Eur Spine J (2000) 9:273–281

SSE BASIC SCIENCE AWARD 2000

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Influence of age and duration of symptoms on fibre type distribution and size of the back muscles in chronic low back pain patients

Received: 9 June 2000
Accepted: 20 June 2000

Abstract Many studies have documented an association between chronic low back pain (LBP) and deficits in back muscle strength and endurance. The sub-optimal performance is believed to be the result of alterations in the size and structure of the muscle, although the long-standing issue of whether the observed changes precede or are a consequence of the pain remains unresolved. If consequent to the problem, and predominantly related to disuse of the muscles, then it may be expected that a relationship between muscle structure and symptom duration would exist. Lumbar paraspinal muscle samples were obtained from 59 chronic LBP patients using the percutaneous biopsy technique. The samples were subject to routine histochemical analysis for the examination of muscle fibre type characteristics and cytochemical architectural changes. In 55 of the patients, the gross cross-sectional areas of magnetic resonance images of the trunk muscles were also measured. Multivariate analysis showed that symptom duration was the strongest predictor of the individual proportions of the fast-fatigable type IIX fibres; with age and gender included in the model, nearly 30% of the variance in fibre type distribution could be accounted for. Duration of pain had no influence on fibre size. Gross muscle cross-sectional area correlated directly with lean body mass and inversely with age, but showed no relationship with symptom duration. Pathological changes in the internal fibre structure were more frequently encountered in older patients, and were independent of symptom duration. The results suggest that, over the long term, fibre type transformations rather than alterations in fibre size are the predominant changes to be found in the muscles of chronic LBP patients. The direction of change supports the results of many previous studies that have demonstrated corresponding differences in the fatigability of the muscles. There is a strong case for the early implementation of active measures to attempt to offset the development of these changes in back pain patients.

Key words Chronic low back pain · Erector spinae muscle · MRI · Muscle biopsy · Fibre type distribution

This paper is dedicated to Prof. W. Zenker on his 75th birthday.

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Introduction

In recent years, numerous studies have documented an association between chronic low back pain (LBP) and sub-optimal performance of the back muscles: deficits in both the strength and fatigue-resistance of the muscles have been reported [3, 14, 23, 25, 30,31], although the long-standing issue as to whether these changes precede or are a consequence of the pain remains unresolved. There is

some, but not unequivocal, evidence to suggest that the possession of highly fatigable back muscles may predispose an individual to the development of LBP [1, 4,16]. These findings are supported by convincing theoretical arguments to suggest why inadequate muscular support could lead to injury of the joints and ligaments of the spine during manual handling tasks [7,34]. Nonetheless, we still have no conclusive evidence of a significant role for muscle fatigue as a risk factor for the development of LBP [17]. In view of this, it is reasonable to propose that the observed alterations in the muscular capacity of the LBP patient arise subsequent to the pain, perhaps as the result of a long period of pain-associated inactivity.

Few studies have attempted to corroborate the conclusions of the muscle function tests by examining the fibre type composition of the back muscles of chronic LBP patients: if their muscles are more fatigable, they would be expected to display (relative to 'normal') an increased presence of type IIX fibres (in older terminology, referred to as type IIB fibres), by means of an increase in either the relative size or the relative number of type IIX fibres at the expense of other fibre types. No studies have investigated in detail these properties of the muscle in patients with chronic, non-specific LBP, although in a population of surgical LBP patients it was shown that the muscle did indeed display a significantly higher proportion of type IIX fibres at the expense of type I fibres, when compared with a group of age-, gender- and body size-matched controls [20]. Nonetheless, this still provides no answer to the question of 'cause or effect?'.

If consequent to the problem, and predominantly related to disuse of the muscles, then it may be expected that a relationship between fibre type distribution and symptom duration would exist. Such an association has previously been shown by Uhlig et al. [33], in studying the ventral neck muscles of patients with cervical spine disorders, but could not be confirmed in the multifidus muscles of patients attending spinal surgery [35]. In analysing changes in muscle structure with increasing duration of long-term chronic musculoskeletal problems, it is imperative that age is controlled for, because age can exert an independent influence on the muscle structure, in a direction that may oppose, and hence mask, the unique effects of the clinical problem. For example, in other muscles, there is typically a decrease in the proportion of the muscle occupied by type IIX fibres with increasing age [15], and this could potentially obscure any positive correlation between this same characteristic of the muscle and symptom duration, in patients with long-term joint problems.

