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Muscle strength in male athletes aged 70-81 years and a population sample

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Summary. Muscle strength characteristics of different muscle groups were studied in active male strength-trained (ST, $n=14$), speed-trained (SP, $n=16$), and endurance-trained (EN, $n=67$) athletes aged between 70 and 81 years. A population sample of similar age ($n=42$) served as a control group. The isometric forces for hand grip, arm flexion, knee extension, trunk extension, and trunk flexion were higher for the athletes than the controls and higher for the ST than EN group. The SP athletes showed higher values in knee extension and trunk flexion than the EN group. When the isometric muscle forces were related to lean body mass, significant differences still existed between the athletes and controls. However, the differences between the ST and EN groups disappeared. The elevation of the body's centre of gravity in the vertical jump was also higher for the athletes than the controls. The SP group performed better in the vertical jump than either the ST or EN group. The results showed that the athletes who trained not only for strength and speed but also for endurance had superior muscle function compared to the average male population of the same age. Although the strength and speed athletes generally showed the highest muscle strength in absolute terms, the endurance athletes also preserved excellent strength characteristics related to body mass.

Key words: Aging – Physical training – Muscle performance

Introduction

With increasing age human muscles undergo many structural and functional changes of myopathic and neuropathic origin. The most striking structural change is the reduction in muscle mass caused by a loss of muscle fibres (Lexell et al. 1983, 1988) and, especially in type II fibres, by a reduction in size (Larsson 1978; Aniansson et al. 1986). At the functional level, there is a decline in dynamic and isometric muscle strength (Larsson 1978; Dannenskiold-Samsoe et al. 1984; Murray et al. 1985; Viitasalo et al. 1985; Aniansson et al. 1986; Vandervoort and Hayes 1989; Viljanen et al. 1990). A steeper decline, which is associated with muscle atrophy, begins after the age of 50 (Montoye and Lamphiear 1977; Larsson 1978; Viitasalo et al. 1985; Aniansson et al. 1986). Most of the studies published on age-related changes in muscle strength have, however, been cross-sectional in nature and have concerned only one or two muscles or muscle groups.

One of the factors associated with the observed age-related structural and functional changes in muscles is disuse, i.e. a decline in physical activity. Reports on the effects of life-long physical training on aging human muscles have shown that physically active people perform better than sedentary people (Kuta et al. 1970; Suominen et al. 1980; Rikli and Busch 1986; Suominen et al. 1989). Moreover, studies in previously untrained subjects have shown that physical training of 2-6 months' duration can significantly increase both muscle strength and cross-sectional area (Moritani and De Vries 1980; Aniansson and Gustafsson 1981; Larsson 1982; Frontera et al. 1988; Fiatarone et al. 1990) and the activity of the energy metabolism enzymes (Suominen et al. 1977a, b) in the elderly.

The purpose of the present study was to investigate the association between long-term physical training and muscle strength characteristics by assessing isometric force in tests of hand grip, arm flexion, knee extension, trunk flexion and extension, and vertical jump performance in male athletes still active when aged 70-81 years. The athletes were drawn from various types of sport and they were compared with a sample from a population of similar age.

Methods

Subjects. The study was part of a larger, interdisciplinary investigation of health and functional capacity among elderly athletes and untrained men. A total of 111 male athletes aged between 70

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to 81 years were selected from among the 287 veteran members of the Finnish sports organizations for track and field, cross-country skiing, and orienteering. Selection was based on a postal questionnaire which included questions about the subjects' past and present levels of physical activity. The most active athletes during the years immediately preceding this study were invited to a laboratory examination. The athletes were divided into three groups on the basis of their preferred sport and training regime. The strength-trained group (ST) comprised throwers and weight-lifters, the speed-trained group (SP) sprinters and jumpers, and the endurance-trained (EN) group long-distance runners, orienteers and cross-country skiers. A random sample of men aged between 70 to 81 years ($n=67$) from the population register of the rural municipality of Jyväskylä served as the control group. Eighty-seven percent of the athletes (14 ST, 16 SP, and 67 EN) and 63% of the control subjects ($n=42$) participated in the laboratory examinations. Written informed consent was obtained in all cases.

Most of the athletes had trained throughout their lives and were still active in competitive sport. The ST group had been training regularly for 45 years (median 53, range 5–70), SP for 56 years (60, 8–69) and EN for 49 years (55, 7–70).

