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Original Article

# The effect of chronic low back pain on size and contraction of the lumbar multifidus muscle☆

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Decreases in the size of the multifidus muscle have been consistently documented in people with low back pain. Recently, ultrasound imaging techniques have been used to measure contraction size of the multifidus muscle, via comparison of the thickness of the muscle at rest and on contraction. The aim of this study was to compare both the size (cross-sectional area, CSA) and the ability to voluntarily perform an isometric contraction of the multifidus muscle at four vertebral levels in 34 subjects with and without chronic low back pain (CLBP). Ultrasound imaging was used for assessments, conducted by independent examiners. Results showed a significantly smaller CSA of the multifidus muscle for the subjects in the CLBP group compared with subjects from the healthy group at the L5 vertebral level ($F = 29.1$, $p = 0.001$) and a significantly smaller percent thickness contraction for subjects of the CLBP group at the same vertebral level ($F = 6.6$, $p = 0.02$). This result was not present at other vertebral levels ($p > 0.05$). The results of this study support previous findings that the pattern of multifidus muscle atrophy in CLBP patients is localized rather than generalized but also provided evidence of a corresponding reduced ability to voluntarily contract the atrophied muscle.



## 1. Introduction

The lumbar multifidus muscle has been the subject of considerable research using imaging techniques including magnetic resonance imaging (MRI), computerised tomography (CT scanning) and ultrasound imaging (for review, see Stokes et al., 2007). Two aspects of muscle function that can be assessed using imaging techniques are muscle size (MRI, CT, ultrasound imaging) and muscle contraction (ultrasound imaging). The clinical relevance of these techniques is that they allow documentation of morphology and dynamic muscle function in both healthy subjects and those with acute and chronic low back pain (CLBP). Detection of changes in multifidus muscle size and motor control in people with low back pain (LBP) (by comparison with healthy subjects) may provide useful information which can be used to guide rehabilitation approaches.

In healthy subjects, the lumbar multifidus muscle has been shown to be symmetrical between sides (Hides et al., 1994, 1995) and increased incrementally in size on progression caudally (Hides et al., 1995). The cross-sectional area (CSA) of the multifidus muscle has been shown to be larger in male subjects, and age was not related to multifidus size (Stokes et al., 2005).

The size of the multifidus muscle has also been documented in people with acute and chronic LBP. In patients with acute unilateral LBP, studies employing ultrasound imaging demonstrated a decrease in the CSA of the multifidus muscle ipsilateral to painful symptoms (Hides et al., 1994, 1996), and the atrophy was predominantly isolated to one vertebral level (L5). Multifidus muscle atrophy has been quantified in MRI and CT studies in terms of both decreased muscle size and alterations in muscle consistency (due to fatty deposits or fibrous/connective tissue infiltration). In a CT study, Danneels et al. (2000) showed that the multifidus muscle was selectively decreased at the lowest lumbar level in patients with CLBP when compared with control subjects. In an MRI study of 78 patients with CLBP, degeneration of the multifidus muscle was present in 80% of the participants, and most commonly was seen at L4–5 and L5–S1 (Kader et al., 2000). Similar patterns of atrophy have been demonstrated using ultrasound imaging (Hides et al., 2008a,b).

Dynamic studies of the multifidus muscle are of interest as they provide information related to motor control of the muscle.

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Viewing the muscle contracting in parasagittal section, two studies have provided feedback of multifidus muscle contraction to patients with acute (Hides et al., 1996) and chronic LBP (Hides et al., 2008a). A randomized controlled trial conducted by Van et al. (2006) showed that provision of visual biofeedback using ultrasound imaging improved the ability to contract the multifidus muscle in healthy subjects.

While observation of multifidus muscle contraction using ultrasound imaging has been used in clinical practice for quite some time, it is only recently that the technique has been validated by comparison with fine wire electromyography (EMG). Kiesel et al. (2007) used graded resistance of contralateral upper extremity lifts to produce incremental involuntary contraction of the lumbar multifidus muscles and demonstrated a relationship between increases in muscle thickness and fine wire EMG activity for contractions of 19–43% of maximum. In addition, the effect of pain on multifidus muscle function has been demonstrated experimentally by using a model of induced pain (Kiesel et al., 2008). However, the ability of patients with CLBP to voluntarily contract the multifidus has not been formally assessed.

