J. Anat. (1985), **141**, pp. 131–137
With 1 *figure*
Printed in Great Britain

The fibre type composition of thoracic and lumbar paravertebral muscles in man

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(*Accepted 22 November* 1984)

INTRODUCTION

Precise data on fibre histochemical composition are required for the evaluation of possible pathological findings in skeletal muscles. The data available for the paravertebral muscles are insufficient in several respects: the number of subjects examined is too small, they vary widely in age and the site of sampling is not defined precisely enough. Sulemana & Suchenwirth (1972) obtained autopsy samples of the erector spinae muscle (the site of sampling was not indicated) from eleven patients aged between 22 and 73 years who died suddenly showing no sign of any known neuromuscular disease. The samples were found to contain from 50 to 75% of Type I fibres (ratio I/II: 1·76) and the mean cross sectional area of the Type I fibres to exceed that of the Type II fibres (ratio of the cross sectional areas I/II: 1·17).

Autopsies of six male subjects aged 17 to 30 years (Johnson, Polgar, Weightman & Appleton, 1973) showed the percentage of Type I fibres to range from 26·7 to 100·0 in the superficial portion of the erector spinae muscle and from 34·0 to 88·6% in the deep portion of the erector, the level of the spine not being indicated, the means for the superficial and deep portions being 58·4% and 54·9% respectively. In the same material, Polgar, Johnson, Weightman & Appleton (1973) found the mean fibre diameter (in μm) in the superficial portion of the muscle to be 60·0 (Type I fibres) and 57·0 (Type II fibres) and in the deep portion 61·6 (Type I fibres) and 53·6 (Type II fibres).

In one of three subjects autopsied, aged 19, 32 and 51 years, it was found that the multifidi at the level of the sixth thoracic spinous process contain 77% of Type I fibres while at the level of the fifth lumbar vertebra (three subjects), the percentage ranges from 43 to 69% (Fidler, Jowett & Troup, 1975). In 17 patients aged 34 to 80 years, with derangement of the lumbar spine, the lumbar multifidi were found to comprise 66·6% of Type I fibres (S.D. $\pm$ 12·98).

A recent study (Bagnall *et al.* 1983) has examined for the first time samples taken from the superficial and deep spinal musculature of the left and right sides in 19 patients, aged 26 to 73 years, undergoing surgery of the lumbar (L4–5) intervertebral disc. It was found that the percentage of Type I fibres in the superficial muscle is 61% (left side) and 50% (right side), the difference not being statistically significant. In the deep muscle the respective values are 47% and 55%. At all sites, Type I fibres are significantly larger than Type II fibres.

The aim of the present study is to reinvestigate, on a larger group of adult individuals, possible histochemical differences between the superficial and deep paraspinal muscles at the thoracic and lumbar levels. This work has been stimulated by the recent finding of reciprocal inhibition of the superficial and deep paraspinal muscles occurring on eliciting proprioceptive reflexes of these muscles. Moreover, the idea

has been advanced that unilateral weakness of the deep paraspinal muscles could be the primary factor in the genesis of idiopathic scoliosis (Trontelj, Pečak & Dimitrijević, 1979).

MATERIALS AND METHODS

Autopsy samples were obtained from 21 male subjects aged 22 to 46 years within 4–26 hours of death. They died suddenly, mostly as victims of road traffic accidents, and led normal active lives until their death. Muscle samples were taken from the longissimus and multifidus muscles of the left side at the level of the eighth thoracic and second lumbar spinous processes. Additionally, 17 biopsies of the lumbar longissimus and multifidus were obtained from 12 male and 5 female subjects, aged between 28 and 50 years, operated on for herniated intervertebral disc of several months' duration.

The samples were frozen in liquid nitrogen. Serial sections were processed to detect adenosinetriphosphatase (ATPase) activity without pre-incubation (Padykula & Herman, 1955) and after acid pre-incubation at pH 4·6 and 4·3 (Brooke & Kaiser, 1970), for succinic dehydrogenase (Nachlas *et al.* 1957), for NADH-tetrazolium reductase (Novikoff, Shin & Drucker, 1961) and for α-glycerophosphate dehydrogenase activities (Wattenberg & Leong, 1960). The typing of fibres was performed on photographs of sections in which the histochemical patterns of at least 200 fibres of each sample were determined. The size of Type I and Type II fibres was estimated by measuring the smallest diameter, i.e. the greatest distance between the opposite sides of the narrowest aspect of the fibre (Brooke & Engel, 1969), on photographs of sections reacted for ATPase activity without pre-incubation. Statistical evaluation of the differences between muscles using the Z test was performed (Sachs, 1982).