During the preceding year, the EN athletes had trained on average for 9 $h \cdot week^{-1}$ (range 4–29). When a weighted sum of self-reported running and cross-country skiing was calculated (the weights were adjusted to 1.0 for running and 0.7 for skiing on the basis of the estimated average distance travelled in a given time unit), their annual training averaged 1240 km (range 140–5000 km, $n=56$).

The ST and SP groups had accomplished considerably fewer training kilometres. The mean value for those who had also included running and/or skiing in their training was 760 km (range 70–1200 km, $n=4$) for ST and 510 km (range 60–1260 km, $n=7$) for SP, respectively. With the exception of one thrower who reported as much as 37 h of physical activity per week (mainly walking and cycling), they trained less regularly than the EN athletes. The other ST athletes averaged 8 $h \cdot week^{-1}$ (range 2–14 $h \cdot week^{-1}$) and the SP 6 $h \cdot week^{-1}$ (range 1–16 $h \cdot week^{-1}$) training for their specific events (track and field, gymnastics, weight-lifting, and ball games).

Of the control subjects, five men were relatively active physically (170–290 km training during the preceding year).

The age and anthropometric characteristics of the subjects are given in Table 1. The ST athletes were taller than the men in the control group and they had also greater lean body mass than the subjects in the other study groups. The ST athletes and the control subjects had greater body mass and percentage of body fat as compared to the EN and SP athletes.

Anthropometric measurements. Body height, body mass, and skinfold thickness from the biceps, triceps, subscapular and suprailiac regions were measured. Body mass index ($mass \cdot height^{-2}$), lean body mass and percentage of body fat (Durnin and Womersley 1974) were determined.

Muscle strength. The maximal isometric strengths for hand grip, arm flexion, and knee extension were measured in a sitting position on a custom-made dynamometer chair which was a modification of that described by Viitasalo et al. (1985). The earlier apparatus was improved so that knee extension force could, if required, be measured at different knee joint angles. The measurements were performed on the ipsilateral side to the dominant hand. During the measurements the elbow was at an angle of 90°. The wrist was attached in a supinated position at the level of the styloid processes by belts connected to the strain-gauge system. The knee was set at an angle of 60° from the full extension obtained for each individual and the ankle was attached above the malleolus to a belt-strain-gauge system. Hand grip was measured with a dynamometer which was attached to the arm of the chair.

The trunk extension and flexion isometric strengths were measured in a standing position according to the methods described by Viitasalo et al. (1977).

As an indicator of the dynamic muscle strength production of the lower extremities, the height of the elevation of the body's centre of gravity was measured during a vertical jump with counter movement on a contact mat (Komi and Bosco 1978; Bosco et al. 1983).

In each test, the subjects were encouraged to perform three maximal efforts. The highest values in each case were used in the analyses.

The coefficient of variation (CV) for the two best performances was 2.9% for hand grip, 3.7% for arm flexion, 4.8% for knee extension, 8.1% for trunk extension, 5.0% for trunk flexion and 5.0% for vertical jump. There were no systematic differences between the study groups in the CV of the measurements.

Statistical methods. Standard procedures were used to calculate means and standard deviations (SD). One-way analysis of variance was used to assess the differences between the groups studied. The significance of the differences between the means was localized with the least significant difference test. The statistical analyses were performed using a SPSS-X software package (Nie et al. 1975).

Results

The mean values for isometric muscle force in the four groups studied are shown in Figs. 1 and 2. When expressed in absolute terms, all the measured isometric forces were higher for the athletes than the controls and for the ST than the EN athletes. The SP group had significantly higher values in knee extension and trunk flexion than the EN group.

When the isometric muscle forces were related to lean body mass, significant differences still existed be-

Table 1. Age and anthropometric characteristics in strength (ST), speed (SP), and endurance (EN) trained athletes and control group

Variable	ST $n=14$ 1		SP $n=16$ 2		EN $n=67$ 3		Control $n=42$ 4		Anova F-value	Comparisons Least significant difference test				
	mean	SD	mean	SD	mean	SD	mean	SD		1, 2	1, 3	1, 4	2, 4	3, 4
Age (years)	74.3	2.9	75.5	3.8	73.7	2.7	74.2	2.8	1.58					
Height (cm)	174.3	5.9	169.8	6.3	170.6	6.5	169.1	6.6	2.36			**		
Body mass (kg)	82.4	12.5	69.4	12.0	69.3	8.6	76.3	12.0	8.40***	***	***		*	**
Body mass index	27.0	2.9	24.1	3.7	23.8	2.6	26.7	3.8	9.77***	*	***		**	***
Body fat (%)	24.5	5.1	20.4	5.8	20.3	4.8	25.7	5.2	11.26***	*	**		***	***
Lean body mass (kg)	61.8	6.8	54.8	6.7	55.0	5.4	56.2	6.3	5.18**	***	**	**		

