Effects of strength and endurance training on muscle fibre characteristics in elderly women

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Summary. The effects of 18 weeks' intensive strength and endurance training on fibre characteristics of the vastus lateralis muscle were studied in 76- to 78-year-old women. Type I and type IIa fibres constituted over 90% of the cell population and were almost equally represented. No changes were observed in the proportions of the different fibre types. When comparing the baseline and the 18-week measurements within the groups, the strength group showed a mean increase of 34% ($P=0.028$) in mean type I fibre area. The frequency histograms showed an increased proportion of larger type I fibres after strength training and a decreased proportion of smaller type IIa fibres after endurance training. In the control subjects, the proportion of smaller type I and type IIa fibres increased during the experimental period. The results indicate that intensive strength training induces type I fibre hypertrophy, whereas the effects of endurance training are less evident. The considerable variation found in the change in muscle fibre cross-sectional areas is also noteworthy.

Key words: ageing, exercise, fibre type, vastus lateralis.

Introduction

Age-related muscle atrophy, shown in several studies, occurs mainly as a loss of muscle fibres (Lexell *et al.*, 1983a, 1988) and reduction in fibre size (Larsson *et al.*, 1979; Lexell *et al.*, 1988). Type II fibres seem to be the most vulnerable fibres during the ageing process (Larsson *et al.*, 1979). The percentage of type IIb fibres decreases, whereas that of type I and IIa tends to increase (Kovanen & Suominen, 1987; Aniansson *et al.*, 1992). Despite the compensatory hypertrophy of both type I and IIa fibres seen in old age (Aniansson *et al.*, 1992), type II fibres, in particular, remain smaller in elderly men and women than in their younger counterparts (Essen-Gustavsson & Borges, 1986). Furthermore, the muscles of elderly women have smaller type I and type II fibre areas than their male age peers (Grimby *et al.*, 1982; Essen-Gustavsson & Borges, 1986; Stålberg *et al.*, 1989). In contrast to the case with men, not only elderly women (Grimby *et al.*,

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1982; Essen-Gustavsson & Borges, 1986; Charette *et al.*, 1991) but also younger women (Nygaard, 1981; Staron *et al.*, 1989) seem to have smaller type II fibres than type I fibres.

Several experimental studies suggest that strength training produces no change in the relative occurrence of the different fibre types in the vastus lateralis (Frontera *et al.*, 1988; Charette *et al.*, 1991; Grimby *et al.*, 1992) or biceps brachii (Brown *et al.*, 1990; Roman *et al.,* 1993) in elderly people. Aniansson & Gustafsson (1981), however, showed a decrease in the percentage of type I fibres and an increase in that of type IIa fibres in 69- to 74-year-old men after a light resistance training regimen. Previous studies have also shown that the proportion of type I fibres increases after endurance training (Howald *et al.*, 1985) and that in endurance-trained athletes type I fibres seem to predominate (Suominen *et al.*, 1980; Tesch & Karlsson, 1985). However, a more recent exercise intervention study failed to show endurance training-induced changes in the relative occurrence of type I fibres in the gastrocnemius muscle of elderly men and women. Instead, the percentage of type IIa fibres increased and that of type IIb fibres decreased (Coggan *et al.*, 1992).

Studies investigating training effects on muscle fibre cross-sectional area in elderly people to some extent also show conflicting results. Intensive strength training has increased the cross-sectional area of type II fibres in elderly men (Frontera *et al.*, 1988; Brown *et al.*, 1990; Roman *et al.*, 1993) and women (Charette *et al.*, 1991), and also that of type I fibres in elderly men (Frontera *et al.*, 1988; Brown *et al.*, 1990). In the study by Pyka *et al.* (1994), type I fibre cross-sectional area increased during the first 15 weeks of strength training, after which type II fibre area was mostly affected. However, Grimby *et al.* (1992) could not show hypertrophy in either type I or type II fibres in elderly men after an intensive resistance training period. Endurance training (walking/jogging) for around 1 year resulted in a significant increase of 10% in type I and 12% in type IIa fibre area in 60- to 70-year-old men and women (Coggan *et al.*, 1992).

Only a few trials investigating the effects of physical training programmes on muscle fibres in elderly people have included control groups or compared the effects of strength and endurance training in the same experiment. The need for carefully controlled exercise intervention studies in elderly women becomes evident after considering the different contribution of type I and type II fibres in various movements, the presence of smaller type II than type I fibres in women, and the vulnerability of type II fibres during the ageing process. This paper reports a randomized experimental trial investigating the effects of progressive strength and endurance training on the relative occurrence and cross-sectional area of different muscle fibre types in the vastus lateralis in elderly women.