RESULTS

Fibre types

Fibre typing was based on the ATPase reactions (Fig. 1*a–e*; Table 1). Reactions for the glycolytic enzymes were distinctly positive in Type II fibres, though no clear difference between Type IIA and Type IIB fibres was noted. The results with the oxidative enzymes did not run in parallel with the ATPase reactions: many Type IIA fibres were more oxidative than Type I fibres. In other samples, particularly in cadaveric material, no clear distinction could be made between Type I and Type II fibres concerning their oxidative activity. These observations were based on visual evaluation of the intensity of histochemical reactions since quantitative analysis of oxidative-activity was not carried out.

The results demonstrated distinct differences in fibre composition between thoracic and lumbar paravertebral muscles. The great proportion of Type I fibres, amounting to 75 % of all the fibres counted, was characteristic of the thoracic level. There was no significant difference between the superficial and deep muscles. At the lumbar level, the fibre composition more closely resembled that of a typical mixed muscle in that Type I and Type II fibres were present in nearly equal percentages. There were more Type I fibres in the deep than in the superficial muscle. An unusual finding in one of the autopsies was that four muscle samples, with Type I and Type II fibres identified by the ATPase reaction at pH 9·4, did not display the usual reversal of activity after acid pre-incubation. In two other subjects, some fibres showed a moderately positive ATPase reaction at pH 9·4; taking into consideration the results

Table 1. *Fibre composition of paravertebral muscles at two levels of the spine*

Level	Number of samples	Number of fibres	Types of fibre (%) I ± S.D.		IIA	IIB	IIC
Autopsies							
T IX							
Superficial	14	3078	74·30 ± 2·7	n.s.	18·19	6·51	1·00
Deep	12	2522	73·16 ± 2·9		17·45	8·97	0·42
L III							
Superficial	13	2665	56·96 ± 3·3	$P < 0·01$	20·70	22·34	0·30
Deep	12	2471	63·21 ± 3·1		25·87	10·60	0·32
Biopsies							
L III							
Superficial	17	3723	56·38 ± 3·1	$P < 0·01$	25·84	16·92	0·86
Deep	17	3391	63·02 ± 3·2		24·18	12·50	0·30

n.s., not significant; S.D. standard deviation; T, thoracic; L, lumbar.

Table 2. *Diameter of Type I and Type II fibres at two levels of the spine*

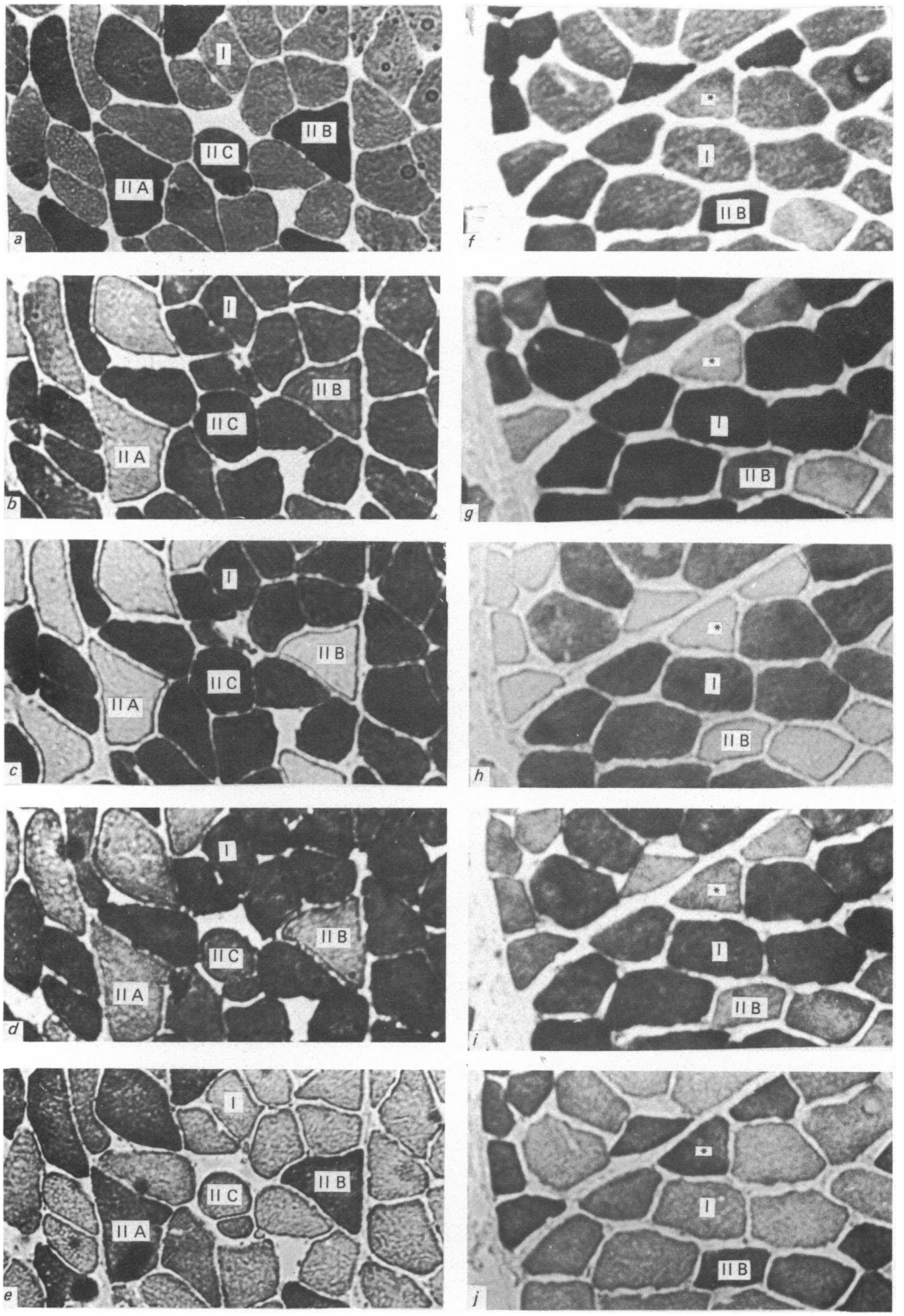
Level	Type I fibres Number	Mean	S.D.	C.V.	S.E.M.	Type II fibres Number	Mean	S.D.	C.V.	S.E.M.
Autopsies										
T IX										
Superficial	2025	52·5	9·0	15·3	0·72	683	53·4	9·1	17·2	1·22
Deep	1794	49·6	8·5	17·4	0·70	674	46·9	7·7	18·7	1·18
L III										
Superficial	1641	58·1	10·3	17·7	0·87	1097	47·9	8·9	18·7	0·92
Deep	1773	54·8	10·6	19·4	0·91	1015	41·6	8·9	21·7	0·99
Biopsies										
L III										
Superficial	2121	44·75	10·98	24·53	0·98	1961	35·1	10·7	32·5	0·98
Deep	2117	50·02	12·1	24·02	1·06	1695	39·6	11·1	28·7	1·13

