The effect of different physical activity levels on muscle fiber size and type distribution of lumbar multifidus. A biopsy study on low back pain patient groups and healthy control subjects

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Aim. Previous studies examining the multifidus fiber characteristics among low back pain (LBP) patients have not considered the variable of physical activity. The present study sought to investigate the muscle fiber size and type distribution of the lumbar multifidus muscle among LBP patient groups with different physical activity levels and healthy controls.

Methods. Sixty-four patients were assigned to one of three groups named according to the physical activity level, determined for each patient by the International Physical Activity Questionnaire. These were low (LPA), medium (MPA) and high (HPA) physical activity groups. A control group comprising of 17 healthy individuals was also recruited. Muscle biopsy samples were obtained from the multifidus muscle at the level L4-L5.

Results. In contrast with the control group, LBP patient groups showed a significantly higher Type II fiber distribution as well as reduced diameter in both fiber types (P<0.05). The physical activity level did not have an effect on multifidus characteristics since no significant differences were observed in fiber type and diameter (P>0.05) among LPA, MPA and HPA patient groups. Various pathological conditions were detected which were more pronounced in LBP groups compared to the control (P<0.05). Males had a larger fiber diameter compared to females for both fiber types (P<0.05).

Conclusion. The results showed that the level of physical activity did not affect muscle fiber size and type distribution among LBP patient groups. These findings suggest that not only inactivity but also high physical activity levels can have an adverse effect on the multifidus muscle fiber characteristics.

KEY WORDS: Physical activity - Biopsy - Low back pain - Muscle fibers, skeletal - Histology.

It is well established that each skeletal muscle is designed to perform specific functions that are directly related to its morphological, histochemical and biochemical features.1, 2 According to these features, muscles are classified into two categories: Type I and Type II.3 Type I (slow-twitch) fibers are relatively small in cross section and contain abundant mitochondria. They are rich in sarcoplasm, which in turn, contains a large volume of myoglobin, an oxygen-storage molecule, responsible for the red colour of these fibers.3, 6 Type I fibers are related to continuous contraction and their energy derives from oxidative phosphorylation of fatty acids.2, 3 On the other hand, Type II (fast-twitch) fibers are related to muscles responsible for rapid but intense discontinuous contraction.2, 7 They contain less myoglobin, accounting for their light-red colour.2, 3 These muscle fibers are rich in glycogen and glycolytic enzymes and in contrast to Type II fibers, they have a narrow Z-band.1, 4
Low back pain (LBP) is a common and disabling condition which poses a major economic burden to society. Many studies have advocated the association between muscular insufficiency and the presence of LBP. More specifically, alterations on the multifidus muscle fiber characteristics have been detected in previous research papers. This muscle, which is the most medially located back muscle and the largest that spans the lumbosacral junction, maintains the erect posture of the trunk, abducts and rotates it. In addition, the lumbar part of the multifidus muscle contributes to the stabilization of the spine as well as the control of the intervertebral motion.

Studies have documented that the multifidus muscle of the patients with LBP exhibits a higher proportion of type II fibers as well as smaller fiber size, which consequently results in a decreased ability to generate muscle strength. It has been also supported that dysfunctional signs of the particular muscle, such as muscle waste and side-to-side cross sectional area asymmetry, are responsible for the high recurrence of LBP following an initial episode. Furthermore, it has been documented that the multifidus muscle undergoes specific pathologic changes such as fiber type grouping, small angulated fibers, group atrophy, moth eaten appearance and internal nuclei.

Various studies have reported that muscle fibers are affected by occupational and physical activity loads showing structural and histological abnormalities. Findings in subjects exposed to heavy workloads and increased physical activity levels have shown various disturbances in fiber type characteristics.

When attempting to determine the muscle fiber characteristics in patients with LBP, few previous studies have taken into account factors such as gender, age, size, duration of symptoms and physical activity levels which have all been considered to affect fiber type distribution and morphology.

Therefore, the purpose of the present study was to compare the multifidus muscle fiber microscopic characteristics of LBP patient groups with different physical activity levels matched for age, gender, size and duration of symptoms. To our knowledge this is the first research examining the multifidus fiber characteristics of LBP patients and healthy controls that takes into account the physical activity variable.

Materials and methods

Participants and procedure

From a total of 77 LBP patients, 64 (33 males and 31 females) were recruited to serve as subjects. In addition, a control group that comprised of 17 (9 males and 8 females) matched healthy, generally active (but not specifically trained) individuals, who had never experienced an episode of back pain, was recruited. All subjects participated voluntarily and were informed of the purpose and potential risks of the research. A written consent form was obtained prior to the initiation of the study. The study was approved by The Medical Ethics Committee of the University of Patras and completed in accordance with the Declaration of Helsinki for studies involving human subjects.