Subjects and methods

This study was part of an experimental trial investigating the effects of physical training on muscle mass and strength in elderly women. A more detailed description of the

study design and training programmes has been published elsewhere (Sipilä & Suominen, 1995; Sipilä *et al.*, 1996).

SUBJECTS

A random sample of 240 women born between 1915 and 1917 was drawn from the population register of the city of Jyväskylä, Finland. Of this sample, 64 women who reported no severe diseases or functional impairments were invited for clinical and laboratory examinations. After the examinations, the sample was further reduced to 42 women with no indications against intensive physical exercise. Subjects were excluded if they had unstable chronic diseases, rapidly progressive illnesses, endoprothesis or any impairment that interfered with mobility. The subjects included were physically more active than those excluded, but they had no previous experience in more intensive physical exercise (Sipilä & Suominen, 1995). The subjects were randomly assigned to strength (*n*=16), endurance (*n*=15) and control (*n*=11) groups. Twelve women from the strength group, 12 from the endurance group and 11 from the control group completed the study. Of the seven women who withdrew from the study, six were excluded because of disease and illness and one was unwilling to continue because of the lack of time in her daily schedule.

One woman from the strength group, one from the endurance group and two from the control group had administered oestrogen medication on average 17 years (range 15–20 years) preceding the study. One woman from the strength group and another from the endurance group were using thyroxine for hypothyroidism. They were euthyroid during the study. Two women from the strength group were receiving permanent oral prednisolone treatment because of chronic pulmonale asthma. The subjects had no history of operative treatment or radiotherapy to any endocrine gland. There was no difference between the hormone users and non-users in any of the physical measurements during the study period. It is apparent that the subjects studied were endocrinologically in the same functional state.

The study was approved by the ethics committees of the Central Hospital of Central Finland and of the University of Jyväskylä. Written informed consent was obtained in advance from all the subjects.

ANTHROPOMETRY

Body height, body mass and body fat, measured using bioelectrical impedance (Spectrum II, RJL Systems, Detroit, MI, USA) were determined (Sipilä *et al.*, 1996). The results for body fat from one woman from the endurance group were excluded because of technical failure.

MUSCLE BIOPSY

Needle biopsies (Bergström, 1962) were obtained from the midregion of the vastus lateralis muscle under local anaesthesia (2% lidocaine hydrochloride) before and after

the training period. Suction was used except when there was considerable bleeding. An ultrasound scanner (Aloka SSD-280 LS) fitted with a 7·5-MHz transducer and the scale marked on the biopsy needle were used to evaluate the site and the depth for taking the sample. Post-training biopsies were taken from the incision site of the pretraining biopsy. The results are given for the seven women in the strength group, nine in the endurance group and seven in the control group who yielded acceptable samples in both the baseline and 18-week measurements. Samples excluded contained too few or longitudinally oriented fibres or, as in five women in the baseline measurements, only adipose tissue. For histochemistry, the muscle specimen was transversely oriented under a stereomicroscope in the OCT embedding compound (Tissue-Tek, Division Miles Laboratories, Naperville, IL, USA) and frozen in isopentane cooled by liquid nitrogen. The samples were stored at $-80°C$ pending further analysis.

HISTOCHEMICAL ANALYSIS

Transverse sections of 10 μm were cut using Ames cryostat II at $-20°C$. Cross-sections were stained for myofibrillar ATPase (Padykula & Herman, 1955) at pH 9·4 after preincubation at pH 4·3, 4·5, and 10·3. Cross-sectional areas for type I, IIa, IIb, IIab and IIc fibres (Staron & Pette, 1986) were analysed from the whole section under a microscope (Nikon Optiphot II, Japan). The orientation of fibres was carefully controlled by excluding the edges of the specimen and fibres with longitudinal cuts. An FG-100-A5 Image Processor (Imaging Tech. Woburn, USA) together with MCID/M1 software (Imaging Research, Brock University, Canada) was used for the analysis. The average number of fibres counted was 285 (range 117–616, one sample 53). There were no systematic differences in the number of fibres counted before and after training or between the study groups. Owing to the scarcity of the muscle fibre subtypes IIab, IIb, and IIc, these fibres were combined and named as intermediate fibres in the results. Frequency histograms for cross-sectional areas and their cumulative distribution curves were analysed for type I and type IIa fibres.

Routine haematoxylin-eosin staining was conducted to demonstrate possible histopathological changes, such as muscle fibre atrophy, central nuclei or necrosis. Gomori's silver impregnation technique (Romeis, 1968) was used for the histological visualization of collagen and reticulin. An olympus BX 50 microscope was used for the evaluation of the stained sections.