S.D. standard deviation; C.V., coefficient of variation; S.E.M., standard error of the mean; T, thoracic; L, lumbar.

of other histochemical reactions, including acid pre-incubation, they could have been classified as either Type I or Type II fibres (Fig. 1*f–j*). Paradoxically, with ATPase at pH 9·4, Type I fibres were sometimes darker than Type II fibres. Though the possibility of artefacts was ruled out, the samples containing these anomalous fibres were not included in the statistical evaluation.

Fibre diameter

Fibre diameters, from which the cross sectional areas of Type I and Type II fibres were calculated, are shown in Table 2. In autopsy material, Type I fibres in the lumbar muscles were significantly larger than Type II fibres. At the thoracic level, fibres of both types were nearly equal in diameter. In biopsies from lumbar muscles of patients with disc lesions, the diameters of both fibre types were significantly smaller than in lumbar muscles from autopsies.


I
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DISCUSSION

In the present study, most fibres could be classified without difficulty, based on the ATPase reaction, although there was a small number of fibres with unusual ATPase patterns. The interpretation of the non-reversal phenomenon following acid pre-incubation is beyond the scope of this article. The finding that unusual fibres were present only in autopsy samples suggests that postmortem changes, which occur in muscle after prolonged storage of specimens, might be responsible for the inverse reaction for ATPase at pH 9·4, as described by Eriksson, Eriksson, Ringqvist & Thornell (1980). An unaltered ATPase reaction after acid pre-incubation can also be a normal finding in human intrafusal muscle fibres, as shown by Kucera & Donovini-Zis (1979).

The fibres with a moderately positive ATPase reaction at pH 9·4 are also difficult to explain. They do not resemble Type IIC fibres for two reasons. They are not distinctly positive at pH 9·4 and some of them are darker after acid pre-incubation than they are without preincubation. These fibres resemble those described in biopsies of the masticatory muscles in man and monkey (Ringqvist, 1973; Maxwell, Carlson & Brangwyn, 1980; Vignon, Pellisier & Serratrice, 1980). After pre-incubation at pH 4·35, the intermediate fibres of these muscles were either not stained and corresponded to Type II fibres or, in other cases, showed an activity comparable to that of Type I fibres.

The present findings concerning the percentages of the two fibre types at the two levels of the spine are statistically valid as confirmed by the very low variation, and by the fact that nearly identical results are obtained from biopsy and autopsy samples of the lumbar muscles.