Three comparable LBP patient groups were formed based on the physical activity level profile of each subject, which was determined by the International Physical Activity Questionnaire. The validity of the specific questionnaire has been previously assessed. The physical activity level classification was conducted based on the energy expended every week by each individual to perform different physical activities expressed in METs (a MET being defined as a multiple of the resting metabolic rate). The three groups were named according to the physical activity level of the patients as follows: low (LPA; <3.0 METs, expending <1 000 kcal/week), medium (MPA; 3.0-6.0 METs, expending 1 000-1 999 kcal/week) and high (HPA; >6.0 METs, expending ≥2 000 kcal/week). All LBP groups were comprising of patients for whom conservative treatment had failed and who were undergoing posterior surgery for intervertebral disc degeneration (IDV) disorders sharing similar aetiology, pathophysiological mechanisms and signs/symptoms (i.e., disc herniation, stenosis). The level and side of IDV were confirmed through magnetic resonance imaging and/or computed tomography scan and further during the time of operation. Each subject of each group was matched to a subject of the other groups for gender, age and body mass in such a way that the difference among the patients of the same gender was never greater than five years in age and 8 kg in body weight. The duration of symptoms ranged from 24 to 36 months (mean 28.3 months). Subjects were also matched for this variable keeping the difference among the patients of no greater than six months. None of the subjects had undergone pre-
The physical characteristics of the three LBP groups and the control group are presented in Table I.

### Histochemical analysis

The muscle samples (approximately 5 x 5 x 10 mm) for biopsy were taken from the transversospinal corner of the multifidus muscle at the level of L4-L5, after retracting the lumbodorsal fascia and the overlying sacrospinalis. To reduce the risk of sampling from the adjacent longissimus, the specimens were taken 1 cm lateral from the midline on the side of extrusion deeper than the aponeurosis of the erector spinae muscle. The multifidus muscle was identified by its position adjacent to the spinous process and the cranial/medial-to-caudal/lateral projection of its fibers. Tissue was embedded in paraffin cubes. Five µm thick sections were obtained from each cube for classical hematoxylin and eosin (H&E) staining. It is important to notice that since the nature of the present study was retrospective, fresh tissue was not available for the performance of myosine adenosine triphosphatase or NADH-tetrazolium reductase (NADH-TR) histochemical staining procedures. Therefore, the histologic findings were defined exclusively by evaluating H&E sections of each case. Muscle fibers were categorized as Type I or Type II, according to their “dark red” or “white-red” colouration under light microscopy. The alterations of the internal morphologic features were quantified by calculating the percentage of their frequencies in a total of approximately 100 muscle fibers. These alterations were graded on a scale of 0-2+ according to the following assessment, stated by previously published studies: 0, <1%; 1+, 1-3%; 2+, ≥3% of the cells display each of the examined structural abnormalities. All H&E sections were evaluated by two independent experienced pathologists (D.J.P., C.D.S.). The size of each muscle fiber was calculated as the “lesser fiber diameter” using a digitizer interfaced with a metric microcomputer system.

### Statistical analysis

Data analysis was performed on Windows XP-2000 software using SPSS 14 statistical package (SPSS Inc., Chicago, IL, USA). A two-way ANOVA was used to determine the statistical differences in percentage fiber type and diameter. Kruskal Wallis test and Fisher test was used to examine the differences in pathologic findings.

### Results

The results for the multifidus muscle fiber type distribution for each group as well as for each sex are presented in Figure 1. The percentage of Type II fibers was overall greater than Type I for all patient groups. The percentage of the muscle occupied by Type II fibers did not vary significantly between HPA, MPA and LPA groups (P>0.05). In contrast, the control group had a significantly greater percentage of Type I fibers (P<0.05). Although females had a slightly higher area percentage occupied by Type I fibers than males, the area percentage of Type I and Type II fibers did not differ significantly between males and females (P>0.05) in all experimental groups.

Figure 2 presents the results for the multifidus muscle fiber type diameter for each group as well as for each sex. Both Type I and Type II fibers were significantly greater in diameter in the control group (P<0.05). No statistical differences were observed in

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**Table I.**—Physical characteristics of the groups (mean ± SD).

