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Muscle fibre size and type distribution in thoracic and lumbar regions of erector spinae in healthy subjects without low back pain: normal values and sex differences

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ABSTRACT

This study sought to investigate the normal muscle fibre size and type distribution of the human erector spinae, both in thoracic and lumbar regions, in a group of 31 young healthy male (n = 17) and female (n = 14) volunteers. Two percutaneous muscle biopsy samples were obtained under local anaesthesia, from the belly of the left erector spinae, at the levels of the 10th thoracic and 3rd lumbar vertebrae. Samples were prepared for routine histochemistry for the identification of fibre types. Fibre size (cross-sectional area (CSA) and narrow diameter (ND)) was quantified using computerised image analysis. The mean CSA/ND for each fibre type was greater in the thoracic than the lumbar region, but there was no difference between the 2 regions either for percentage type I (i.e. percentage distribution by number), percentage type I area (i.e. relative area of the muscle occupied by type I fibres) or the ratio describing the size of the type I fibre relative to that of the type II. Men had larger fibres than women, for each fibre type and at both sampling sites. In the men, each fibre type was of a similar mean size, whereas in the women the type I fibres were considerably larger than both the type IIA and type IIB fibres, with no difference between the latter two. In both regions of the erector spinae there was no difference between men and women for the proportion (%) of a given fibre type, but the percentage type I fibre area was significantly higher in the women.

The erector spinae display muscle fibre characteristics which are clearly very different from those of other skeletal muscles, and which, with their predominance of relatively large type I (slow twitch) fibres, befit their function as postural muscles. Differences between thoracic and lumbar fascicles of the muscle, and between the muscles of men and women, may reflect adaptive responses to differences in function. In assessing the degree of any pathological change in the muscle of patients with low back pain, it seems clear that (1) sex cannot be disregarded and (2) 'atrophied' (using the criteria from other muscles) type II fibres are not necessarily abnormal for the erector spinae, particularly in women.

Key words: Erector spinae muscles; fibre typing.

INTRODUCTION

It has been reported that the back extensor muscles of patients with low back pain (LBP) commonly display type II (fast twitch) fibre atrophy (Fidler et al. 1975; Ford et al. 1983; Mattila et al. 1986; Zhu et al. 1989; Rantanen et al. 1993; Sihvonen et al. 1993; Rissanen et al. 1995; Weber et al. 1996). This has been related to the effects of disuse (Mattila et al. 1986; Cooper et al. 1992; Rantanen et al. 1993), as well as neurological damage following disc herniation (Mattila et al. 1986; Zhu et al. 1989; Rantanen et al. 1993) or spinal surgery (Rantanen et al. 1993; Sihvonen et al. 1993; Kawaguchi et al. 1994, 1996). However, these histomorphometric findings do not accord with the numerous reports of an increased back muscle fatiguability in LBP patients compared with pain-free controls (Nicolaisen & Jorgensen, 1985; Roy et al. 1989, 1990, 1995; Cooper et al. 1993; DeLuca 1993; Mannion et al. 1997) because a decreased relative area

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of the muscle occupied by type II fibres (as a result of selective type II atrophy, should render the muscle less, not more, fatiguable during sustained isometric contraction (Saltin & Gollnick, 1983; Jones & Round, 1990). Compared with many other muscles, the erector spinae are rather atypical in that they are primarily postural muscles, responsible for slow and sustained contractions at relatively low force outputs. It is therefore possible that the type II fibre is typically smaller in cross-section than the type I fibre even in the absence of back pain, suggesting that what has previously been considered abnormal for LBP patients, may only be so when compared with other skeletal muscles.

Many reports of the so-called 'typical' fibre type size and distribution of lumbar fascicles of the erector spinae have come from examination of the muscle removed during surgery from acute disc prolapse patients, on the basis that the muscle structure is apparently unaffected by the short duration of the spinal derangement (Ford et al. 1983; Bagnall et al. 1984). However, even if this is so, growing evidence of an association between the physiology of the muscle (e.g. its fatiguability, velocity of contraction, etc.) and the development of low back pain (Biering-Sørensen, 1984; Luoto et al. 1995) suggests that the muscle of this select group of individuals might not necessarily represent the norm, as it may be particularly biased towards certain characteristics which predisposed to the development of low back pain in the first place.

