. Furthermore, the test results of three persons were excluded since the angle of their lordosis was different from the defined criteria (cf. Methods section). This resulted in a select group of 32 patients (17 men and 15 women). The mean duration of pain in this CLBP group was 9.16 ± 7.41 years. The CSAs of their paraspinal muscles and hip flexors were compared with a control sample of normal subjects of similar gender distribution.

Twenty-three normal active volunteers (13 men and 10 women), with varied histories of occupational and leisure-time physical activities and reporting no experience of back pain, were randomly chosen from the staff of the Hospital Jan Palfijn – Campus Gallifort. The two study groups were highly comparable with regard to height, weight, age and physical activity (Table 1). In both populations, the amount of the physical activity was evaluated with regard to occupational background, sport, daily living activities and transport.

### Computerized tomography

The CT procedure in all subjects included three standardised transaxial images, positioned accurately through an end-plate of a vertebral body. The first through the upper end-plate of L3, the second and third through the upper and lower end-plates of L4 (Fig. 1). Some authors have asserted that the CSA of the paraspinal and psoas muscles are at or near maximal at the upper end-plate of L4 [3, 9,21], others have found that the total CSA of the back muscles was maximal at about the L3 [11,15] or the L4-L5 level [16, 24, 25,30]. In this study, in order to screen the most suitable level and to detect a possible systematic difference between the different levels, three levels were analysed. Instead of the upper end-plate of L5, the lower end-plate of L4 was chosen, because in many per-

**Table 1** Characteristics of the control and low back pain groups: mean and standard deviation (significance level $P = 0.05$)

| | Controls | Patients | *P*-value |
|---|---|---|---|
| Age (yr) | 36.91 ± 10.26 | 37.34 ± 9.78 | 0.905 |
| Height (cm) | 172.87 ± 10.89 | 171.97 ± 10.48 | 0.84 |
| Weight (kg) | 67.85 ± 11.33 | 71.21 ± 14.31 | 0.54 |
| Activity index | 2.71 ± 0.58 | 2.75 ± 0.58 | 0.68 |

**Fig. 1** A scouth view representing the three standardised views positioned accurately along the upper end-plate of L3 and the upper and lower end-plate of L4. The angulation of the vertebrae was estimated by measuring the angle between the plane of cut and a line drawn between the dorsal upper apex of L1 and the dorsal lower apex of L5

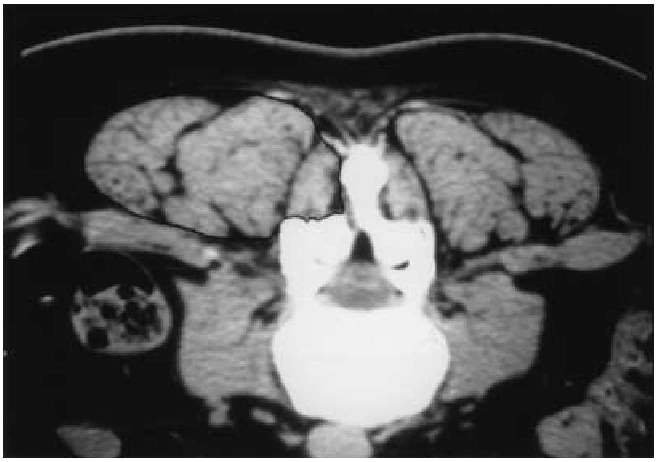

**Fig. 2** The cross-sectional areas (CSAs) of the paravertebral muscles were measured on the transaxial view. The outlines of the region of interest were cursor identified on the computer screen

sons the vertebra of L5 is steeply angulated [16]. Because of such an angulation the sections would not be comparable with the other levels.

Joint position and muscle length influence CSA values of the muscles; therefore, every attempt was made to standardize the position. During CT, each subject was positioned prone to avoid compression of the back muscles with the hips in a neutral position. The lumbar lordosis was minimized by placing a pillow under the abdomen. The subjects were instructed to relax and remain motionless for the duration of the scan. A physical therapist, trained for this purpose, installed the patients and controlled by palpation the back musculature to ensure a relaxed state.