The aim of this study was to compare both the size (CSAs) and the ability to voluntarily contract the multifidus muscle at four vertebral levels in subjects with and without CLBP using real-time ultrasound imaging.

## 2. Methods

### 2.1. Subjects

Seventeen subjects with CLBP (8 males, 9 females, age range 18–60) and seventeen healthy subjects (8 males, 9 females, age range 18–45) participated in the study (Table 1). CLBP was defined in this study as a history of non-specific LBP for more than 3 months (International Association for the Study of Pain, 2008). Exclusion criteria for the CLBP subjects included histories suggestive of non-mechanical LBP, overt neurological signs, previous lumbar surgery, self-reported pain levels of less than 3 on a visual analogue scale (VAS) and LBP associated with a worker's compensation or motor vehicle accident claim. Exclusion criteria for all subjects included pregnancy, presence of spinal abnormalities, presence of scoliosis with a rib height difference of greater than 2 cm on forward flexion, histories of severe trauma, spinal or abdominal surgery, reported neuromuscular or joint disease, training involving the back muscles within 3 months and difficulty lying in the prone position. This study was approved by the Medical Research Ethics Committee at the host institution. Informed consent was obtained and the rights of human subjects were protected.

### 2.2. Procedure

Three experienced musculoskeletal physiotherapists were involved in data collection. Examiner 1 was responsible for applying inclusion and exclusion criteria and collection of demographic data. For subjects with LBP a body chart was used to record distribution of symptoms and a VAS was used to assess pain levels experienced over the last week. Height and weight were measured and age, gender and weekly activity levels (<1.5, 1.5–3, >3 h) were recorded for all subjects. Examiner 2 assessed multifidus muscle size (CSA) and examiner 3 assessed the ability to voluntarily contract the multifidus muscle (muscle thickness measures). Examiners 2 and 3 were blinded to group allocation of the subjects. The assessors were blinded to each other's results.

**Table 1**
Demographics of subjects in Group 1 (CLBP) and Group 2 (Unimpaired).

| | Age | | Weight | | Height | |
|---|---|---|---|---|---|---|
| | Mean | (SD) | Mean | (SD) | Mean | (SD) |
| Group 1 (Unimpaired) $n = 17$ | 33.9 | (11.2) | 81.2 | (12.5) | 176.6 | (10.3) |
| Group 2 (CLBP) $n = 17$ | 41.9 | (13.7) | 76.1 | (16.7) | 174.2 | (10.3) |

#### 2.2.1. Assessment using ultrasound imaging

Ultrasound imaging was conducted using Diasonics Synergy ultrasound imaging apparatus equipped with a 5 MHz curvilinear transducer (GE-Diasonics, Japan). Subjects were positioned in prone lying, with a pillow placed under the abdomen to minimize the lumbar lordosis. The spinous processes from L2–L5 were marked with a pen. Detection of spinous processes was determined manually using the iliac crests as a landmark. The location of the spinous processes was then confirmed using ultrasound imaging by viewing the spinous processes relative to the sacrum in sagittal section.

#### 2.2.2. Assessment of multifidus muscle CSAs

CSAs of the multifidus muscle were measured from L2 to L5 vertebral segments. Reliability of performing these measures has been previously reported (Hides et al., 1992, 1994; Stokes et al., 2005; Pressler et al., 2006) and previous clinical trials have shown the highly trained assessor (examiner 2) in the present study to be repeatable and reliable with ultrasound measurements of multifidus muscle CSA (Hides et al., 1992, 1994). The validity of measurements obtained using ultrasound imaging has also been demonstrated by comparison with MRI measurements (Hides et al., 1995).

Subjects were instructed to relax the paraspinal musculature, electroconductive gel was applied, and the transducer placed transversely over the spinous process of the vertebral level being measured. This produced images in which the spinous process and laminae could be seen, with multifidus muscles visible on both sides of the spine (Fig. 1A). The echogenic vertebral lamina was used consistently as a landmark to identify the muscle's deep border. The multifidus muscle is bordered superiorly by the thoracolumbar fascia, and the medial border was provided by the acoustic shadow from the tip of the spinous process of the vertebral level being assessed. The lateral border was formed by the fascia surrounding the multifidus and separating it from the longissimus component of the lumbar erector spinae muscle.