Long-term disuse is often considered to be associated with a certain degree of atrophy of the muscle, measurable at both the macroscopic and the individual fibre level. With regard to the muscles of LBP patients, however, this phenomenon has not been reliably demonstrated.No clear difference exists between patients and controls in the size of their muscle fibres [20, 22,28], and studies examining the gross cross-sectional area of the back muscles have produced equivocal findings with respect to the issue of gross muscle atrophy. Some studies report no statistically significant difference in back muscle size between patients and controls [12, 24, 26], whilst others maintain that atrophy can be demonstrated in patients with long-term back problems, as long as the muscle size is expressed in relation to the vertebral body size [5].

The aim of the present study was to examine the relationship between erector spinae muscle size/fibre type characteristics and the duration of pain in a large group of chronic LBP patients. By taking into account potential confounding variables (such as gender, age, body size) we hoped to arrive at an unambiguous conclusion regarding the changes in muscle structure that occur with time throughout the course of this chronic musculoskeletal problem.

Materials and methods

Patients

Fifty-nine patients (29 men, 30 women) with chronic LBP took part; some of their physical and LBP characteristics are described in Table 1.

Patients were recruited into the study through advertisements in the local media. They attended the hospital, where all the admission criteria were checked in detail through medical history interview/clinical examination by neurologists. Criteria for inclusion

Table 1 Physical and low back pain (LBP) characteristics of the patients; means ± SD (LBM lean body mass, VAS visual analogue scale)

Parameter	Males (n = 29)	Females (n = 30)	All patients (n = 59)
Age (years)	42.5 ± 11.2	45.1 ± 10.7	43.8 ± 10.9
Height (m)	1.78 ± 0.09	1.65 ± 0.08	1.71 ± 0.11
Body mass (kg)	78.7 ± 10.5	64.6 ± 10.7	71.7 ± 12.7
LBM (kg)	60.8 ± 7.7	43.3 ± 5.8	52.1 ± 11.1
Duration of LBP (mo.)	170 ± 114	144 ± 133	157 ± 124
Highest pain intensity (0–10 VAS)	6.6 ± 2.2	6.9 ± 2.2	6.8 ± 2.2
Average pain intensity (0–10 VAS)	3.9 ± 2.1	4.6 ± 1.9	4.3 ± 2.0
Self-rated disability (Roland & Morris [29], 0–24)	6.1 ± 4.8	10.1 ± 4.5	8.1 ± 5.0

were: less than 65 years old and more than 3 months' continuous or recurrent episodes of LBP, with or without referred pain (of a non-radicular nature), serious enough to cause sickness absence from work and/or seek medical attention. The exclusion criteria were: constant or persistent severe pain, pregnancy, previous spinal surgery, current nerve root entrapment accompanied by neurological deficit, spinal cord compression, tumour, severe structural deformity, severe instability, severe osteoporosis, fresh fracture, inflammatory disease of the spine, spinal infection, severe cardiovascular or metabolic disease, other corresponding disorders preventing active rehabilitation, acute infection, lack of co-operation.

After receiving an oral and written explanation of what would be required of them, the patients signed an informed consent form confirming their agreement to participate. The study was approved by the local University Ethics Committee.

Assessment of pain and disability levels

Patients completed a questionnaire (as in an earlier study [21]), which enquired about the duration and frequency of their LBP, their pain intensity [0–10 on a visual analogue scale (VAS)] and their self-rated disability due to LBP (Roland and Morris Disability Questionnaire, 0–24 points [29]).

Muscle biopsy collection

With the subject lying prone, percutaneous muscle biopsy samples were taken from the belly of the lateral tract (iliocostalis/longissimus) of the left erector spinae, at the level of the 3rd/4th lumbar vertebra, using 6.5-mm Tilley-Henckel punch forceps [6]. Routine aseptic precautions were taken. After local anaesthesia (5–10 ml 1% lidocaine), a 5- to 8-mm incision was made in the skin and underlying fascia. The forceps were then inserted through the incision to retrieve a 50- to 100-mg piece of muscle.

Muscle histochemistry/immunohistochemistry and fibre type/size analysis

The specimens were orientated in an embedding medium (Tissue Tek, Miles Elkhart, Ind., USA) then snap-frozen in isopentane cooled by liquid nitrogen, and stored at –80 °C. Serial sections, 14 μm thick, were cut in a cryostat at –20 °C, then reacted for myofibrillar adenosine triphosphatase (mATPase) following acid (pH 4.3 and 4.6) and alkali (pH 10.5) preincubations (according to Guth and Samaha [11], with certain modifications).

Consecutive sections (14 μm) were incubated for demonstration of cytochrome *c* oxidase [36] and α-glycerophosphate dehydrogenase [8,27].