A CT Pace Plus – General Electric – was used at 120 kV and 160 mA. A window wide of 400 HU, with the centre of + 4 HU was applied. The slice thickness was 5 mm.

### Image analysis

The CT images were enlarged and visualized on a computer screen. The muscles analysed in this study were the paraspinal muscles as a whole (PA), the isolated multifidus (MF) and the psoas muscles (PS).

The analysis of each muscle or group of muscles consisted of three steps using a computer programme written for this purpose. For the PA (multifidus, longissimus and iliocostalis), first the CSA of the muscles with fat, second the muscles without the clearly visible fat and third the low-fat muscle mass were determined. In order to determine the first area, the outlines of the region of interest were cursor identified on the computer screen: the fascia thoracolumbalis was followed down to the dorsal side of the quadratus lumborum and then the side of the bone and ligament structures were taken as a reference. This CSA was considered to represent the paravertebral muscles with fat (Fig. 2).

The next two CSAs were exposed by means of an elimination technique. Image segmentation was performed using a threshold technique based on differences in the grey values of the pixels. First, the bone and the clear fat deposits were eliminated. In the main, this was the fat that was situated around the different muscle bellies. These eliminations resulted in the second CSA: "muscle without clearly visible fat" (Fig. 3).

Finally, the contrast was enlarged by spreading out the pixels of the second area over the whole histogram. This procedure made it possible to remove the remaining fat, more particularly the fat within the different muscle bellies. By this, the third CSA was determined, which was termed the low-fat muscle tissue (Fig. 4). The above CSAs were each time described in relation to the CSA of the vertebral body. The relative values were necessary to compare individuals [3,21]. Since the second CSA was only meant as an intermediate step, only the first and the third CSA (muscle with fat and low-fat muscle) were taken into account in comparing the two groups.

After the back extensor muscle mass, the MF and PS muscles were determined. The customised programme made it possible to trace the margins of the MF and the PS. In a second and third step, as explained before, the histographic method was used to isolate muscle tissue from fat deposits. The number of pixels with signal