Thus despite much investigation in recent years, using material collected intraoperatively (Ford et al. 1983; Bagnall et al. 1984), at postmortem (Johnson et al. 1973; Polgar et al. 1973; Sirca & Kostevc 1985; Rantanen et al. 1994) and from biopsy sampling (Thorstensson & Carlson 1987; Jørgensen et al. 1993), our knowledge of the typical fibre type characteristics of the erector spinae is far from complete. This is particularly true for women and for the thoracic fascicles of this muscle group. The latter contribute significantly to the total extensor moment exerted on the lumbar spine (Bogduk et al. 1992) and must therefore make an important contribution to performance during commonly employed tests of back extensor muscle strength and fatigue. These same fascicles are also the focus of interest in idiopathic scoliosis (Spencer & Zorab, 1976; Yarom & Robin, 1979; Zetterberg et al. 1983; Bylund et al. 1987; Wright et al. 1992), where progress in establishing the precise location and extent of fibre type abnormalities has been hampered by a lack of normative data for this region of the muscle group. Few previous studies of normal erector spinae muscle have included women in their investigation (Thorstensson & Carlson, 1987; Rantanen et al. 1994; only 7 female subjects in each study and no subtyping of the type II fibres available for the latter study), yet evidence from performance data suggests that a sex difference in the fibre type distributional area might be expected, both in upper and lower regions of this muscle group (Mannion & Dolan, 1994).

There is clearly a need to obtain comprehensive information regarding the typical fibre type characteristics of the paraspinal muscles so that any deviations observed in clinical practice can be interpreted with greater confidence, and the situation rectified in the most appropriate manner. The present study was carried out to characterise fibre type size and distribution both in the thoracic and lumbar regions of the erector spinae in normal healthy physically active individuals with no history of low back pain. A further aim was to make a between-sex comparison of these characteristics of the muscle.

METHODS

Subjects

Thirty-one healthy physically active men (n = 17) and women (n = 14) volunteered to participate in the study, which was approved by the local Ethical Committee. Each was informed of the purpose and potential risks of the study before their written voluntary consent was obtained. The physical characteristics of the subjects are shown in Table 1.

Muscle biopsy collection

With the subject lying prone, percutaneous muscle biopsy samples were taken from the belly of the left erector spinae, approximately 3–4 cm from the midline of the back and at the levels of the 10th thoracic and 3rd lumbar vertebrae, using 6.5 mm Tilley–Henckel punch forceps (Dietrichson et al. 1987). Routine aseptic precautions were taken. The skin was

Table 1. *Physical characteristics of the subjects* (*mean* ± *S.D.*)

Parameter	Men	Women
Age (y)	23.0 ± 4.3	29.4 ± 10.6
Body mass (kg)	75.8 ± 9.7	60.9 ± 7.4
Height (m)	1.77 ± 0.07	1.64 ± 0.05
Body mass index (kg m^{-2})	24.1 ± 2.9	22.5 ± 2.2
Percentage body fat*	14.1 ± 4.3	26.6 ± 3.6
Fat free mass (kg)	65.0 ± 7.0	44.6 ± 5.0

* Determined from skinfold thicknesses (Durnin & Womersley, 1974).

Table 2. *Parameters derived from quantitative analysis of the muscle biopsy samples*

Parameter	Definition
Mean CSA I, IIA, or IIB (μm^2)	Mean cross-sectional area of the type I, IIA, or IIB fibre
Mean ND I, IIA, or IIB (μm)	Mean narrow diameter of the type I, IIA, or IIB fibre
MFA (mean fibre area) (μm^2)	Weighted mean cross-sectional area of all fibres (i.e. average size of all the fibres regardless of their type)
MND (mean narrow diameter) (μm)	Weighted mean narrow diameter of all fibres (i.e. average size of all the fibres regardless of their type)
CSA I:II ratio (CSA I ÷ CSA II)	Mean CSA type I ÷ mean CSA type II (CSA type II = weighted mean of type IIA CSA and type IIB CSA)
ND I:II ratio (ND I ÷ ND II)	Mean ND type I ÷ mean ND type II (ND type II = weighted mean of type IIA ND and type IIB ND)
Percentage type I, IIA, IIB, or IIC	Percentage by number of fibres classified as type I, IIA, IIB or IIC
Percentage type I, IIA or IIB area	Relative area of the muscle occupied by type I, IIA or IIB fibres e.g. percentage area = (percentage type I × CSA type I)/[percentage type I × CSA type I) + (percentage type IIA × CSA IIA) + (percentage type IIB × CSA IIB)]