Bilateral images of the multifidus muscles were obtained where possible (Fig. 1A), except in the case of larger muscles where left and right sides were imaged separately. The CSA (in $cm^2$) of the multifidus was measured by tracing around the muscle border with the on-screen cursor (Fig. 1B). For consistency, the inner edge of the border was used.

#### 2.2.3. Assessment of multifidus muscle thickness and contraction

Prior to testing of contraction of the multifidus muscle, all subjects received an initial explanation. The anatomical location of the multifidus muscle was demonstrated using a model of the lumbar spine, and pictures of the muscle were provided and explained. A demonstration of an isometric contraction of the biceps was performed as a simple example of the type of contraction required. Subjects were further instructed to take a relaxed breath in and out, pause breathing and then try to "swell" or contract the muscle. They were also instructed not to move their spine or pelvis when they contracted the muscle, and the type of muscle contraction required was a slow gentle sustained contraction. To familiarize subjects with the contraction prior to measuring, subjects were asked to perform 3 contractions with tactile and verbal feedback while the examiner manually palpated the multifidus muscle. It was explained to the subjects that during testing they would have 5 s to try to contract the multifidus muscle and hold the contraction. At the end of the 5 s period, the image would be saved on the ultrasound screen, and measurements performed.

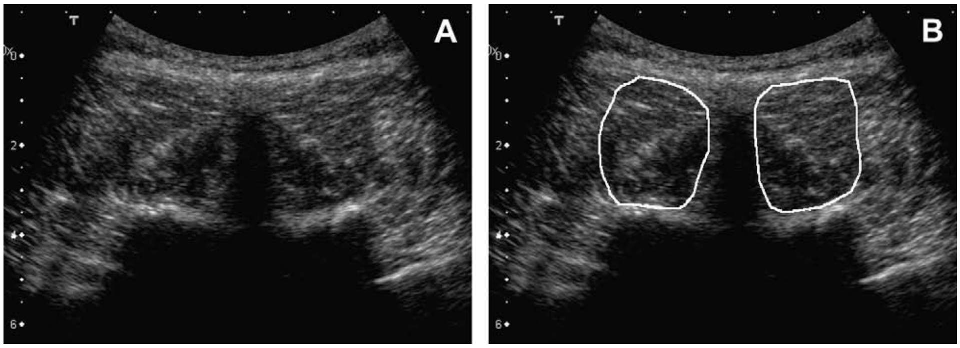


**Fig. 1.** A. Bilateral transverse ultrasound image at the L4 vertebral level, without CSA tracings. B. Bilateral transverse ultrasound image at the L4 vertebral level with CSA tracings. The CSA (in $cm^2$) of the multifidus was measured by tracing around the muscle border with the on-screen cursor.

The multifidus muscle was imaged in parasagittal (longitudinal) section allowing visualisation of the zygapophyseal joints, muscle bulk and thoracolumbar fascia (Hides et al., 1992, 1995, 1996; Van et al., 2006). The multifidus muscle was imaged on both sides from L2 to L5 vertebral levels. Linear measurements (multifidus muscle thickness measures) using on-screen callipers were made in all cases from the tip of the zygapophyseal joint to the superior border of the multifidus muscle for each vertebral level (Fig. 2).

In order to assess multifidus muscle contraction, the difference between the multifidus muscle thickness at rest and during contraction was calculated. A split-screen technique was used to make this measurement more reliable, by allowing anatomical orientation to be maintained in both cases (Fig. 2). Subjects were not allowed to watch the ultrasound monitor or receive feedback about the contractions performed during testing.

Prior to the present study, a reliability trial was performed on 10 healthy subjects not involved in the main study (Wallwork et al., 2007). Each subject was positioned in the standard testing position. Three separate ultrasound images were obtained at rest and the anteroposterior (thickness) measurement was conducted on parasagittal images at two vertebral levels by two raters (examiner 3 and an expert). Intraclass correlations (ICC) were used to determine intra-rater and inter-rater reliability. Results of the $ICC_{3,1}$ for intra-rater reliability was 0.89 for L2/3 (95%$CI = 0.72–0.97$) and 0.88 for L4/5 (95%$CI = 0.68–0.97$). The results of the $ICC_{2,3}$ for inter-rater reliability was 0.96 for L2/3 (95%$CI = 0.84–0.99$) and 0.97 for L4/5 (95%$CI = 0.87–0.99$) (Wallwork et al., 2007).