TRAINING

Both experimental groups participated in an 18-week progressive physical training programme comprising supervised training sessions three times a week.

The strength group trained on exercise machines using compressed air as resistance (HUR, Kokkola, Finland). These machines are of the variable resistance type, providing both concentric and eccentric resistance, which vary in a predefined way through-

out the range of motion. This variation is made to compensate for the force–length relationship of the muscles. The dynamic training was specifically directed at increasing the mass and strength of the quadriceps femoris by means of the leg press and the leg extension curl, the hamstrings by the leg flexion curl in the standing position and the calf muscles using the heel raise. Principally, each training session included all the above-mentioned exercises except for the leg extension curl, which was included in the training programme after 9 weeks' training. The resistance was individually adjusted according to the one repetition maximum test (1 RM) measured at 2-week intervals. To obtain the 1 RM, the initial resistance was set close to the previous 1 RM result. The resistance increment was 0·25 bar, which corresponded to 2·5 kg in the leg flexion curl, 3 kg in the leg extension curl and 5 kg in the leg press. One repetition maximum test was defined as the heaviest load that the subject could move in an acceptable way throughout the complete range of motion. The intensity of the training was gradually increased during the 18-week period from 60% to 75% of the 1 RM. The subjects performed three or four sets of eight to ten repetitions with a 30-s pause between the sets. After the 18-week training period, the 1 RM for the leg press increased on the average by 60% and that for the leg flexion curl by 40%. The knee extension curl was used with caution because it produced discomfort in the knee area in several subjects.

The training of the endurance group included track walking twice a week and step aerobics once a week. During the first training session the subjects walked an average of 1500 m (range 1200–2200 m). By the end of the training period, the mean walking distance had reached 2700 m (range 2400–3300 m). The step aerobics sessions lasted for 40 min, during which stepping on a bench 0·10 m in height was performed continuously to music. The choreography was designed to stress the cardiovascular system by using the major muscle groups of the lower extremities. The stepping height was kept constant throughout the whole training period for all of the subjects, with the exception of two women who raised their steps to 0·15 m after the fourth and fifth weeks of training and one woman who raised her step to 0·15 m during the last 3 weeks of training. The training intensity of the endurance group was gradually increased during the training period from 50% to 80% of the initial peak heart rate reserve determined in the baseline measurements by the bicycle ergometer test.

Mean participation in the strength training sessions varied between 71% (leg extension curl) and 86% (leg press), compared with an average attendance of 87% in the endurance training sessions (Sipilä & Suominen, 1995). The main reasons for non-participation in a training session were a trip abroad and acute respiratory infection.

The controls were instructed to continue their daily routines and not to change their physical activity levels.

To determine the actual physical activity level of the subjects and possible changes in it during the experiment, all the subjects in each study group were instructed to keep a diary recording their daily physical activities according to the type and duration of the physical activity performed. This included recording the number of kilometres for walking, cycling and swimming. Apart from the training included in the trial, the study

groups did not differ with respect to the overall level of physical activity, which remained constant throughout the experiment (Sipilä & Suominen, 1995).

STATISTICAL ANALYSIS

Standard procedures were used to calculate means and standard deviations (SD). The differences between the study groups in the baseline measurements were assessed using one-way ANOVA. The effects of the training programmes were assessed using sphericity-corrected ANOVA for repeated measures. Because the relatively small number of acceptable biopsy samples limited the statistical power of the design, non-parametric tests were also used. Within-group differences between the baseline and post-training measurements were assessed using the Wilcoxon matched-pairs signed-ranks test. The difference between type I and type IIa cross-sectional area was assessed using the Mann-Whitney *U*-test. The differences between the frequency distributions of fibre areas before and after training within the study groups were statistically tested by the Kolmogorov-Smirnov two-sample test.

Results

In the baseline measurements, the study groups did not differ with respect to any of the physical or muscle fibre characteristics under investigation.

The physical characteristics of the subjects who completed the study are shown in Table 1. There was an overall change in physical characteristics over time. No significant interaction of groups with time was, however, observed.

On the basis of routine haematoxylin–eosin staining and Gomori's reticulin staining the muscle fibres showed normal histomorphology. No necrotic fibres, overt fibrosis or elevated accumulation of extracellular fat were observed. However, several specimens demonstrated atrophied and/or angulated muscle fibres that appeared to be type IIa fibres on the basis of ATPase staining. Grouping of both type I and IIa fibres was also observed (Fig. 1)

The results for the proportions of the different fibre types as well as mean and relative fibre areas are shown in Table 2. Type I and type IIa fibres accounted for more than 90% of the total cell population and both of these fibre types were almost equally represented. No significant interaction of group by time or within group changes were observed in the proportion of the different fibre types.