firstly cleaned and disinfected, before local anaesthetic (5–10 ml; 1% lidocaine) was infiltrated into the skin and subcutaneous tissue at the biopsy site. A 5 mm skin incision was made at the crest of the muscle belly, and the fascia penetrated with a scalpel blade. The closed jaws of the conchotome were then inserted through the incision and into the muscle (approximately 10–15 mm deep) with the long axis of the jaws perpendicular to the muscle fibres. The jaws were opened and the conchotome advanced 2–3 mm. In a single movement the jaws were closed, twisted through 180° and withdrawn, retrieving a 50–100 mg piece of muscle. Pressure was applied to the site for 5–10 min to stop bleeding and prevent haematoma formation. A single suture was used to close the incision.

Muscle biopsy analyses

The specimens were inspected under a dissecting stereomicroscope and oriented in OCT compound embedding medium (Tissue Tek, Miles Elkhart, IN, USA) such that the muscle fibres ran perpendicular to the block on which they were mounted. The muscle blocks were then snap frozen in isopentane suspended over liquid nitrogen, and stored at −80 °C. Serial sections (14 μm) were cut in a cryostat at −20 °C, stained with haematoxylin and eosin, and reacted for NADH tetrazolium reductase (NADH), cytochrome c oxidase (according to the method of Wong-Riley (1979) with 1 ml catalase added (200 μg/ml)) and myofibrillar adenosine triphosphatase (ATPase) following acid (pH 4.3 and 4.6) and alkali (pH 10.5) preincubations ((Guth & Samaha, 1970), with certain modifications). Muscle fibres (an average 1480 per section) were assessed for staining intensity by examination of Xerox print-outs from a microfiche viewer and by microscopic investigation, and identified as either type, I, IIA, IIB or IM (intermediate: IIC/IB). Fibre type distribution was given by the percentage of each fibre type within the section.

Images of the selections were captured with a video camera (Hamamatsu CCD CD3077; Sony, Japan) attached to a microscope (Olympus BH2; Olympus Optical Co., UK) and interfaced to a microcomputer (Apple Macintosh Quadra 950) running image analysis software (Prism View; Analytical Vision Inc., Raleigh, NC, USA). Images were captured from representative regions of the whole biopsy section, at a magnification of approximately × 250. For the measurement of muscle fibre size a computerised image analysis system (NIH Image; Research Services Branch, National Institutes of Health) was used to circumscribe all muscle fibres contained within, and crossing 2 sides, of a 400 × 400 μm area of interest identified within each image. The fibres were measured for cross-sectional area (CSA) and narrow diameter (given by the narrow aspect of an ellipse fitted to the circumscribed area) (ND). An average 280 (range 48–850) fibres per biopsy sample were measured. The parameters derived from the type distribution and cross-sectional area measurements are shown in Table 2.

Statistics

Results are presented as means ± 1 S.D. Erector spinae regional and sex differences were analysed using analysis of variance (1 factor between (= sex) and either 1 factor within (= region; for percentage fibre type, for percentage area occupied by each fibre type, and for mean fibre area) or 2 factors within (= region and fibre type; for fibre cross-sectional area, and for fibre narrow diameter)). Correlation and/or regression analysis was used to examine the relationship

between 2 variables. Statistical significance was accepted at the 5% level.

RESULTS

A total of 58 biopsies provided sufficient muscle for analysis, 54 of which comprised paired (i.e. both thoracic and lumbar) samples from 27 subjects (16 men, 11 women).

The mean muscle fibre type characteristics, separated by erector spinae region and sex, for the 27 paired samples, are shown in Table 3. One of the most striking features of the group results was the predominance of type I muscle fibres: only 2 thoracic and 3 lumbar samples had a greater than 50% number of type II fibres. On average, less than 1.5% of all fibres were classified as 'intermediate' (IM), and there was no significant difference in the mean frequency of IM fibres between thoracic and lumbar levels or between men and women. Because an insufficient number of IM fibres were available for size measurement, these were not considered in any further analyses.