### 2.3. Statistical analysis

Those without low back pain have greater capacity to produce relatively larger contractions than those with low back pain, threatening the homogeneity of variance of the two samples. To address this issue, the data for two males and two females were excluded from the study as outliers (more than 3 standard deviations above the sample mean). In the analyses of the thickness contraction, the data for 30 participants were used (16 in the CLBP group and 14 in the unimpaired group). Due to limited availability of examiner 2, CSA of the multifidus muscle was only possible for 22 of the 30 participants (11 in the CLBP group and 11 in the unimpaired group).

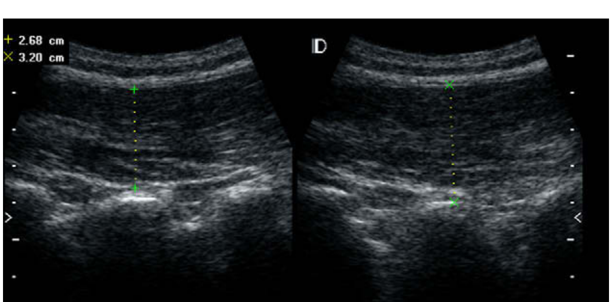


**Fig. 2.** Ultrasound image of the multifidus muscle in parasagittal section at rest and on contraction using a split-screen. Relaxed multifidus muscle thickness = 2.68 cm, contracted value = 3.20 cm.

A mixed design analysis of covariance (ANCOVA) was used to separately analyse the outcome measures of 'percent change in multifidus muscle thickness due to contraction' (called multifidus CSA percent thickness contraction) at each vertebral level. Percent thickness contraction was calculated as; [(contracted thickness − resting thickness/contracted thickness) × 100]. In this study there were 7 independent variables: age, weight, height, gender, activity level (coded as low, moderate or high), group (CLBP or unimpaired), and the repeated measures of asymmetry (larger or smaller side). The variables of age, weight and height were treated as covariates in the analyses. Post-hoc contrasts were used to test for differences among the 3 activity levels if the main effect for this factor was statistically significant.

For both the dependent variables, measures of 'size' and 'asymmetry' are of interest. As calculation of average size across 'side' is confounded by asymmetry across 'side', the data for 'larger' and 'smaller' side were used rather than calculating the percentage difference between the 'larger' and 'smaller' sides. In addition, as higher-order interactions between the covariates and factors confounded the analysis, a Type I sums of squares model was used in preference to a Type III model.

## 3. Results

Demographic details for subjects of both groups are shown in Table 1. Results of an initial analyses of variance showed that there was no significant difference between the two groups for the variables of age ($F = 3.4$, $p = 0.07$), weight ($F = 1.0$, $p = 0.32$) and height ($F = 0.5$, $p = 0.49$). Results of a chi-square test showed that both genders ($p = 0.63$) and all 3 activity levels ($p = 0.75$) were represented in similar proportions across the 2 groups.

### 3.1. Multifidus muscle size

Results of the ANCOVA showed a significantly smaller CSA of the multifidus muscle for the CLBP group compared to the unimpaired group at the L5 vertebral level ($F = 29.1$, $p = 0.001$), and slightly larger size at L2 ($F = 5.8$, $p = 0.047$). A small but significant effect (mean net difference of 0.17 $cm^2$) was found for multifidus muscle 'asymmetry' at each vertebral level ($p < 0.05$) but this was similar for both groups ($p > 0.05$). There were no significant effects for 'gender' at the L4 and L5 vertebral levels, but male subjects had significantly larger mutifidus muscles than females at the L3 vertebral level (difference of 0.9 $cm^2$) and at L2 (difference of 0.15 $cm^2$). 'Activity level' was significantly associated with multifidus size at L3 ($F = 5.9$, $p = 0.03$), L4 ($F = 11.9$, $p = 0.006$) and L5 ($F = 5.4$, $p = 0.04$), but this was similar for both groups (no interaction effect, $p > 0.05$). There were no significant higher-order interactions. Table 2 shows the estimated marginal means of multifidus CSA for the CLBP and unimpaired groups at each level. Table 3 shows the estimated marginal means of multifidus size for the 3 levels of activity.