Muscle fibres (typically 300–400 per section) were assessed for staining intensity, while the specimen was under the microscope (using a camera lucida for drawing). By comparison of consecutive sections stained for mATPase after alkaline and acid preincubations, fibres were identified as either type I (slow-twitch oxidative), IIA (fast-twitch oxidative glycolytic), IIX (fast-twitch glycolytic) or IIC (intermediate).

The cytochemical architecture of the fibres [8] was investigated in sections stained for cytochrome *c* oxidase. The proportions of pathological although non-specific changes such as core fibres [32], 'moth-eaten' fibres [2] and target fibres [10] were calculated (Fig. 1).

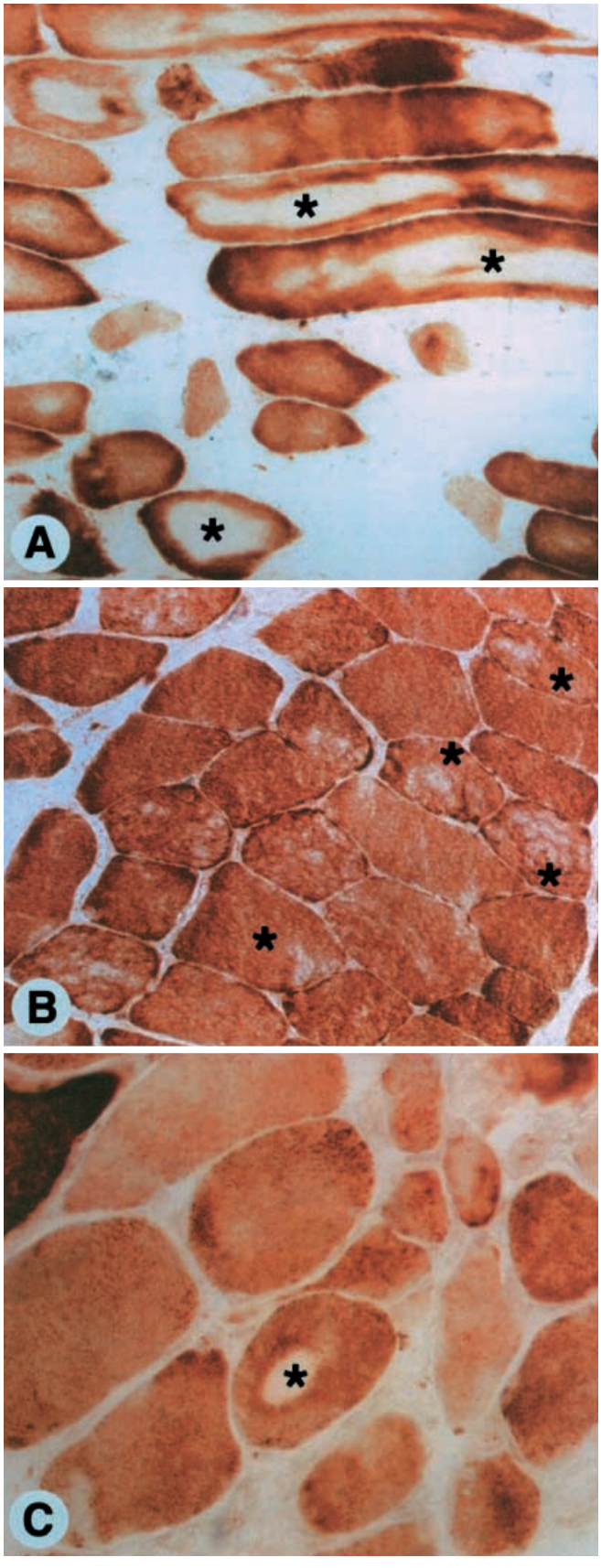

Fig. 1 A–C Micrographs of pathological changes of cytochemical architecture: **A** core fibres (20×), **B** 'moth-eaten' fibres (20×), and **C** target fibres (40×). Pathological fibres are marked with an asterisk (*). Cryostat sections were stained for cytochrome *c* oxidase

Images of the sections were captured using a video camera (Videk 1400; Kodak, Canandaigua, N.Y., USA) attached to a microscope (Axioplan; Carl Zeiss, Oberkochen, Germany) and interfaced to a computer running image analysis software (MCID-M2, v 1.2; Imaging Research, St Catherines, Ontario, Canada) for the measurement of lesser fibre diameter [8]. Where possible, at least 50 of each of the main fibre types were measured; in small samples, all available fibres were measured. A measure that we have previously shown to correlate well with the gross performance characteristics of a muscle is the relative area of the muscle occupied by a given fibre type (= % fibre type area) [18]. This measure combines data on the fibre type distribution and the mean fibre type size, but requires that the fibre size be expressed as a cross-sectional area (CSA). For these purposes, the fibres were assumed to be circular, and the estimated CSA was calculated from the lesser diameter.