Regression analysis revealed that the 2 measures of muscle fibre size, CSA and ND, were highly

Table 3. *Erector spinae muscle fibre type characteristics.*

Parameter	Men	Women
Thoracic		
CSA type I (μm^2)	6314 (1245)†*	4846 (1149)†
CSA type IIA (μm^2)	6707 (2531)†*	3343 (1081)†¶
CSA type IIB (μm^2)	6032 (2574)†*	2981 (930)†¶
MFA (μm^2)	6241 (1738)†*	4265 (1011)†
ND type I (μm)	69.6 (6.8)†	63.0 (8.7)†
ND type IIA (μm)	69.8 (12.4)†*	50.5 (9.4)†¶
ND type IIB (μm)	65.5 (13.3)†‡*	47.3 (7.7)†¶
MND (μm)	68.3 (8.8)†*	58.1 (8.0)†
CSA ratio I/II	1.013 (0.178)*	1.572 (0.436)
ND ratio I/II	1.024 (0.107)*	1.273 (0.192)
Percentage type I	62.0 (9.3)	67.8 (10.5)
Percentage type IIA	26.8 (8.2)	27.3 (10.8)
Percentage type IIB	10.9 (6.3)*	4.6 (4.7)
Percentage type IM	0.3 (0.5)	0.3 (0.5)
Percentage type I area	61.9 (9.5)*	76.0 (9.3)
Percentage type IIA area	27.7 (8.9)*	21.0 (10.1)
Percentage type IIB area	10.1 (5.7)*	2.8 (2.9)†
Percentage type IIC area	0.3 (0.5)	0.2 (0.5)
Lumbar		
CSA type I (μm^2)	5058 (1349)*	3809 (664)
CSA type IIA (μm^2)	4941 (1371)*	2560 (676)¶
CSA type IIB (μm^2)	4703 (1703)*	2374 (723)¶
MFA (μm^2)	4897 (1251)*	3251 (694)
ND type I (μm)	63.4 (9.1)*	54.6 (5.4)
ND type IIA (μm)	61.6 (9.1)*	42.8 (5.4)¶
ND type IIB (μm)	59.0 (11.7)*	41.6 (7.5)¶
MND (μm)	61.9 (8.5)*	49.0 (5.4)
CSA ratio I/II	1.085 (0.225)*	1.641 (0.522)
ND ratio I/II	1.063 (0.125)*	1.340 (0.262)
Percentage type I	65.0 (10.3)	63.6 (11.9)
Percentage type IIA	24.2 (6.7)	26.9 (7.5)
Percentage type IIB	9.6 (6.9)	9.0 (6.3)
Percentage IM	1.2 (2.9)	0.5 (0.9)
Percentage type I area	66.4 (9.2)*	72.8 (9.3)
Percentage type IIA area	23.9 (5.8)*	20.7 (6.9)
Percentage type IIB area	8.8 (6.9)	6.2 (4.0)
Percentage type IIC area	0.9 (2.7)	0.3 (0.7)

Values are mean (S.D.).
† $P < 0.05$ significantly different from the corresponding value in the lumbar region.
* $P < 0.05$ significantly different from the corresponding value in women.
‡ $P < 0.05$ significantly different from the corresponding value for the type IIA fibre.
¶ $P < 0.05$ significantly different from the corresponding value for the type I fibre.
CSA, cross-sectional area; MFA, mean (regardless of type) fibre area μm^2; percentage type I, relative distribution of type I fibres; percentage type I area, area of the muscle occupied by type I fibres.

correlated with each other (r = 0.96 and 0.98 in the thoracic and lumbar regions respectively).