### 3.2. Multifidus muscle thickness and contraction

Table 4 shows the thickness measurements of the multifidus muscle for rest and contracted conditions, averaged across left and right sides. Analysis of these data was based on calculation of the percent contraction from rest. Results of the ANCOVA showed a significantly smaller percent thickness contraction for the CLBP group compared to the unimpaired group at the L5 vertebral level ($F = 6.6$, $p = 0.02$), but not at other vertebral levels ($p > 0.05$). A small but significant effect (mean net difference of 2.7%) was found for contraction 'asymmetry' at each vertebral level ($p < 0.05$) but this was similar for both groups (i.e. there was no significant interaction between 'asymmetry' and 'group', $p > 0.05$). There were no significant effects for the variables of 'activity level' or 'gender' and no significant higher-order interactions. Table 5 shows the estimated marginal means (and standard deviations) for the CLBP and unimpaired groups at each level.

## 4. Discussion

### 4.1. Multifidus muscle size

Results from the current investigation showed a specific and localized pattern of atrophy of the multifidus muscles in the presence of chronic LBP. In this study, atrophy was greatest at the L5 vertebral level, and there was a trend towards significance at the L4 vertebral level. Several previous imaging studies have reported evidence of multifidus muscle atrophy in patients with LBP. Researchers have investigated post-operative patients (Sihvonen et al., 1993), patients with acute/subacute LBP (Hides et al., 1994, 1996) and patients with chronic LBP (Kader et al., 2000; Danneels et al., 2000, 2001; Barker et al., 2004; Hides et al., 2008a,b). In agreement with these previous studies, the pattern of atrophy seen in the chronic LBP patients investigated appeared to be specific and localized in nature.

### 4.2. Multifidus muscle thickness and contraction

The results of this study suggest that the neuromotor control of multifidus was altered at the L5 vertebral in patients with CLBP. Subjects with CLBP were less able than healthy subjects to voluntarily contract the multifidus muscle at the same vertebral level where atrophy was present. The clinical relevance of this finding is that rehabilitation may need to be specific in order to target localized impairments in motor control.

Clinical approaches targeting motor control of muscles including the multifidus, transversus abdominis and pelvic floor have been shown to be effective in randomized clinical trials (RCTs) (Hides et al., 1996; O'Sullivan et al., 1997; Stuge et al., 2004; Goldby et al., 2006). A RCT conducted on subjects with first episode acute LBP provided the first evidence of a localized, segmental impairment in the CSA of the multifidus muscle (Hides et al., 1996). Similar to the findings of the current study, it was reported that subjects could not voluntarily contract the multifidus muscle at the vertebral level where the atrophy of the muscle was observed. A tailored exercise approach targeting the impaired muscle restored muscle size and resulted in lower recurrence rates of LBP (Hides et al., 2001). Ultrasound imaging was used to provide feedback of multifidus muscle contraction (Hides et al., 1996; Van et al., 2006). A motor control approach was also recently successfully employed in a study involving elite cricketers with LBP (Hides et al., 2008b). Results showed that the CSAs of the multifidus muscles at the L5 vertebral level increased with training and these changes were commensurate with a 50% decrease in mean reported pain levels.

The finding that subjects who have LBP are less able to contract the multifidus has also been reported in a laboratory study. The effect of pain on multifidus muscle function was demonstrated experimentally using a model of induced pain (Kiesel et al., 2008). Increases in multifidus muscle thickness during arm lifting tasks were significantly reduced by pain in response to injection of saline into the erector spinae muscles. While Kiesel et al. (2008) did not examine voluntary contractions of the multifidus muscle, the findings may support the current clinical practice of using physiotherapeutic modalities to decrease pain prior to commencing rehabilitation of the multifidus muscle, and performance of voluntary multifidus contractions in pain-free positions (Hides et al., 1996).

#### 4.2.1. Limitations and future directions

This study has some limitations. The study sample size is small, though comparable with other similar investigations (Hides et al., 1996; Danneels et al., 2000; Van et al., 2006). Thickness measures of the multifidus muscle were obtained in 30 subjects, where CSA measures were only obtained in 22 participants. While this is not ideal, the results from this study in relation to CSA of the multifidus are in line with previous reports (e.g. Danneels et al., 2000; Hides

**Table 2**
Group differences (marginal means[a] and standard deviations) in multifidus muscle size ($cm^2$) across vertebral levels L2–L5.

| | L2[b] | | L3 | | L4 | | L5[b] | |
|---|---|---|---|---|---|---|---|---|
| | Mean | (SD) | Mean | (SD) | Mean | (SD) | Mean | (SD) |
| Group 1 (unimpaired) | 1.94 | (0.9) | 3.09 | (1.3) | 4.61 | (1.0) | 5.56 | (1.1) |
| Group 2 (CLBP) | 2.40 | (0.9) | 3.02 | (1.4) | 3.47 | (1.1) | 3.81 | (1.2) |

[a] Adjusted for the covariates of age, weight and height.
[b] Statistically significant difference at $p < 0.05$.