Muscle cross-sectional area measurements

Patients lay in the imager in a comfortable and relaxed supine position with the knees slightly flexed by a support positioned underneath them. Transverse magnetic resonance (MR) spin echo T1-weighted images were obtained through the centre of the L3/4 and L4/5 lumbar discs using a 1.5-T Siemens Magnetom Vision VIS with a phase-array surface coil. Slice thickness was 4 mm.

The MRI films were photographed using a digital camera (Fuji HC 1000) and the digital images were stored on compact disc. The cross-sectional areas of the trunk muscles (erector spinae, medial and lateral tracts combined; quadratus lumborum; psoas) were measured using an image analysis programme (NIH Image 1.55); each muscle was circumscribed three times and the average value was calculated (Fig. 2). Values for the right- and left-hand sides were then averaged and used to represent the unilateral size of the muscle. Each picture was calibrated with a 10-cm rule placed on the original analogue images.

Lean body mass (LBM) measurement

Proportion of body fat (% fat) was determined from the sum of skinfold thicknesses at subscapular, suprailiac, biceps and triceps sites [9]. LBM (kg) was then calculated as: body mass – (body mass × % fat/100).

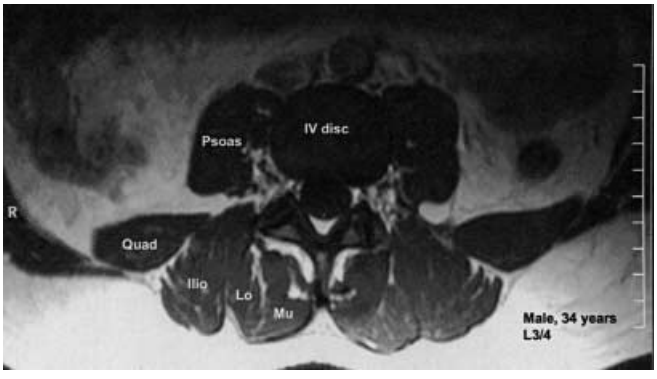

Fig 2 Magnetic resonance imaging (MRI) cross-section of the trunk muscles at L3/4, in a 34-year-old man (10-cm calibration rule on *right*). The iliocostalis lumborum, longissimus thoracis pars lumborum and multifidus muscles were combined to give a measure of the erector spinae size. (*IV Disc* intervertebral disc, *Quad* quadratus lumborum, *Ilio* iliocostalis lumborum, *Lo* longissimus thoracis pars lumborum, *Mu* multifidus)

Statistics

Results are presented as means ± standard deviation (SD). Analysis of variance was used to examine gender differences in muscle fibre type characteristics. Regression analysis (simple linear, multiple linear and stepwise) was employed to quantify the influence of one variable on another. Contingency analysis was used in investigating the association between categorical variables (e.g. the relative frequencies of pathological changes in the muscle and age-group, gender). Significance was accepted at the 5% level.

Results

Univariate analyses of factors influencing fibre type characteristics

Significant *gender differences* in the muscle fibre type characteristics were observed, as shown in Table 2. The muscles of the men tended to have a greater proportion of type IIX fibres and a lower value for the type I:II fibre size ratio – and hence a higher proportional area of the muscle occupied by type IIX fibres – compared with the women.

Age did not demonstrate a significant influence on any of the muscle fibre type characteristics, although a number of trends were observed: there was a tendency for an increase in age to be associated with smaller muscle fibres (particularly type II fibres), increased proportions of type I fibres and decreased proportions of type IIX fibres.

Table 2 Erector spinae muscle fibre type characteristics (mean ± SD)

Parameter	Males (n = 29)	Females (n = 29)[a]
% fibre type		
I	65.4 ± 12.6	73.0 ± 10.1[b]
IIA	18.1 ± 9.3	16.1 ± 8.4
IIX	15.4 ± 7.4	10.4 ± 6.8[b]
IIC	1.1 ± 1.1	0.5 ± 0.7[b]
Fibre diameter (μm)		
I	66.2 ± 8.3	64.2 ± 7.9
IIA	59.5 ± 9.7	50.5 ± 10.4[b]
IIX	59.7 ± 10.3	49.0 ± 7.8[b]
Mean fibre size (all fibre types)	64.0 ± 8.2	60.8 ± 7.9
Size I:II ratio[c]	1.13 ± 0.28	1.28 ± 0.31[b]
% fibre type area		
I	69.7 ± 13.2	80.3 ± 9.5[b]
IIA	15.7 ± 9.5	11.8 ± 8.4
IIX	13.5 ± 7.5	7.5 ± 5.4[b]
IIC	1.1 ± 1.0	0.4 ± 0.6[b]