In the baseline measurements, the coefficient of variation for cross-sectional area of muscle fibres within the samples was on average 36% for type I and 49% for type IIa fibres with no change during the 18-week period.

Type I fibres had a larger cross-sectional area than type IIa fibres in both the baseline and 18-week measurements ($P=0\cdot004$–$0\cdot180$). No significant interaction of group by time was observed in the type I, type IIa or intermediate fibre mean or relative cross-sectional areas. When the baseline and the 18-week measurements were com-

Table 1. Physical characteristics in 76- to 78-year-old women before and after 18 weeks of strength and endurance training (mean, SD)

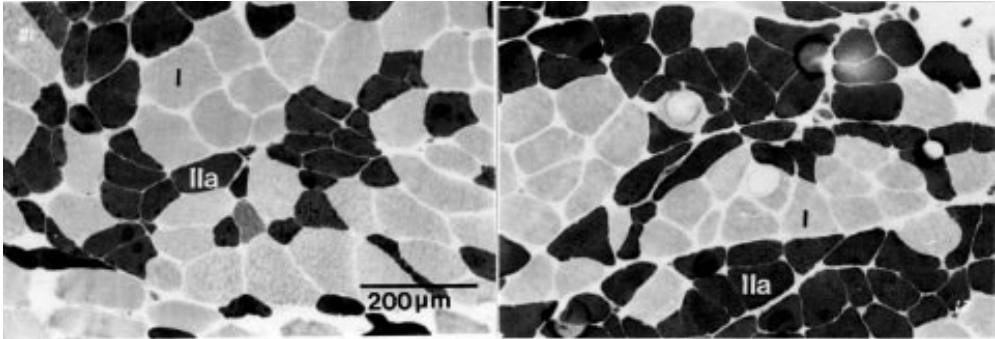| Variable	Strength (n=7)		Endurance (n=9)		Control (n=7)		ANOVA significance (P)		
	Baseline	18 weeks	Baseline	18 weeks	Baseline	18 weeks	Interaction	Group	Time
Body height (cm)	160·1 (4·1)	160·3 (4·0)	156·8 (5·4)	157·0 (5·2)	160·3 (5·7)	160·6 (5·9)	0·865	0·311	0·021
Body mass (kg)	63·8 (8·3)	62·5 (9·0)	66·6 (10·8)	65·4 (10·1)	69·3 (15·2)	68·0 (16·0)	0·977	0·689	0·002
Body fat (%)	29·7 (6·5)	27·0 (8·3)	34·3 (7·1)†	33·3 (6·3)†	31·1 (9·8)	30·1 (9·8)	0·213	0·437	0·002

†n=8.

Fig. 1. Transverse sections taken from the vastus lateralis muscle of two 76- to 78-year-old women stained by myofibrillar ATPase at pH 9·4 after preincubation at pH 10·3, showing irregular recurrence of small, angulated and atrophied preferentially type IIa fibres and grouping of both type I and IIa fibres.

pared within the study groups separately, the strength training group showed an increase in mean type I fibre area ($P=0·028$).

Individual changes in both type I and type IIa fibre areas varied considerably in every study group (Figs 2 and 3). Both positive and negative changes were observed, except in the type I fibre area in the strength group, in which the individual changes varied between +196 and 0%. In the control group, a huge positive change in the type IIa fibre area was observed in one woman (198%). In all the other control women, the type IIa fibre area either remained unchanged or decreased.

The analyses of the frequency histograms of the type I and IIa fibre cross-sectional areas, presented in Figs 4 and 5, showed significant differences between the baseline
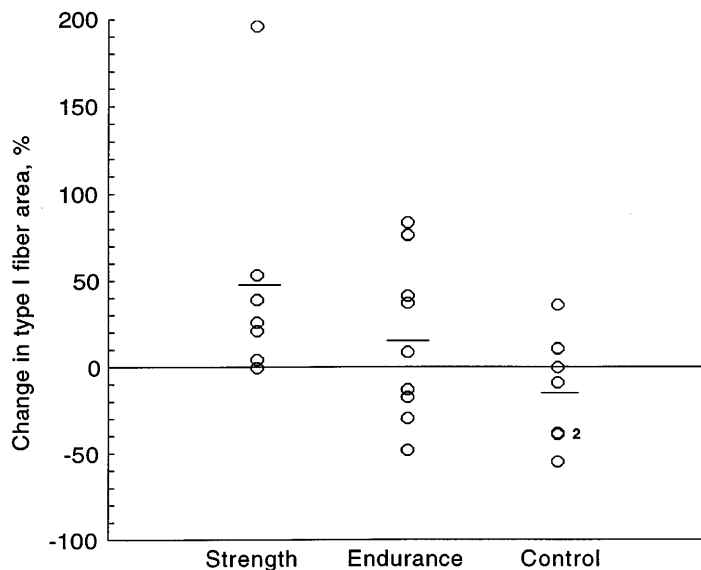

Fig. 2. Individual changes in type I fibre cross-sectional area in 76- to 78-year-old strength-trained, endurance-trained and control women. —, Means.