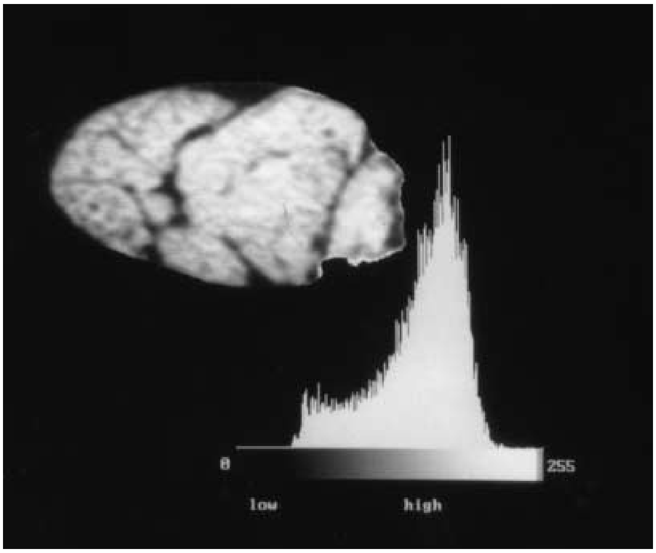

**Fig. 3** The histographic method was used to isolate muscle tissue from fat deposits

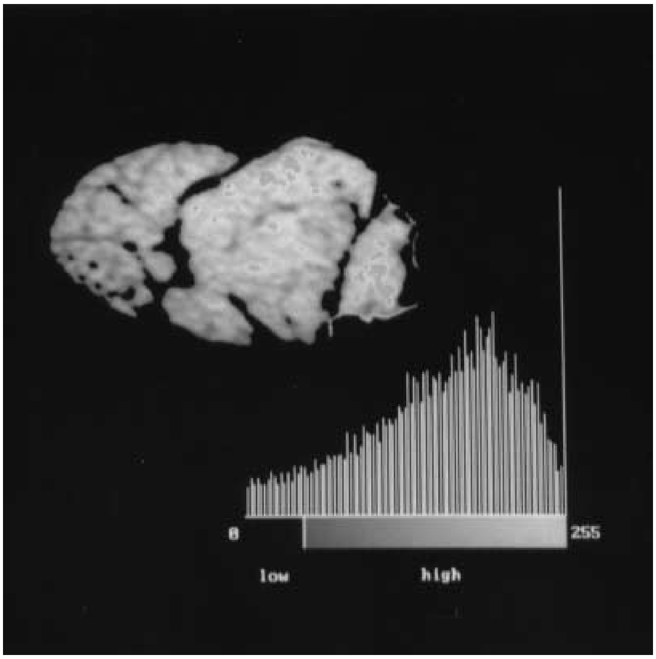

**Fig. 4** The contrast was enlarged by spreading out the pixels from the previous selected area (Fig. 3) over the whole histogram. This procedure made possible removal of the remaining fat

intensity characteristics of muscle and fat tissue were measured and the CSAs calculated.

All measurements were made by one observer, who was blinded to all subject information to eliminate potential bias. In addition, the area measurements were repeated by a second analyst for 15 randomly picked subjects to calculate the correlation coefficients in inter-observer comparisons. The inter-rater reliability coefficients were high (0.81–0.92), indicating that the current measurement technique will be able to be duplicated by other investigators in a similar fashion.

### Fibre orientation

The position of the patients, which was determined by the need to place them in a comfortable and relaxed position, resulted in minimal lordosis remaining. Consequently, there was always an angulation of one or more vertebrae. Since each plane of cut was through one of the vertebral end-plates, any angulation of the vertebra would mean that this section would not be perpendicular to the muscle bundles. An extreme angulation could influence the CSA, which would make a correction necessary [11]. Therefore, in each subject the lumbar lordosis was estimated on the scouth view (Fig. 1) by drawing a line between the dorsal upper apex of L1 and the dorsal lower apex of L5. The angle between the plane of cut and the L1-L5 line was then determined. An angle of 85° ± 5° (L3 upper), 82° ± 5° (L4 upper), 80° ± 5° (L4 lower) was accepted. In three patients and one control subject the angle was outside of these values at the lower end-plate of L4. The results of these persons were not included for analysis.

### Data analysis

Regions of interest were drawn and a histographic method was used to determine the different CSAs. This procedure was carried out three times in succession for each of the following muscles: PA, the isolated MF and the PS. The amount of fat was calculated by subtracting the third (low-fat muscle) from the first CSA [(PA + fat) – PA, (MF + fat) – MF and (PS + fat) – PS]. To make possible a comparison of CSAs between subjects, the muscle to bone ratios were used. Both right and left sides were studied. To assess the total CSA of the trunk muscles, the arithmetic sum of the right and left PA, MF and PS were calculated [9, 15, 21,24].

### Statistical analysis

Data are presented as mean ± standard deviation (SD). Repeated measures analysis of variance was carried out. Calculation of the intraclass correlation coefficient *(R)* was done to assess the reliability of measures. Differences between the two groups were analysed with the Mann-Whitney U-test, since there was not always a Gaussian distribution of the results (Kolmogorov-Smirnov test significant). For the statistical analysis, the software SPSS 9.0. was used. Statistical significance was accepted at the 5% level. Power of the statistical analysis in this study was between 0.79 and 0.96.