[a] It was not possible to clearly distinguish between type IIA and IIX fibres in the sample of one female patient
[b] Significant difference between males and females ($P < 0.05$).
[c] Size I:II ratio = the ratio of the mean size of the type I fibre to the *weighted* mean size of the type II (IIA and IIX) fibres (i.e. weighted in relation to the proportion of each subtype)

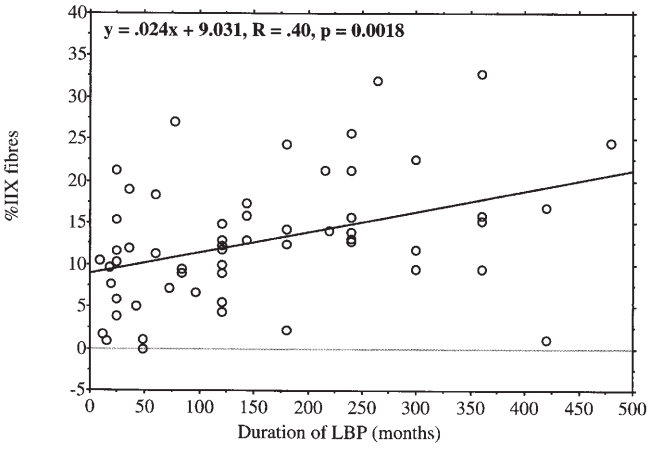

Fig. 3 Relationship between duration of low back pain and the proportion of type IIX fibres in the erector spinae muscle

LBM showed a significant positive correlation with the size of the type IIA ($P = 0.0001$) and IIX fibre ($P = 0.0016$). When the genders were analysed separately, the relationships were no longer significant, although the same 'trends' were retained.

Duration of LBP displayed a significant negative relationship with the proportion of type I fibres ($P = 0.015$) (or *proportional area* occupied by type I fibres: $P = 0.012$) and a highly significant positive relationship with the proportion of type IIX fibres ($P = 0.0018$; Fig. 3) (or *proportional area* occupied by type IIX fibres: $P = 0.0054$). Thus, the longer the duration of symptoms of LBP, the lower the type I fibre presence and the higher the type IIX fibre presence in the muscle. There was no relationship between duration of pain and muscle fibre size, for any of the fibre types.

Self-rated *disability* (Roland and Morris disability questionnaire) and *average pain* levels (0–10 VAS) had no independent relationship with the fibre type characteristics.

Multivariate analyses of factors influencing fibre type characteristics

Owing to the potentially confounding influences of gender and age on the relationship between duration of low back pain and fibre type distributions, stepwise linear regression analyses involving all three independent variables – gender, age and LBP duration – were carried out for each of the dependent variables that were highlighted by the univariate analyses (% type I, % type I area, % type IIX, % type IIX area). The results of these analyses are shown in Table 3. The three independent variables were together able to account for up to 28% of the variance in the proportion (and proportional area) of the type I and the type IIX fibres ($P < 0.05$); i.e. up to 28% of the interindividual variability in fibre type characteristics could be accounted for by the duration of LBP, gender and age of the patient.

Morphological changes of the muscle fibres

'Moth-eaten' fibres were visible in 20% of the biopsy samples, core fibres in 37% and target fibres in 5%. The average proportions of fibres (per sample) affected by each of these cytochemical architectural changes in the muscle fibres were respectively 1.7% (range 0.2–3.6%), 2.6% (range 0.2–10.3%) and 0.6% (range 0.1–1.5%).

There was no significant association between gender and the presence of any of the three pathological changes in internal fibre structure examined ('moth-eaten', core, and target fibres). Fifty-seven percent of the women and 41% of the men demonstrated at least one of the three cytochemical architectural changes within their muscles ($P = 0.24$).

The presence of pathological changes was encountered more frequently in the muscles of older patients, and, with respect to core fibres, this association with age was highly significant (Table 4). It was also observed that the samples demonstrating at least one type of pathology had a higher

Table 3 Results of stepwise regression analyses of gender, age and pain duration (= independent variables) on some of the muscle fibre type characteristics (= dependent variables). The independent variables are shown in order of their entry into the model, which is determined by their ability to predict the dependent variable. The first factor is entered, then the model is reassessed to see whether the addition of another variable can make a significant contribution to explaining/predicting the dependent variable. The analysis is concluded when the remaining variables fail to contribute significantly to explaining any more of the variance in the dependent variable. The adjusted R^2 value shows the proportion of the variance in the dependent variable accounted for by the addition of each of the independent variables, i.e. how much of the interindividual variability can be accounted for by differences in the independent variable