* $P<0.05$, ** $P<0.01$, *** $P<0.001$

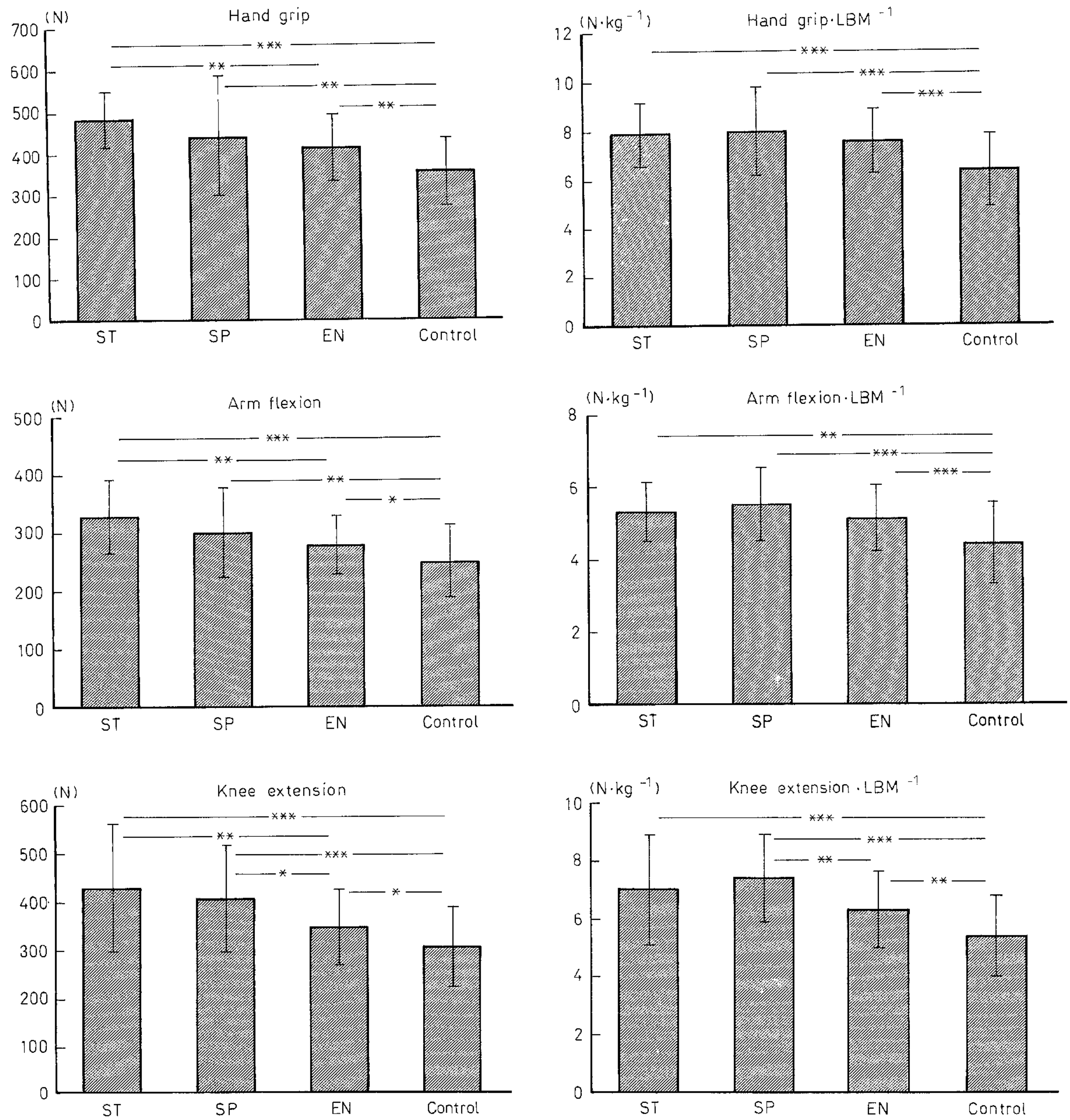

Fig. 1. Isometric muscle force and force related to lean body mass (*LBM*) for hand grip, arm flexion, and knee extension in strength (ST, $n=14$), speed (SP, $n=16$), and endurance (EN, $n=67$) trained athletes and a control group aged 70–81 years ($n=41$). Means and SD are given. * $P<0.05$, ** $P<0.01$, *** $P<0.001$

tween the athletes and the controls. However, the differences between the ST and EN groups diminished. Knee extension and trunk flexion were higher for the SP than the EN athletes.