Table 2. Effects of strength and endurance training on muscle fibre characteristics in 76- to 78-year-old women (mean, SD)

| Variable	Strength (n=7)		Endurance (n=9)		Control (n=7)		ANOVA significance (P)		
	Baseline	18 weeks	Baseline	18 weeks	Baseline	18 weeks	Interaction	Group	Time
Fibre composition (%)									
I	46·7 (8·3)	48·9 (16·2)	43·3 (14·0)	44·4 (12·9)	47·9 (9·9)	43·2 (12·4)	0·461	0·785	0·834
IIa	50·7 (8·0)	48·6 (16·9)	49·8 (14·0)	45·2 (15·9)	44·4 (10·0)	48·2 (19·4)	0·672	0·855	0·807
Intermediate	2·5 (1·2)	2·5 (2·8)	6·9 (7·7)	10·4 (15·4)	7·6 (5·4)	8·6 (10·8)	0·852	0·158	0·590
Fibre area (μm^2)									
I	3351 (1630)	4497 (1640)	3823 (1620)	4029 (1702)	3591 (1115)	2995 (1331)	0·170	0·568	0·478
IIa	1950 (605)	2092 (770)	2276 (1468)	2294 (763)	2628 (1491)	2176 (1766)	0·743	0·747	0·765
Intermediate	1246 (579)	1746 (557)	1599 (501)	1700 (700)	2036 (1317)	1609 (1293)	0·542	0·696	0·870
Relative area (%)									
I	58·7 (9·9)	65·6 (19·0)	57·9 (12·2)	58·0 (12·5)	58·4 (12·6)	55·2 (13·9)	0·315	0·684	0·628
IIa	39·7 (9·9)	33·2 (19·3)	38·1 (12·5)	35·5 (14·7)	37·2 (11·7)	37·4 (13·0)	0·727	0·989	0·375
Intermediate	1·7 (0·9)	1·2 (1·1)	4·0 (3·5)	6·5 (11·5)	4·4 (2·1)	7·4 (11·4)	0·766	0·227	0·422
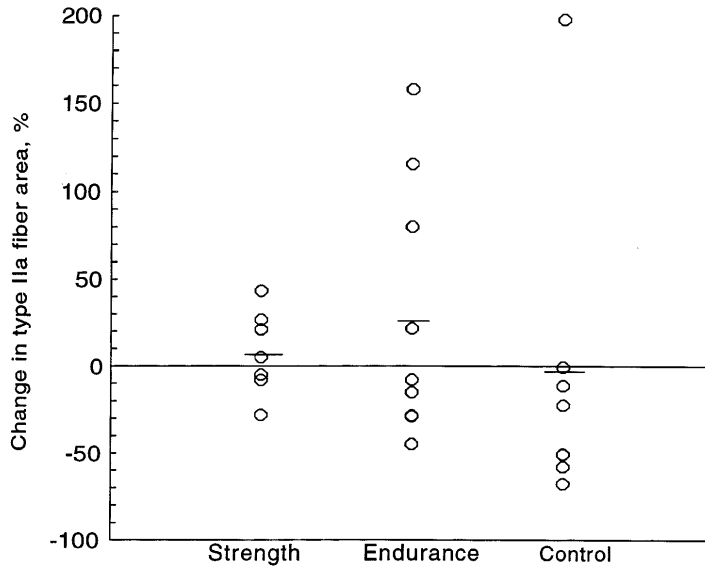
Fig. 3. Individual changes in type IIa fibre cross--sectional area in 76- to 78-year-old strength-trained women, endurance--trained women and control women. —, Means.

and the 18-week measurements within the study groups. The proportion of larger type I fibres was higher after strength training than the baseline situation. After endurance training, the proportion of smaller type IIa fibres was lower and the proportion of mid-size type I fibres higher than the baseline histogram. In the controls, the proportion of smaller type I and type IIa fibres was higher than the baseline distributions.

Regardless of the variation in the number of actual training sessions, the abovementioned changes that occurred in the muscles during the experiment were not related to the number of training sessions.