'*Pathological*' *changes in the muscle*

On the whole, the muscle samples displayed few 'abnormalities' classified as pathological; the abnormalities which were seen were mainly confined to samples obtained from the thoracic region and affected men and women approximately equally. The thoracic sample of one female had a fascicle comprising particularly small type I and II fibres which were, on average, 23% of the mean size of the fibres in the rest of the section. Another thoracic sample (male) showed signs of possible type-grouping in 2 fascicles. Of the remaining 13 samples, 11 (10 thoracic, 1 lumbar) showed moth-eaten, angulated, split or core-targetoid fibres with a frequency of, on average, 0.4%. The final 2 samples, both from the same male individual, displayed moth-eaten fibres at a frequency of 4.8% (thoracic) and 6.5% (lumbar). Forty-three out of the 58 samples had no pathological changes whatsoever.

Regional differences in fibre type size and distribution

The mean cross-sectional area (CSA) of each fibre type (I, IIA and IIB) was significantly greater in the thoracic than the lumbar region (Table 3), and this was also the case on an individual basis in approximately 85% of subjects. However, the ratio describing the mean size of the type I fibre relative to that of the type II (where the weighted mean of the IIA and IIB CSAs was used to derive an average value for the type II fibre) did not differ significantly between regions. In men, the CSA of the type I fibre showed a highly significant correlation with the weighted mean type II CSA in each region (thoracic, r = 0.82, $P = 0.0001$; lumbar, r = 0.66; $P = 0.006$). Each of these relationships failed to reach significance in the women. Qualitatively identical findings to those observed for CSA were recorded for the other measure of fibre size, narrow diameter.

The 2 erector spinae regions did not differ significantly in their percentage distribution (by number) of the 3 main fibre types. The same was true for the relative area of the muscle occupied by each fibre type, with the exception of the percentage type IIB area which, in females only, was significantly lower in the thoracic than the lumbar region.

For the lumbar region only, there was a weak but significant relationship between the percentage type I fibres and the type I:II size ratio (r = 0.41, $P = 0.026$): the lower the percentage type I fibres in the muscle sample, the greater was the size of the type I fibre relative to that of the type II. The same trend was observed when examining the male and female data separately, although in each case the relationship just failed to reach significance (men $P = 0.06$; women $P = 0.056$).

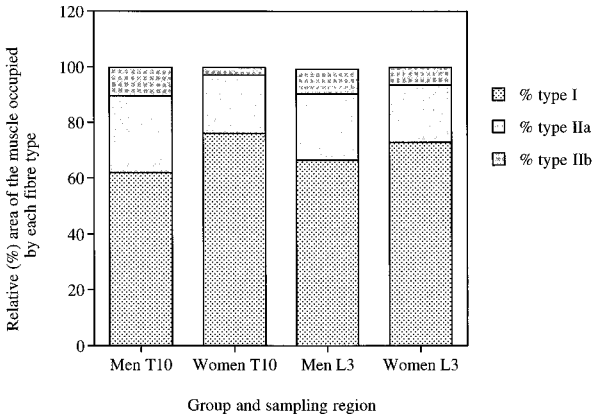

Fig. 1. Relative area of the muscle occupied by each fibre type, in men and women, at thoracic and lumbar regions of the erector spinae.

Sex differences in fibre type size and distribution

The muscle fibres were significantly larger in the samples from the men than in those from the women, for each fibre type and at both sampling sites (Table 3). In both thoracic and lumbar regions, there was no significant difference between the mean CSA of each of the main fibre types in the men, whereas in women, the mean size of the type I fibre was significantly greater than that of either the type IIA or the type IIB fibre. In the women, the type II subtypes showed no significant difference from each other with respect to size. Sex differences in the size ratio of the 2 main fibre types (types I:II) were highly significant, in both thoracic and lumbar regions of the muscle (Table 3). As far as fibre size was concerned, almost identical findings to those observed for CSA (above) were recorded for narrow diameter, except that, in the thoracic region of men, the smaller size of the type IIB fibres relative to the type IIA reached significance (Table 3).

There was no significant difference between men and women for the percentage of type I, or the percentage of type IIA fibres, at either level of the erector spinae. In the thoracic region (but not the lumbar), the percentage type IIB fibres was significantly higher in men than women.