## Results

A repeated measures analysis of variance was carried out to calculate the intraclass correlation coefficient between the three repeated measurements. Since the intraclass reli-

**Table 2** The mean (SD) cross-sectional areas (CSAs) of the paraspinal muscles (PA), the multifidus (MF) and psoas (PS), with and without fat at the three different levels (significance level $P = 0.05$)

| CSA | PA+fat | PA | MF+fat | MF | PS+fat | PS |
|---|---|---|---|---|---|---|
| L3 upper | | | | | | |
| Controls | 2.67 (0.48) | 2.35 (0.47) | 0.47 (0.14) | 0.44 (0.14) | 1.13 (0.37) | 1 (0.35) |
| Patients | 2.60 (0.46) | 2.25 (0.44) | 0.41 (0.10) | 0.38 (0.10) | 1.04 (0.33) | 0.92 (0.32) |
| *P*-value | 0.57 | 0.43 | 0.105 | 0.094 | 0.38 | 0.28 |
| L4 upper | | | | | | |
| Controls | 2.65 (0.4) | 2.26 (0.43) | 0.63 (0.14) | 0.57 (0.14) | 1.7 (0.49) | 1.54 (0.49) |
| Patients | 2.57 (0.39) | 2.16 (0.38) | 0.58 (0.11) | 0.52 (0.11) | 1.57 (0.42) | 1.40 (0.41) |
| *P*-value | 0.50 | 0.54 | 0.23 | 0.28 | 0.33 | 0.25 |
| L4 lower | | | | | | |
| Controls | 2.72 (0.42) | 2.26 (0.39) | 0.9 (0.15) | 0.8 (0.15) | 1.78 (0.34) | 1.57 (0.31) |
| Patients | 2.46 (0.4) | 2.01 (0.37) | 0.77 (0.14) | 0.68 (0.13) | 1.72 (0.43) | 1.51 (0.41) |
| *P*-value | 0.048* | 0.036* | 0.009* | 0.012* | 0.62 | 0.56 |