Dependent variable	First variable entered	R^2	Second variable added	R^2	Third variable added	R^2
% type I fibres	Pain duration	8.5	Age	**15.3**	–	
% type IIX fibres	Pain duration	14.7	Age	23.1	Gender	**27.9**
% area type I fibres	Gender	14.0	Pain duration	20.9	Age	**25.1**
% area type IIX fibres	Gender	14.3	Pain duration	23.3	Age	**28.0**

Table 4 Occurrence of cytochemical architectural changes in the muscle fibres in different age-groups

Cytochemical architectural change	Age group				*P*-value[a]
	21–30 (*n* = 5)	31–40 (*n* = 21)	41–50 (*n* = 13)	> 50 (*n* = 20)	
% patients with 'moth-eaten' fibres	0	19	23	25	0.653
% patients with core fibres	0	24	15	75	0.0002
% patients with target fibres	0	0	0	15	0.104
% patients with *any* architectural changes ('moth-eaten', core, *or* target fibres)	0	43	31	80	0.002

[a] Significant association between proportion of patients displaying cytochemical architectural changes in the muscle fibres and age-group, $P < 0.05$

proportion of type I fibres (pathology present, mean type I = 72.9 ± 11.2%; no pathology present, mean type I = 65.7 ± 11.6%, $P = 0.018$).

Patients displaying at least one type of cytochemical change in the architecture of the fibres tended to have suffered with low back pain for a longer period of time than those who showed no such structural changes, but the difference was not significant (176 vs 135 months; $P = 0.20$).

Age, gender and duration of LBP showed no interactions with each other with regard to the presence of pathological changes in the internal structure of the fibres.

Univariate analyses of factors influencing gross muscle size

Significant *gender differences* in the mean cross-sectional area of all the back muscles examined were observed (Table 5), with the men displaying consistently higher values than the women.

Increasing *age* was associated with a decrease in the cross-sectional area of the muscles; the association was weak, but reached significance ($P < 0.05$) for the majority of the muscle groups (Table 6).

LBM showed a highly significant positive relationship with trunk muscle size, for each of the muscle groups under investigation (e.g. Fig. 4). In each case, correlation coefficients of between 0.68 and 0.81 were recorded ($P < 0.001$).

Duration of LBP displayed no relationship with the mean size of any of the trunk muscles ($P > 0.05$).

Self-rated *disability* (Roland and Morris disability questionnaire) and *average pain levels* (0–10 VAS) also had no independent effect on gross muscle size.

Table 5 Trunk muscle cross-sectional areas (mean ± SD)

Muscle and vertebral level	Cross-sectional area (cm^2)	
	Males (*n* = 29)	Females (*n* = 26)[a]
Erector spinae		
L3/4	25.1 ± 3.4	18.8 ± 3.0[b]
L4/5	23.4 ± 3.6	18.4 ± 2.7[b]
Quadratus lumborum		
L3/4	7.6 ± 1.4	4.5 ± 1.1[b]
Psoas		
L3/4	16.1 ± 4.0	9.2 ± 2.4[b]
L4/5	20.4 ± 4.3	11.6 ± 2.8[b]

[a] Four females were not prepared to undergo MRI examination (due to claustrophobia)
[b] Significantly different from males, $P < 0.05$

Table 6 Correlation coefficients for the relationship between age and trunk muscle cross-sectional areas

Muscle and vertebral level	Correlation coefficient *r*	*P*- value
Erector spinae		
L3/4	–0.19	0.16
L4/5	–0.30	0.03 [a]
Quadratus lumborum		
L3/4	–0.32	0.02[a]
Psoas		
L3/4	–0.33	0.01[a]
L4/5	–0.32	0.02[a]

[a] Significant correlation between muscle size and age, $P < 0.05$

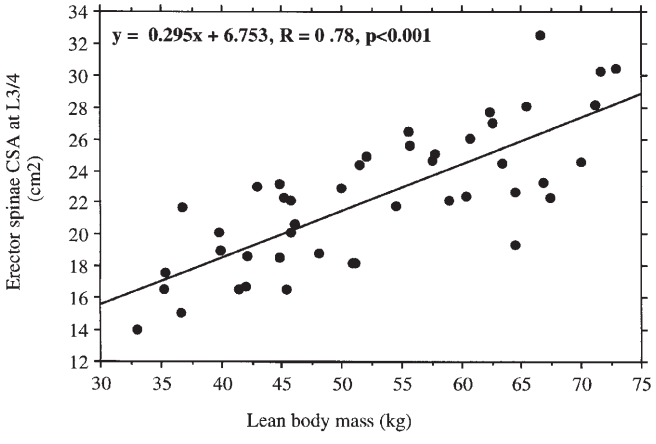

Fig. 4 Relationship between lean body mass (fat-free mass) and the cross-sectional area (CSA) of the erector spinae muscles at the level of the L3/L4 intervertebral disc