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<tr>
<th></th>
<th>HPA (n=19)</th>
<th>MPA (n=20)</th>
<th>LPA (n=25)</th>
<th>Control (n=17)</th>
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<tr>
<td></td>
<td>Males (n=10) Females (n=9)</td>
<td>Males (n=11) Females (n=9)</td>
<td>Males (n=12) Females (n=13)</td>
<td>Males (n=9) Females (n=8)</td>
</tr>
<tr>
<td>Age (yrs)</td>
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<td>Height (m)</td>
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<td>Body Mass (kg)</td>
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<td>BMI (kg.m²)</td>
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<td>21.5±2.8</td>
<td>22.7±3.1</td>
<td>22.2±4.2</td>
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HPA = high physical activity group; MPA = medium physical activity group; LPA = low physical activity group; BMI = body mass index (body mass/height²)
the diameter of both fiber types between HPA, MPA and LPA groups (P>0.05). Overall men had larger fibers than women for both Type I and Type II fibers (P<0.05). For a given gender, the mean diameter of the muscle fibers was significantly larger only at the control group (P<0.05) with no significant differences between the three patient groups (P>0.05).

Table II presents the overall pathological findings on multifidus muscle fibers of each group. The microscopic abnormalities were detected in males and

<table>
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<tr>
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<th>MPA (n=20)</th>
<th>LPA (n=25)</th>
<th>Control (n=17)</th>
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<td>Core target fibres</td>
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</table>

HPA = high physical activity group; MPA = medium physical activity group; LPA = low physical activity group.

Figure 1.—Muscle fibre type percentage of the groups. A) Males; B) females. The effect of different physical activity levels on muscle fiber size and type distribution of lumbar multifidus. A biopsy study on low back pain patient groups and healthy control subjects.

Figure 2.—Muscle fibre type diameter (µm) of the groups. A) Males; B) females. The effect of different physical activity levels on muscle fiber size and type distribution of lumbar multifidus. A biopsy study on low back pain patient groups and healthy control subjects.
females approximately equally. Histological analysis revealed specific neurogenic and myogenic alterations in all groups. These did not vary significantly between the different physical activity level LBP groups (P>0.05). However, the control group had significantly fewer incidences of pathologic findings compared to the patient groups (P<0.05).

**Discussion**

The aim of the research was to compare the multifidus characteristics such as muscle fiber size and type distribution between LBP patients with different physical activity levels and a control group consisting of healthy individuals who had never experienced back pain. In order to serve the purposes of the present study the subjects were matched for factors that have been considered to influence muscle fiber characteristics such as age, gender, body mass and duration of symptoms. Furthermore, it should be noted that to our knowledge this is the first investigation examining the variable of physical activity in relation to multifidus muscle fiber characteristics among LBP patients.

**Fiber distribution and diameter**

Previously published data on healthy individuals have shown a large proportion of Type I (slow twitch fibers), indicating the postural role of the multifidus muscle. The data on healthy individuals of the present study are in agreement with those studies mentioned above. More specifically, it has been found that the multifidus muscle of the control group was occupied mainly by Type I fibers, varying significantly from the patient groups for both fiber type distribution and fiber diameter. Overall the patient groups, in contrast to the control group, had a higher percentage of Type II, in comparison with Type I, muscle fibers. Both fiber type diameters of the LBP patient groups appeared significantly smaller comparing to the control group suggesting an atrophic fiber profile. Although a few studies have found no differences in the percentage of Type I fibers and fiber diameter between healthy individuals and LBP patients, a decrease in the Type I fiber percentage, in relation to Type II, has been well documented in LBP patients.

The significantly higher proportion of Type II fibers of the patient groups observed in the present study has been shown to be associated with greater fatigability during prolonged contractions. Studies have shown that the back muscles which are considered highly fatigable have an increased risk for LBP development, leaving the spine vulnerable to injury. The lower percentage of Type I fibers in the patients' multifidus muscle observed in the present study might reflect an alteration in the muscle microstructure. The existence of a fast and more fatigable fiber type in the multifidus muscle, documented in the patient groups, reflects adaptive alterations consequent to LBP. However, it is questionable whether the typical fiber type characteristics observed in the present study are a result of the disease process or inherited genetically and function as a predisposition factor for LBP development.

**Group differences**

Various studies have supported the notion that a low physical activity level results in a transformation of the muscle fiber towards a faster type (Type II). Similarly, others have advocated that reduced fiber diameter and muscle atrophy are increased by physical deconditioning. Moreover, inactivity is considered a plausible cause of fiber atrophy and fiber type transformation in healthy individuals as well as in LBP patients. Based on these reports we would expect individuals of the HPA group who were exposed to regular physical activity to show a higher proportion of Type I fibers and a larger fiber diameter compared to the other patient groups. Interestingly, the results of the present study showed that physical activity levels did not have an affect on the multifidus muscle fiber characteristics since the HPA group patients exhibited a similar fiber type distribution (Type II predominant type) and fiber diameter with MPA and LPA patient groups. Nevertheless, although all LBP patient groups demonstrated similar muscular features, different causes and mechanisms could be suggested in order to explain the muscle fiber alterations of physically active LBP patients and those with a reduced physical activity level profile.