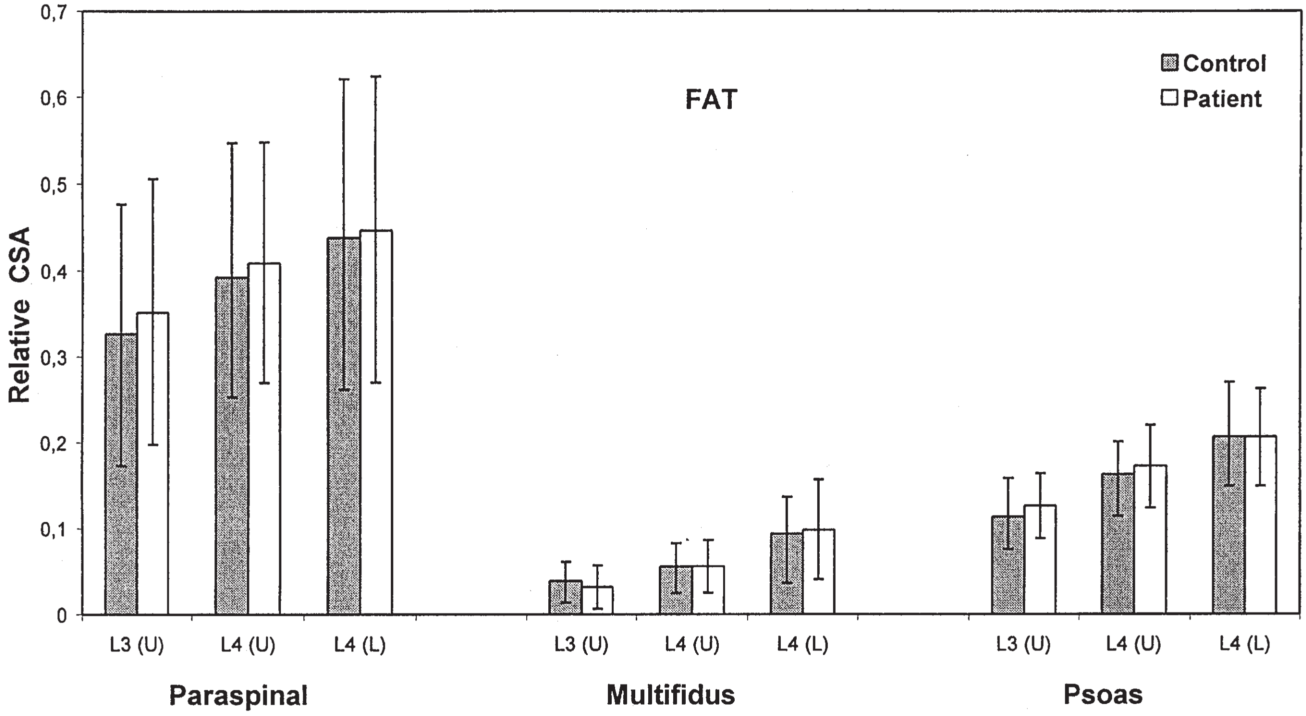

**Fig. 5** The relative CSA of the fat deposits in the paravertebral muscles, the multifidus and the psoas in healthy subjects and chronic low back pain patients (*L3 (U)* upper end-plate of L3, *L4 (U)* upper end-plate of L4, *L4 (L)* lower end-plate of L4)

ability coefficient, *R*, was high for all variables (0.90–0.96), further calculations were done with the mean of the repeated trials.

The results of the CSA showed that at the upper end-plate of L3 and L4, no statistical differences were found between the healthy subjects and the CLBP patients. At the lower end-plate of L4, the PA and the MF (both with and without fat) were statistically smaller in the patient group (Table 2).

To answer more specifically the question of selective wasting of the MF, the CSA of the erector spinae (ES) was also calculated (PA–MF). The difference between the CSA of the ES in the two populations was not significant (L3 upper: $P = 0.79$; L4 upper: $P = 0.707$; L4 lower: $P = 0.25$).

Statistical analysis revealed no statistically significant differences between the two groups for the CSAs of the PS (Table 2). Neither was a significant difference observed between the two groups with regard to the amount of fat (Fig. 5).

## Discussion

Macroscopically, there are two cardinal signs of muscle degeneration, which can be easily detected on CT images: a decrease in the size of the muscles and an increase in the amount of fat deposits.

In this study, the CSAs of the paravertebral muscles in toto, the isolated multifidus and psoas of CLBP patients are compared with those of a matched control group. In the healthy subjects, the CSAs of the muscles were consistently greater, though significant differences were found only for the MF and PA at the lower end-plate of L4. Since the MF becomes greater at lower levels [14], it is obvious why the differences become significant at this level for the paravertebral muscles in toto. At the lower endplate of L4, the MF forms approximately one-third of the paraspinal muscles (± one-sixth at the upper end-plate of L3). Therefore, the results suggest that the observed differences for the PA muscles were caused by a selective atrophy of the MF in the CLBP patients. This is affirmed by the calculations of the CSA of the ES, where no significant differences were found between the two populations.

Our findings at the L3 level are in concordance with Hultman et al., who found no significant decrease in the CSA of the ES muscles in CLBP patients [15]. However, these results are not supported by some earlier studies [3,24]. Cooper et al. [3] demonstrated reduced PA muscle ratios on CT in CLBP and found that the PA/PS ratios did not alter with duration of symptoms, thus indicating simultaneous rather than selective PA and PS wasting. Nonetheless, two limitations of the study by Cooper and co-workers should be noted. First, the majority of the chronic patients had undergone previous surgery. Second, the patients were significantly older than their counterparts with recent symptoms. In a study by Parkkola et al.

[24], there was a significant difference in the frequency of visually assessed muscle degeneration of the PS and back muscles between moderate LBP patients and healthy volunteers. However, this study also had several limitations. First, no transparent results were given of the comparison between the two groups. Second, it seems that the activity level was not taken into account.

Atrophy of the hip flexors was not found in our study, indicating that the observed muscle wasting was not just part of general disuse atrophy resulting from global inactivity. The fact that the amount of physical activity was matched across the two groups probably ensured that the phenomenon of deconditioning was not found.