In each region of the erector spinae, the relative area of the muscle occupied by type I fibres was significantly higher in women than men; the converse was true for the percentage type IIA area and

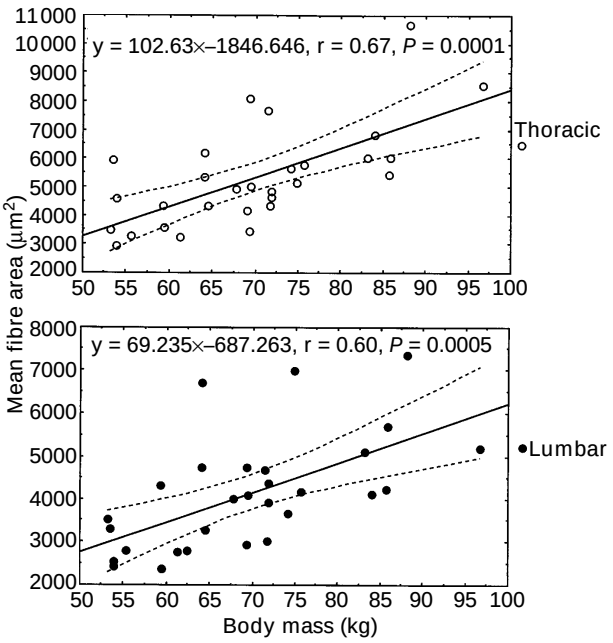

Fig. 2. Relationship between body mass and mean fibre area in thoracic (*a*) and lumbar (*b*) regions of the erector spinae, for both men and women.

percentage type II B area (Fig. 1). For percentage type II B area, there was a significant interaction between the effects of sex and erector spinae sampling region ($P = 0.03$): in men, the percentage type II B area was greater in the thoracic than the lumbar region of the muscle, whilst the opposite was the case for women (percentage II B L $\gg$ T).

Correlation between muscle fibre size and fat-free body mass

Body mass and fat-free body mass each showed a highly significant correlation with mean fibre cross-sectional area, both in the thoracic and the lumbar regions ($P < 0.001$; Fig. 2). When the male and female data were treated separately, the same tendency for a positive correlation between body size and fibre size was observed, but the relationship retained significance in the thoracic region only for the men ($P < 0.03$) and failed to reach significance in the lumbar region for both sexes ($P > 0.11$).

DISCUSSION

The present study provides normative data for the size and distribution of the muscle fibre types within thoracic and lumbar fascicles of erector spinae, as determined from in vivo muscle biopsy samples taken from healthy individuals with no history of low back pain. A minority of samples (15/58), the majority of which were from the thoracic region, displayed non-specific abnormalities which could be classified as pathological, existing in the main at a very low prevalence (on average, $< 0.4\%$ of fibres examined). One male displayed more numerous 'moth-eaten' fibres (approximately 5%) both in thoracic and lumbar regions, but even this prevalence is considered by some authors to be borderline normal (Rantanen et al. 1994). Interestingly, as well as being the oldest of the male subjects, the individual in question declared that he had been particularly inactive over the preceding few years, compared with the rest of the group. Perhaps these 'abnormal' phenomena represent an early indication of impending pathological alteration of the muscle architecture, consequent to prolonged inactivity or disuse.

Our assessment of muscle fibre size included measurement both of the narrow diameter (ND) and the cross-sectional area (CSA). ND is more frequently used in the clinical assessment of muscle pathology, whilst CSA is usually favoured by those involved in human performance research, because it allows for calculation of the relative area of the muscle occupied by a given fibre type—the measure which seems best to correlate with the functional capacity of the muscle (e.g. Bar-Or et al. 1980; Mannion et al. 1995). The CSA and ND measures would be expected to correlate well, unless particularly irregular-shaped fibres were present in the sample.

It was observed that the muscle fibres of each type were significantly larger in the thoracic region than in the lumbar region (by approximately 30%). There is no immediately apparent reason for this, although it is interesting to note that longissimus thoracis pars thoracis is reputedly one of the largest of the back muscles, exhibiting the greatest physiological CSA and being capable of generating the greatest total force in the sagittal plane (Bogduk et al. 1992). In other muscles, it has been observed that the mean size of the fibres correlates well with the total cross-sectional area of the muscle (Polgar et al. 1971; Schantz et al. 1981) and the same was inferred in the present study from the significant correlation between mean muscle fibre size and body mass (because, generally, bigger individuals will have a larger muscle mass). Although the mean size of each fibre type was greater in the thoracic than the lumbar region, the size ratio of the type I fibre relative to that of the type II was fairly constant between the 2 sites. In this sense, it appears that the thoracic and lumbar fascicles were not differentially adapted for particular movement-types but just displayed different maximum force generating capacities. In other words, the difference between the upper and lower sites was most

likely in the quantity, rather than the quality, of the muscle available (see below for further discussion).