Multivariate analyses
of factors influencing gross muscle size

Stepwise linear regression analyses involving the above independent variables – gender, age, LBM and LBP duration – showed that the only variable selected for entry into the equation to predict muscle size was LBM (except in the case of quadratus lumborum, where age and gender were more predictive of the muscle size than was LBM). LBM alone accounted for between 45 and 65% of the variance in the muscle cross-sectional areas. This means that once the LBM differences between the individuals had been taken into account, the other variables did not account sufficiently for the remaining variance to enable their entry into the model.

Discussion

The present study was carried out to examine the influence of duration of pain on the size and fibre type distribution of the erector spinae muscles in chronic LBP patients, and to examine the confounding effects of other factors such as age, gender and body size on these relationships. The latter variables have previously been shown to exert a significant influence on the size and structure of the muscle [19] and hence need to be taken into consideration in studies that seek to identify the unique role of long-term pain on the characteristics of the muscle.

Previous studies in which changes in the structure of the muscles have been observed in connection with chronic LBP have been unable to establish whether the effects preceded or were consequent to the pain. If these muscle characteristics are innate, i.e. intrinsic to the constitution of an individual, then no relationship between the duration of the back condition and these muscle characteristics would necessarily be expected. If, however, they represent the result of long-term physical inactivity associated with the pain, then an association between the condition of the muscle and the duration of symptoms would be expected, and there would be a strong case for attempting to counteract the changes through appropriate rehabilitation.

Gender and, to a certain extent, age had a significant influence on the relative proportions of the type I and type IIX fibres. When these two factors were controlled for, symptom duration was shown to have an additional unique influence on fibre type distribution: a prolonged period of symptoms was associated with the development of a significantly more ‘glycolytic’ profile within the muscle, i.e. an increased proportion of type IIX fibres and decreased proportion of type I fibres. This is in agreement with the conclusion from our previous cross-sectional study, in which the back muscles of patients attending lumbar spinal surgery were compared with those of normal controls [20], and also accords with the results of studies carried out on the muscles of patients with dysfunctions of the cervical spine [33,35]. This is interesting, because the aetiology of the joint dysfunctions examined in each of these previous studies was quite different (trauma-associated, degenerative, rheumatoid), yet the same response appears to have been educed in terms of muscular adaptation. This suggests that the process is one of general ‘disuse’, consequent to pain-induced inactivity, rather than anything specifically associated with the underlying orthopaedic or rheumatic problem. In contrast to the process described for the neck muscles, where changes were most evident within 24 months of the onset of symptoms, it appears that in the back muscles the process is a ‘continuous’ one, as a linear relationship between fibre type distribution and duration of symptoms was found. Perhaps it is more difficult to avoid using the neck muscles in daily life, as a certain minimal level of activity is required for the basic control of head posture, with the result that the greatest changes occur early after development of the spinal problem, following which the muscles ‘adapt’ to a somewhat reduced – but nonetheless continuing – level of activity. It is arguable that in the lumbar spine the requirement for back muscle activity can more readily be avoided, by the adoption of a protective, ‘stiff back’ style of movement, of the sort often displayed by long-term LBP sufferers. It is then conceivable that the muscles of these patients would enter into a state of continuous decline. The apparent differences in the time-dependent response of the paraspinal muscles in the cervical and lumbar regions may also have resulted from there being too few patients with a short history of pain in the present study. The minimum duration of pain for classification as ‘chronic’ was 3 months, and there were only 11/59 patients who had suffered for less than 24 months (which was the approximate ‘stabilisation time’ observed in the study of Uhlig et al. [33]). Thus, we may have missed the early, most conspicuous changes that are normally encountered immediately after the onset of symptoms, and what we observed may have been the ‘tail-end’ of an exponential pattern of change. The fact that very low proportions of type IIC fibres were encountered in the muscles of the chronic LBP patients would tend to support this conclusion, as the IIC fibre is typically more abundant during phases of fibre type transformation.

Considering that an individual’s muscle fibre type distribution resides under heavy genetic control, it is surprising that nearly a quarter of the variance in individual values for the proportion of the fibre types could be accounted for simply on the basis of age and duration of LBP symptoms. This demonstrates that, with sufficiently profound and prolonged stimuli, the muscle’s fibre type distribution is malleable – a contention that has long been the subject of discussion, particularly in relation to physiological (rather than pathological or experimental) stimuli. These transformations of the muscle are presumably reversible, but the most beneficial means of effecting the

change, and the time required to do so, remain to be elucidated [13].