The elevation of the body's centre of gravity in the vertical jump was also higher for the athletes than the controls (Fig. 3). The SP group jumped higher than either the ST or EN group.

Discussion

There is increasing evidence of the positive effects of physical training on muscle performance in the elderly (Aniansson and Gustafsson 1981; Larsson 1982; Era 1988; Suominen et al. 1989; Fiatarone et al. 1990). Good neuromuscular performance is associated with the ability to cope with the activities of daily living and reduced risk of falls (Wickham et al. 1989; Era 1990; Fiatarone et al. 1990). The athletes of the present study who were active at over 70 years of age performed better in all the strength tests than the average male population of the same age.

In this study, it was possible to compare older athletes from different sports. As expected, the strength and speed trained athletes achieved the best results in the isometric muscle strength measurements. Although an earlier study among middle-aged men had shown the endurance athletes to have similar muscle strength to that of the population sample (Suominen et al. 1989),

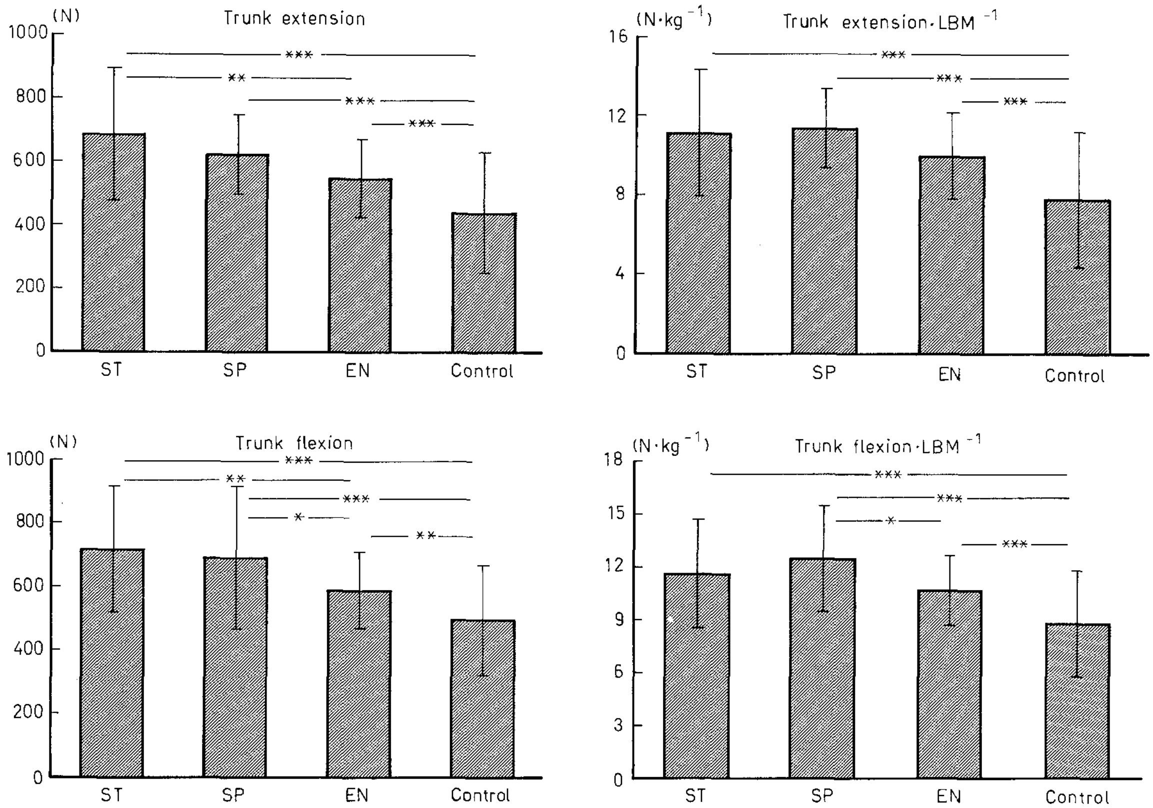

Fig. 2. Isometric muscle force and force related to lean body mass (*LBM*) for trunk extension and flexion in strength (ST, $n=14$), speed (SP, $n=16$), and endurance (EN, $n=67$) trained athletes and a control group aged 70–81 years ($n=40$–41). Means and SD are given. * $P<0.05$, ** $P<0.01$, *** $P<0.001$