The most relevant finding is the very high proportion (about 75%) of Type I fibres in the superficial as well as in the deep muscles at the thoracic level. In no single muscle sample is there found a prevalence of Type II fibres. As the material was taken from apparently healthy young subjects who were physically active before their sudden death, the 'prevalence' of Type I fibres in paravertebral muscles cannot be interpreted as a pathological deviation, as is the custom in muscle pathology (Dubowitz & Brooke, 1973). The definition of Type I fibre prevalence according to Dubowitz & Brooke probably refers to certain muscles of the extremities which normally contain Type I and Type II fibres in the ratio of about 1:2 or 1:1. In such muscles, certainly, the 2:1 ratio would be highly abnormal, whilst in the paraspinal thoracic muscles this proportion must be considered normal, as indeed is the case in the human soleus muscle (Edgerton, Smith & Simpson, 1974; Gollnick *et al.* 1974).

As the Type I fibres are present in large clusters, they are the only fibre type found in certain muscle fascicles, Type II fibres being scarce or absent. This should not be regarded as grouping of Type I fibres, which is a pathological phenomenon. In true grouping characteristic of a re-innervation both fibre types, of variable diameter, are involved.

In contrast to the thoracic region, the lumbar muscles contain the two fibre types

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Fig. 1 (*a–j*). Histochemical fibre Types I, IIA, IIB, IIC in the human thoracic multifidus muscle. × 135. (*a–e*). Serial sections of normal muscle. (*f–j*). Serial sections with atypical fibres(*). (*a, f*) ATPase reaction at pH 9·4, without pre-incubation. (*b, g*) ATPase reaction, pre-incubation at pH 4·6. (*c, h*) ATPase reaction, pre-incubation at pH 4·3. (*d, i*) Reaction for NADH–tetrazolium reductase. (*e, j*) Reaction for α-glycerophosphate dehydrogenase.

in roughly the same proportion, with slightly more Type I fibres in the deep muscles. The difference in fibre type composition between the lumbar and thoracic muscles is most probably due to a difference in the function of the two segments of the spine. Using electromyography with surface electrodes, Joseph & McColl (1961) have shown that the activity of the posterior vertebral muscles varies from one level to another. Subjects standing in a relaxed position show little or no detectable electrical activity in the lumbar region as compared to the lower thoracic region. According to these authors, this is due to the fact that in the thoracic region the centre of gravity passes in front of the transverse axis of the intervertebral joints while in the lumbar region the centre of gravity passes behind the transverse axis. Hence the trunk extends in the lumbar region under the influence of gravity, the extensors, i.e. the posterior vertebral muscles, being inactive. It may be suggested, therefore, that the activity of the thoracic muscles is permanent and tonic in character and that consequently slow twitch–low fatigue fibres predominate.

The function of individual paravertebral muscles is difficult to assess with the aid of available anatomical and electromyographic techniques. Electromyography using needle electrodes has proved that superficial and deep muscles are involved in a variety of movements, such as flexion and extension, lateral flexion and rotation of the spine (Jonsson, 1970; Waters & Morris, 1972). These observations do not afford a satisfactory explanation of the histochemical differences between the superficial and deep muscles at various levels of the spine. Even less satisfactory is the explanation of differences in diameter between the two principal fibre types in paravertebral muscles. In the vastus lateralis and biceps brachii muscles, the diameter of both fibre types is of the same range and is greater in males than in females (Dubowitz & Brooke, 1973). Brooke & Engel (1969) stated that in males Type II fibres are usually larger than Type I fibres. Quite the opposite was noted in the present study of autopsy samples from normal adult males: Type I fibres were larger, but only in the lumbar region, whereas at the thoracic level the differences between the two fibre types were not significant. These data suggest that a functional difference may exist between the muscles at two different levels of the spine. In biopsies of muscles from patients with disc lesions, the diameter of both fibre types is diminished as compared to normal muscles. This can be attributed to muscular atrophy following prolonged limitation of lumbar motion in patients with chronic disc lesions (Fidler *et al.* 1975).

SUMMARY

Samples of longissimus and multifidi muscles at the thoracic and lumbar levels of the spine were examined histochemically on autopsy specimens from 21 adult male subjects (aged 22 to 46 years) and on biopsies from 17 adult patients during surgery for disorders of the lumbar intervertebral disc. In the superficial and deep thoracic muscles, 74 % of fibres were of the Type I variety. In the lumbar region, Type I fibres amounted to 57 % in the superficial, and to 63 % in the deep muscles. The diameter of Type I fibres was significantly greater than that of Type II fibres.

This work was supported by a grant from the Research Community of Slovenia, Ljubljana. The authors wish to thank Milena Jarc and Ana Tomažinčič for their technical assistance.

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