Discussion

In this study, intensive physical training for 18 weeks produced relatively minor changes in the mean muscle fibre area of m. vastus lateralis in 76- to 78-year-old women. It seems, however, that strength training increased the cross-sectional area of type I fibres. Frequency histograms and individual changes in muscle fibre cross-sectional area also suggested that the proportion of smaller type IIa fibres decreased in the endurance group and that of smaller types I and IIa fibres increased in the controls. The relative proportion of the different fibre types remained unchanged during the trial in every study group.

In the present study, the fibre types were classified by using the three different preincubation pHs to detect the fibre subtypes (Staron & Pette, 1986). Type I and type IIa fibres were equally represented in the samples. The type IIab, IIb and IIc fibres
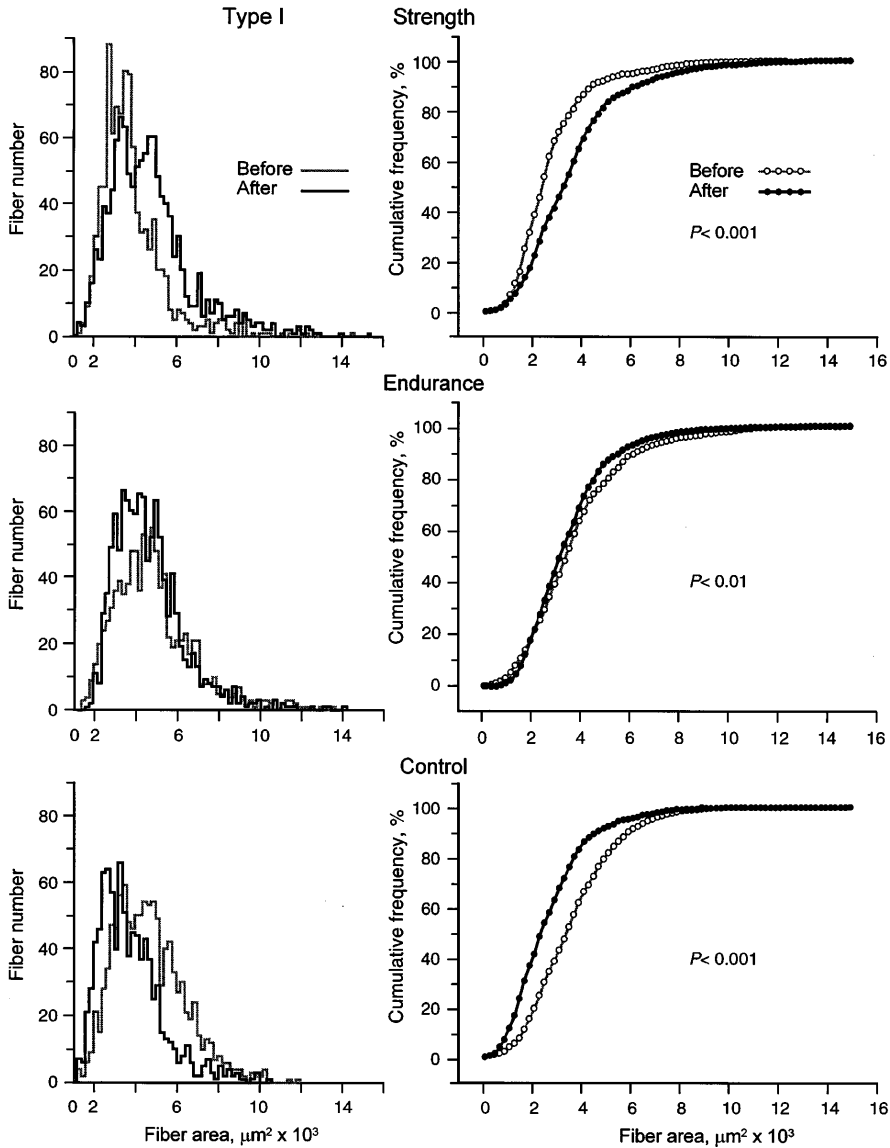
Fig. 4. Frequency histograms and cumulative distribution curves for type I muscle fibre cross-sectional area in 76- to 78-year-old strength-trained women, endurance--trained women and control women.