Cytochemical architectural changes such as 'moth-eaten' fibres [2,28], core fibres [32], and target fibres [10] were found more frequently in the older patients, but were not associated with duration of LBP symptoms. Core fibres demonstrate a zone that is devoid of mitochondria and oxidative enzyme activity and runs the length of the fibre, whereas 'moth-eaten' fibres reflect a general disruption of the intermyofibrillar network. Target fibres are usually associated with denervating disease, and especially chronic peripheral neuropathies. The low incidence and age-dependency of all the cytoarchitectural changes confirmed their non-specific nature in the muscles of the LBP patients. The changes appeared in biopsies with a higher proportion of type I fibres, confirming the previously reported predilection of these non-specific changes for the type I fibre [8].

Somewhat unusual, in view of popular belief, was the finding that the changes in fibre type distribution were not accompanied by reductions in either the size of the individual muscle fibres or the gross muscle cross-sectional area. A closer look at the literature, however, suggests that these findings may not be as incongruous as they perhaps appear. Much of the evidence supporting the notion of a reduced back muscle bulk in chronic LBP patients has emerged indirectly, from investigations of maximal extensor strength, in which it has been assumed that reduced strength equates to reduced muscle cross-sectional area. However, voluntary strength measurements have a strong psychological component that would be particularly influential during the assessment of patients with musculoskeletal disorders: discomfort, pain, fear of pain/reinjury, or lack of motivation may all contribute to an underestimation of the muscles' true force-generating capacity. Maximal strength measures alone can not be expected to reliably reflect the total muscle mass in these patients. Studies in which the gross cross-sectional area (CSA) of the back muscles has been measured directly, using either computed tomography (CT) or MRI, have produced inconclusive results with respect to the issue of chronic LBP and muscle atrophy: at best, only insignificant trends for a reduced muscle CSA have been demonstrated [5, 12, 24, 26]. Expression of muscle size relative to an 'internal standard', such as the size of the vertebral end-plate, appeared to 'unmask' differences in muscle size between patients with recent and chronic LBP [5], although the validity of this 'internal standard' has not been established. It is conceivable that patients with long-term pain would show more degenerative changes of the spine, including osteophyte formation. This could alter the dimensions of the vertebral end-plate itself, yielding misleading statistics by erroneously inflating the denominator in the equation. Examination of the radiological density of the muscle, which assesses the muscle's 'internal structure', has highlighted differences between chronic LBP patients and controls that were not evident in terms of simple CSA measurements [12]. The reduced density of the patients' muscles was suggested to be caused by atrophy of the individual muscle fibres making up the muscle bulk [12]. In the present study, as no such differences in fibre size were observed, it is questionable whether additional measurements of muscle density would have yielded any more valuable information than that obtained from the CSA values.

In relation to the gross muscle size, it was possible to demonstrate that the most important factor influencing the cross-sectional area of the trunk muscles was the lean body mass LBM of the individual, and this could account for up to 64% of the variance in individual values. Once LBM had been accounted for, neither gender, age, nor duration of LBP symptoms was significantly able to explain any further variance in the values.

It is often suggested that LBP is associated with selective type IIX fibre atrophy in the back muscles. The present study revealed no evidence to support this contention, in line with our previous conclusions [20]. The notion that the type IIX fibre shows selective atrophy appears to have arisen from the injudicious interpretation of previously reported data: careful appraisal of the literature reveals that, although the back muscles of patients do indeed display smaller type IIX than type I fibres, this is entirely normal for this muscle group, and what may appear to be atrophic fibres (compared with other skeletal muscles' standards) are present with equal regularity in the muscles in patients with absolutely no history of LBP [19]. No study has yet been able to convincingly show significant differences in the ratio of the size of the type I:IIX fibre between patients and *matched* controls.

Conclusion

The results suggest that, over the long term, fibre type transformations rather than alterations in fibre size are the predominant changes to be found in the muscles of chronic LBP patients. The direction of change supports the results of many previous studies that have demonstrated corresponding differences in the fatigability of the muscles. There is a strong case for the early implementation of active measures to attempt to offset the development of these changes in back pain patients.

Acknowledgements We are grateful to the Swiss National Science Foundation (Grant no. 32–50979.97) and the Schulthess Klinik Research Fund for funding this work. We would like to thank: Dr. D. Huber and his staff at the Hirslanden Hospital, Zürich, for the magnetic resonance imaging; the Photography Unit of the Rheuma Klinik, University Hospital Zürich, for the digital photography of the MR images; and Alex Zehnder for his assistance with taking the biopsies.

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