**Table 3**
Activity level differences (marginal means[a] and standard deviations) in multifidus size ($cm^2$) across vertebral levels L2–L5.

| Physical activity per week | L2 | | L3 | | L4[b] | | L5[b] | |
|---|---|---|---|---|---|---|---|---|
| | Mean | (SD) | Mean | (SD) | Mean | (SD) | Mean | (SD) |
| Level 1 activity (<1.5 h) | 1.78 | (1.1) | 2.24 | (1.5) | 2.95 | (1.2) | 3.96 | (1.3) |
| Level 2 activity (1.5–3 h) | 2.27 | (0.9) | 3.09 | (1.3) | 4.29 | (1.1) | 5.26 | (1.2) |
| Level 3 activity (>3 h) | 2.44 | (1.3) | 3.82 | (1.9) | 4.87 | (1.5) | 4.84 | (1.7) |

[a] Adjusted for the covariates of age, weight and height.
[b] Statistically significant difference between Activity Level 1 versus Level 2 and Level 3, based on post-hoc contrasts with Bonferroni correction.

**Table 4**
Thickness (means and standard deviations) of the multifidus muscle in the rest and contracted state across vertebral levels L2–L5 (mm).

| | L2 | | L3 | | L4 | | L5 | |
|---|---|---|---|---|---|---|---|---|
| | Mean | (SD) | Mean | (SD) | Mean | (SD) | Mean | (SD) |
| Group 1 (unimpaired) | | | | | | | | |
| Rest | 29 | (5.2) | 33 | (5.0) | 35.9 | (5.3) | 35.9 | (4.8) |
| Contracted | 31 | (5.3) | 34.7 | (4.8) | 37.7 | (4.9) | 38.1 | (4.8) |
| Group 2 (CLBP) | | | | | | | | |
| Rest | 27.6 | (4.7) | 30.5 | (4.5) | 33.6 | (5.3) | 33.9 | (5.5) |
| Contracted | 28.9 | (4.7) | 31.9 | (5.2) | 34.6 | (5.4) | 35.0 | (5.6) |

**Table 5**
Group differences (marginal means[a] and standard deviations) in percentage thickness contraction across vertebral levels L2–L5.

| | L2 | | L3 | | L4 | | L5[b] | |
|---|---|---|---|---|---|---|---|---|
| | Mean | (SD) | Mean | (SD) | Mean | (SD) | Mean | (SD) |
| Group 1 (unimpaired) | 6.93 | (6.7) | 5.20 | (7.0) | 5.15 | (5.9) | 6.29 | (6.5) |
| Group 2 (CLBP) | 4.10 | (7.4) | 4.22 | (7.8) | 2.93 | (6.5) | 3.05 | (7.2) |

[a] Adjusted for the covariates of age, weight and height.
[b] Statistically significant difference at $p < 0.05$.

et al., 2008a). Furthermore, while CSA of the multifidus muscle was measured, consistency changes in the muscle (fatty deposits or fibrous/connective tissue infiltration) were not assessed. Future studies, especially those employing imaging techniques such as CT scanning and magnetic resonance imaging, could assess this. The main new contribution of this paper is the data pertaining to contraction of the multifidus muscle. The measure could be used in future studies to compare the effectiveness of retraining motor control with and without feedback by ultrasound imaging in subjects with CLBP.

### 4.2.2. Conclusion

Patients with CLBP had significantly smaller multifidus muscles than healthy, asymptomatic subjects at the lowest vertebral level of the lumbar spine. Patients with CLBP also had greater difficulty performing a voluntary isometric multifidus contraction at the same vertebral level. The results of this study support previous findings that the pattern of multifidus muscle atrophy in CLBP patients is localized rather than generalized but goes further in also ascertaining a reduced ability to voluntarily contract the atrophied muscle. These findings lend support to the use of specific muscle retraining programmes for patients with CLBP.

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