The reduced workload in the MPA and LPA patient groups, resulting from either the vicious cycle of pain and/or a sedentary lifestyle, can lead to atrophy and reduced diameter of muscle fibers as well as percentage distribution shift from Type I to Type II.
This theory however, cannot explain the alterations in multifidus muscle fiber profile of the physically active patients.

The individuals of the HPA group could have experienced back pain not only due to their pathologic condition but also due to the high activity-related loads localised in the back region. The development of such an increased pain pattern results in inhibition of muscle activation and reflex decreased activation on the painful side of the back muscles, which is associated with altered and/or uneven activity between the different parts of the multifidus muscle. As a consequence, LBP patients experience diminished control and coordination of trunk muscle activity which could render the spine more vulnerable to injury. This excessive and abnormal physical strain has been suggested to result in pathologic muscle changes, explaining the observed alterations in multifidus fiber characteristics of the HPA group. In accordance with our findings, studies on muscle fiber abnormalities related to occupational loads have shown increased frequency and distribution of Type II fibers in patients compared to healthy subjects.

Furthermore, as shown in Table II a number of neurogenic and myogenic changes were observed in our study. These histopathologic results are in agreement with previous reports examining paraspinal muscle fiber characteristics of LBP patients. The incidence of pathologic findings appears consistent with the differences in fiber type distribution and diameter among LBP patient and control groups. Specifically, we documented that the fiber abnormalities observed in the control group were significantly lower compared to the LBP patient groups. However, no differences were detected in the internal structure of the multifidus muscle fibers among HPA, MPA and LPA groups (Figures 3-6).
There are many factors responsible for these changes such as denervation and ischemia, reactive proliferation of connective tissue secondary to the muscle injury and impairment, as well as loss of NADH-TR activity, which is associated with focal loss of mitochondria. The mechanisms responsible for triggering these events are possibly similar to those accounting for the fiber type distribution shift and reduced fiber diameter. Hence, the alterations in the histological and biochemical level of the MPA and LPA groups could be attributed to inactivity due to the vicious cycle of pain and/or sedentary lifestyle. However, the pathologic findings seen at the HPA group could be considered as a result of the effect of the efferent neuromuscular system inducing pain inhibition and reflex decreased activation. Nevertheless, although fiber abnormalities are an interesting observation, further research should be undertaken to establish their functional relevance in relation to LBP musculature.

Gender differences

In agreement with previous studies the data of the present investigation from the control group showed that the relative area of muscle occupied by Type I fibers was larger in women than in men in all groups. This fact is believed to explain the better performance of women on paraspinal muscle endurance test protocols. Even in the patient groups where the Type II fibers were predominant, females overall, had a tendency to exhibit a higher percentage of Type I fibers compared to males. This is in agreement with reports from other studies supporting that women are less fatigable than men, exhibiting a larger area of the back muscles occupied by Type I fibers. The increased proportion of Type II fibers in the three patient groups, observed in the present study, suggests that the alterations in the patients’ muscle structure, as a consequence of the onset of LBP, equally affects muscle fibers of both genders. Significant differences were also observed in the size of both muscle fiber types between female and male individuals. This observation remained constant even at the patient groups where subjects exhibited an atrophic profile. The bigger fibers in male muscles, documented in all study groups, are related to the gross muscle size differences.

Conclusions

In conclusion, the results of the present study have shown overall significant differences between the control group and the three LBP patient groups. In contrast with healthy subjects, LBP patients exhibited a higher distribution of Type II muscle fibers as well as an atrophic fiber profile affecting both fiber types. Interestingly, our investigation was the first to demonstrate that the level of physical activity did not have an effect on the multifidus muscle fiber characteristics since the results revealed that muscle fiber type and distribution did not vary significantly across the HPA, MPA and LPA groups. Various pathological findings in the multifidus muscle structure were detected, which were statistically more obvious in patient groups compared to the control group. Sex differences were observed in fiber size with male’s fiber diameter being larger compared to females. The understanding of muscle fiber alterations due to low back pain can be valuable for use in rehabilitation as well as prevention. Not only inactivity but also increased physical activity levels can have an adverse effect on fiber type size and distribution suggesting different mechanisms for these alterations.

References