Replacement of muscle by adipose or connective tissue has been reported as a sign of muscle atrophy [24]. In our study, the histographic method was used to isolate muscle tissue from fat deposits. The number of pixels with signal intensity characteristics of fat were measured, and the CSA of fat was calculated. The results showed that in none of the three studied muscles there were any significant differences in amount of visible fat. McLoughin et al. [21] found that paraspinal fat deposition is related to age and the amount of subcutaneous fat, and is not a sign of muscle atrophy in the unoperated lumbar paraspinal space. In contrast with these results, Parkkola et al. [24] found that the amount of fat deposits was related to muscle atrophy in the back muscles, but not in the PS. The results of the current study showed no significant fat infiltration in the atrophied MF. In the other muscles, since there was no atrophy, no significant amount of fatty deposits was expected. Since the patient and control population were perfectly matched with regard to age and physical activity, our results support the idea that fatty infiltration is primarily caused by age [21,24] or disuse [15] in unoperated CLBP patients.

The results of the current study suggest a selective significant atrophy of the multifidus in normal active CLBP patients. Since disuse and immobilisation related to back pain leads to atrophy of both flexors and extensors [24], the question arises as to whether reflex inhibition, pain and/or inflammation arising in the lumbar spine could hamper activation of the MF and thus cause the observed selective atrophy of this muscle. Using real-time ultrasound imaging, Hides et al. [12] detected unilateral wasting of the multifidus in acute and subacute LBP patients. The fact that the reduced CSA was unilateral and isolated to one level suggested that the mechanism of wasting was not generalized disuse atrophy or spinal reflex inhibition. Inhibition due to perceived pain, via a long loop reflex, which targeted the vertebral level of pathology to protect the damaged tissues, was the likely mechanism of wasting in the acute stage. The same research group showed that MF recovery did not occur spontaneously on remission of painful symptoms [13].

Therefore, based on the available literature, we suggest that after the pain onset and possible pain inhibition of the MF, in the subacute and chronic stage a combination of reflex inhibition and changes in coordination of the trunk muscles work together. The reflex inhibition hampers alpha motor neuron activity in the anterior horn of the spinal cord and inhibits accurate activity of the MF. Moreover, already in the early stage, different recruitment patterns install, other muscles become active and try to substitute for the stabilizing muscles, particularly the MF [22]. This mechanism becomes chronic and results in a selective atrophy of the MF. Further research, on a greater patient population, will determine whether the atrophy of the MF is correlated with the clinical level of symptoms.

Another possible explanation could be that the atrophy of the MF is not secondary to LBP, but that there is an aetiological relationship. Further prospective studies are required to resolve this question.

Many studies have highlighted the importance of the MF muscle regarding its potential to provide dynamic control [4, 5, 12, 13, 23,31]. Wilke et al. [31] examined the effect of the simulated muscle force of the MF on motion stiffness. When compared with the ES and the PS, the MF contributed two-thirds of the increased stiffness imparted by the simulated contraction of the muscle stiffness. Therefore, wasting of this muscle could be expected to have direct effects on lumbar segmental stability. This could permit spinal instability and thus predispose to further damage, which may explain the progressive nature of symptoms and disability exhibited by many CLBP patients. Although courses of intense physical therapy have been undertaken in severe LBP, and have produced obvious improvements in mobility and back pain, the results of this study suggest that in normal active CLBP patients, a selective training of the stabilising muscular system could be necessary.

## Conclusion

The lumbar muscles play a vital role in the stability and functional movement of the lumbar vertebral column. In this study, in normal active CLBP patients, the lumbar MF, which is thought to be particularly important for stability, was found to be atrophied. It was hypothesized on the basis of the results of this study, that the atrophy was prior to the onset of LBP, or that in the subacute and chronic stage a combination of reflex inhibition and substitution pattern of the trunk muscles occurred. The atrophy and possible dysfunction of the MF could permit spinal instability and could be important factors that contribute to the high recurrence rate in chronic LBP. Therefore, selective training of the stabilising muscle system could be meaningful in the prevention and the rehabilitation of chronic back pain.

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