It was no great surprise to find that the predominantly postural erector spinae musculature comprised a high proportion of type I fibres, although the extent of the interindividual variation could not have been predicted. Individual differences in these fibre type characteristics most likely reflect the cause or consequence of an aptitude for a particular exercise/activity type, whilst the average value for the group can be expected to indicate the predominant function for which that muscle was designed, or to which it has adapted. Our observation that lumbar muscles with a low proportion of type I fibres possessed a higher type I:II fibre size ratio agrees with previous findings (Thorstensson & Carlson, 1987) and suggests that a high proportional area of the muscle occupied by type I fibres is the most desirable constitution for this muscle: if an individual is not genetically endowed with an excess of type I fibres (by number) then the muscle seems to adapt by modifying the relative size of the fibre types in an attempt to achieve the same end result in relation to fatigue resistance. An alteration of fibre size is more readily achievable than is a transformation from one fibre type to another (Goldspink, 1985).

No difference was observed between the thoracic and lumbar regions of the muscle group either for the distribution of, or the relative area occupied by, each of the three main fibre types. This provides further evidence that the 2 regions of the muscle are most likely required to perform similar functions and act synergistically in maintaining posture and extending the spine. This particular finding conflicts with that of Sirca & Kostevc (1985) who concluded that the thoracic region possessed a greater percentage of type I fibres than did the lumbar. They explained their findings on the basis of purported differences between the regions in their line of gravity relative to the intervertebral joints (Joseph & McColl, 1961) and the consequent differences in tonic activity of the muscles in these 2 regions. However, other studies suggest that the centre of gravity differs greatly between individuals, but in the majority acts to cause a flexor moment at *both* thoracic and lumbar regions (Klausen, 1965; Bogduk & Twomey, 1991). Further, it was unclear from the results of Sirca & Kostevc (1985) whether the thoracic and lumbar samples that they were comparing were actually matched pairs—if not, then it is difficult to know whether interindividual differences accounted for some of the observed difference between levels.

Highly significant sex differences in the erector spinae fibre type statistics were observed, which were characterised by (1) larger fibres in the men, and (2) a greater type I fibre presence in the women. The bigger fibres in the male muscles probably relate to the gross muscle size differences discussed above. This sex-difference has been a fairly consistent finding in most previous studies, particularly in relation to the size of the type II fibres (Bagnall et al. 1984; Thorstensson & Carlson, 1987; Zhu et al. 1989; Rantanen et al. 1994), although the occasional report of no sex-difference in fibre size also exists (Mattila et al. 1986). The larger area of the muscle occupied by type I fibres in the women was not so much the result of a higher proportion of type I fibres but rather the consequence of a higher type I:II fibre size ratio when compared with the muscles of the men. Similar sex differences have been reported before, albeit for the lumbar region only (Thorstensson & Carlson, 1987; Rantanen et al. 1994) and it is possible that they account for the previously observed differences in back muscle fatiguability between men and women (women less fatiguable than men) (Mannion & Dolan, 1994). The metabolic and physiological profile of the type I fibre provides it with a higher oxidative potential and with the capacity to sustain an isometric contraction with a greater economy of tension maintenance than the type II fibre (Rall, 1985). Accordingly, a contraction sustained with a predominance of type I fibres, in preference to type II, should result in a lower rate of accumulation of the metabolic by-products that have previously been implicated in fatigue (Mannion et al. 1995).

In summary, the data from the present study could be of use in assessing deviations from the norm in clinical material acquired from patients with various upper and lower back disorders. The relationship established between body size and muscle fibre size could be employed to evaluate the degree of atrophy in muscle samples collected from individuals with widely differing anthropometry. Finally, when assessing the extent of any pathological change in the muscle of low back pain patients, it seems clear that (1) sex cannot be disregarded and (2) 'atrophied' (by the criteria used to assess other muscles) type II fibres are not necessarily abnormal for the erector spinae, particularly in women.

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