combined constituted less than 10% of the total cell population. However, previous studies in elderly people have shown a predominance of type I fibres and 10–25% of type IIb fibres (Aniansson & Gustafsson, 1981; Grimby *et al.*, 1982; Aniansson *et al.*, 1992; Coggan *et al.*, 1992). The classification of fibre subtypes may be problematic as there is no great difference in the staining intensity of types IIab, IIb and IIc.
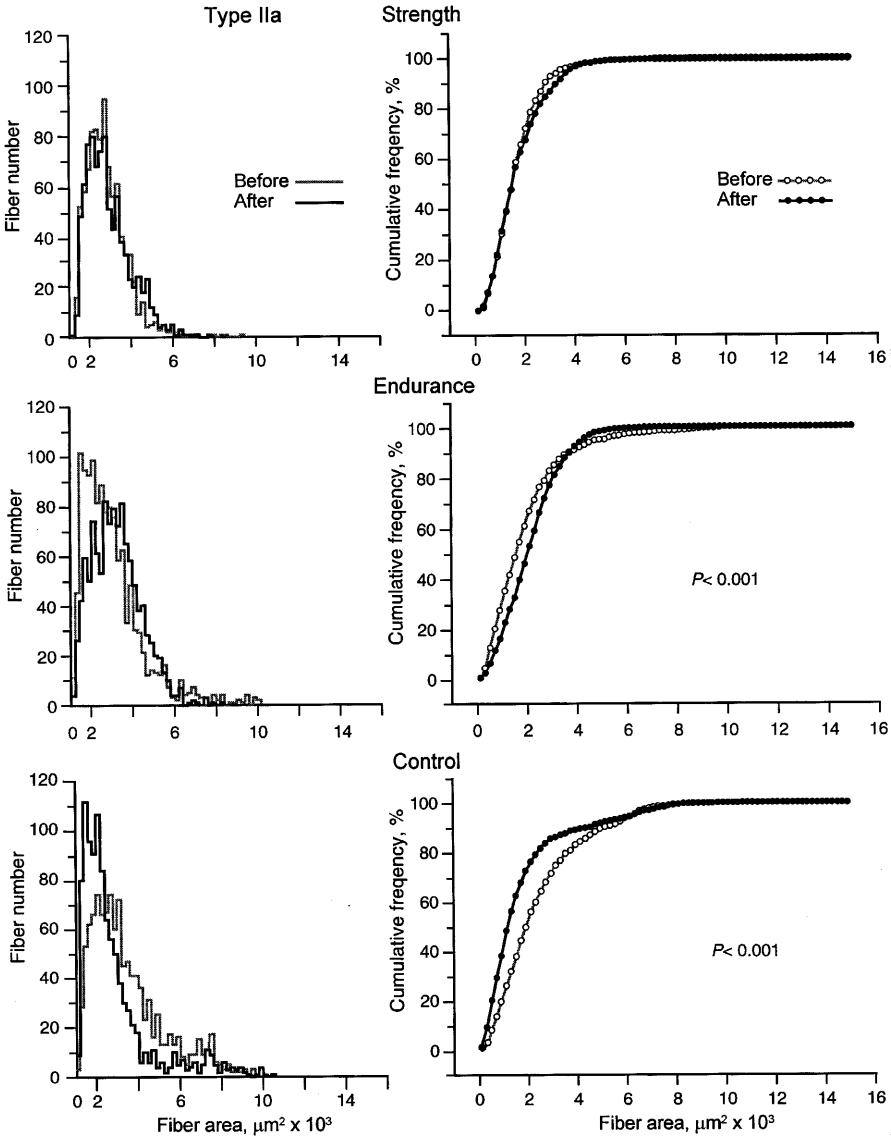
Fig. 5. Frequency histograms and cumulative distribution curves for type IIa muscle fibre cross-sectional area in 76- to 78-year-old strength-trained women, endurance-trained women and control women.

The proportion of different fibre types and their cross-sectional areas within the muscle are known to vary as a function of depth (Lexell & Taylor, 1989), type II fibres predominating superficial parts and type I fibres deeper parts of the muscle, especially in younger subjects (Lexell *et al.*, 1983b). Furthermore, in elderly people, the fibre type grouping (see Fig. 1), may result in false conclusions with respect to the occurrence of fibre types. In the present study, we analysed all the acceptable cells in the sections and

special attention was paid when performing the biopsy. In addition, to the scale on the biopsy needle, B-mode ultrasonography was used to evaluate the place and the depth of the biopsy sample. This was necessary because the subjects in this study had a relatively thick layer of subcutaneous fat (on average 1·1 cm), covering a rather thin knee extensor muscle group (mean combined vastus lateralis and intermedius 2·5 cm). Furthermore, the post-training samples were taken as close to the pretraining samples as possible.

The unchanged proportion of the different fibre types in the study groups after the 18-week training period is in line with most of the previously reported strength training studies in elderly people (Larsson, 1982; Frontera *et al.*, 1988; Brown *et al.*, 1990; Charette *et al.*, 1991; Roman *et al.*, 1993; Pyka *et al.*, 1994). Aniansson and Gustafsson (1981), however, showed increased type II fibre proportions after 12 weeks of light resistance training in 69- to 74-year-old men. Endurance training, on the other hand, has been associated with a decreased proportion of type IIb fibres (Coggan *et al.*, 1992) and increased type I fibres in m. vastus lateralis (Suominen *et al.*, 1980; Tesch & Karlsson, 1985).

When interpreting the results for the cross-sectional areas of the different fibre types, the considerable individual variation observed within the samples and within the study groups is noteworthy. In this study, the variation in type I fibre cross-sectional area within the samples was similar to that reported by Aniansson *et al.* (1992) for elderly men. The angulated type IIa fibres and almost 50% variation in their cross-sectional area, which was higher than reported previously (Aniansson *et al.*, 1992), indicate atrophy of some of the type IIa fibres. There was also great individual variation in the change observed in the cross-sectional area of the different fibre types, especially in type I in the strength group and in type IIa in the control group. The coefficient of variation for the mean muscle fibre cross-sectional area measured using duplicated biopsies has been reported to vary between 10 and 15% depending on fibre type (Bolmstrand *et al.*, 1984).

In this study, the strength-trained women showed a mean increase of 34% in type I fibre cross-sectional area. The observed changes in type I fibres after strength training may be the result of the body building type of programme in which eight to ten repetitions were used together with a resistance of 60–75% from 1 RM. No attention was paid to the speed of contraction. Consequently, the subjects performed the muscle contractions at a relatively low speed, probably preferring the recruitment of type I fibres, even though the training was clearly not of endurance type. The strength-trained women also increased their quadriceps muscle cross-sectional area on average by 5% and lean tissue area by 6% as measured by computerized tomography (Sipilä & Suominen, 1995).

The results of the present study for the muscle fibre cross-sectional area differed somewhat from earlier studies, showing significant increase in both type I and II fibre cross-sectional area (Frontera *et al.*, 1988; Brown *et al.*, 1990) or type II fibre hypertrophy without significant changes in type I fibres (Charette *et al.*, 1991; Roman *et al.*, 1993) after resistance training intervention. Comparison of the different experiments

is, however, difficult because of the lack of correspondence in study design and the characteristics of the subjects under investigation.

The frequency histograms suggested a shift towards mid-size type I and type IIa fibres in the endurance-trained women. No sign of fibre hypertrophy was, however, observed when the mean values were considered. Five of the endurance-trained subjects even showed a decreased mean type IIa fibre cross-sectional area (Fig. 3). It is possible, however, that the relatively high tempo together with unusual loading for the lower extremity muscles, especially during the step aerobics sessions, might have recruited at least some of the type IIa fibres. Endurance training also increased isometric knee extension strength (Sipilä *et al.*, 1996), whereas only a minor increase was observed in maximal oxygen uptake (Kallinen *et al.*, 1995). One earlier study has shown that endurance training, including walking and/or jogging, can produce significant hypertrophy not only in type I fibres but also in type IIa fibres in lateral gastrocnemius in elderly men and women (Coggan *et al.*, 1992). In experimental animal studies, swimming training for 16 weeks also produced significant hypertrophy of both type I and IIa fibres in elderly rats (Klitgaard *et al.*, 1989). On the other hand, long-term endurance training in Wistar rats resulted in smaller cross-sectional areas of type I fibres in the soleus and type IIb in the rectus femoris (Kovanen & Suominen, 1987).

The frequency histograms for type I and IIa fibre cross-sectional area in the control women suggest an increased proportion of smaller type I and type IIa fibres during the 18-week period. Individual changes in the muscle fibre cross-sectional area also show that the type I fibre area decreased in four women and type IIa in five out of the seven control women during the experiment (Figs 2 and 3). However, no significant change was observed in mean type I or type IIa fibre cross-sectional area (Table 2). It seems unlikely that the atrophy of the vastus lateralis muscle in 76- to 78-year-old women could proceed at that rate. The physical activity diary revealed that the weekly walking performed by the control women ranged from 10 to 16 km and that they did not change their level of physical activity during the trial.

In conclusion, the results suggest that in healthy elderly women strength training results in larger type I fibres in the vastus lateralis muscle. The training used did not, however, significantly affect the type II fibres, which are more vulnerable to the ageing effects. It should be noted that the considerable individual variation observed in the changes of the cross-sectional area of the different fibre types analysed makes the interpretation of the results difficult. Neither strength nor endurance training induced changes in the relative proportion of the different fibre types.

Acknowledgments

The authors would also like to thank the personnel of the Department of Anatomy at the University of Oulu, Finland for providing the facilities for the image analysis of muscle biopsies.

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