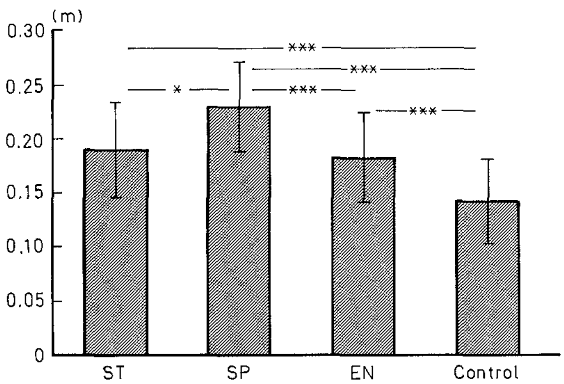

Fig. 3. Height of the elevation of body's centre of gravity during vertical jump with counter movement in strength (ST, $n=12$), speed (SP, $n=16$), and endurance (EN, $n=66$) trained athletes and a control group aged 70–81 years ($n=30$). Means and SD are given. * $P<0.05$, ** $P<0.01$, *** $P<0.001$

the present study showed the athletes involved in endurance training to have above average muscle strength. When the isometric force values were related to lean body mass, there were hardly any differences between the athlete groups. It is possible that sport events such as long-distance running and cross-country skiing are intensive enough to preserve the requisite motor control and muscle structure and thus counteract the changes observed in muscle performance in the average population after age 70 years. The results for muscle strength are in agreement with those of muscle ultrasonography performed on a smaller subgroup of the subjects (Sipilä and Suominen 1991). An indication of a higher fat-free mass together with firmer fasciae and connective tissue septa but less "infiltrated" connective tissue and fat in the quadriceps muscle group was obtained for both the strength/speed and endurance athletes.

The difference between the groups of athletes might have been more pronounced had the athletes' training been more specifically and intensively directed towards the specific sport events characteristic of younger athletes in competitive sports. As described in the Methods, some of the strength and speed athletes also participated in endurance activities and it was also typical of the endurance athletes to do home gymnastics, which may also have helped to maintain muscle strength.

On the other hand, the elevation of the body's centre of gravity in the vertical jump clearly reflected different training backgrounds. The sprinters and jumpers whose sport events are more explosive in nature were able to jump significantly higher than all the other subjects. It was also advantageous for them not to have excess body mass. The speed and endurance athletes were equal in body mass and lean body mass but the speed athletes were significantly better, however, in the jumping test.

In conclusion, the results of the present study showed that the athletes having a long-term history of training in both strength/speed and endurance have superior muscle functioning compared to the average male population of the same age. The strength and speed athletes generally showed the highest muscle strength in absolute terms but the endurance athletes also preserved excellent strength characteristics related to body mass. Although the differences between the athletes and controls in a cross-sectional study of the present type may also have reflected innate differences in muscle strength (Pérusse et al. 1987), which in turn may have contributed to the higher level of activity maintained by the athletes, the results indicated that physical training should be taken into account when studying age-related changes in skeletal muscles.

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References

Aniansson A, Gustafsson E (1981) Physical training in elderly men with special reference to quadriceps muscle strength and morphology. Clin Physiol 1:87–98

Aniansson A, Hedberg M, Henning G-B, Grimby G (1986) Muscle morphology, enzymatic activity and muscle strength in elderly men: a follow-up study. Muscle Nerve 9:585–591

Bosco C, Luhtanen P, Komi P (1983) A simple method for measurement of mechanical power in jumping. Eur J Appl Physiol 50:273–282

Dannenskiold-Samsoe B, Kofod V, Munter J, Grimby G, Schnohr P, Jensen G (1984) Muscle strength and functional capacity in 78–81 year-old men and women. Eur J Appl Physiol 52:310–314

Durnin JVCA, Womersley J (1974) Body fat assessed from total body density and its estimation from skinfold thickness: measurement on 481 men and women aged from 16 to 72 years. Br J Nutr 32:77–79

Era P (1988) Posture control in the elderly. Int J Technol Aging 1:166–179

Era P (1990) Assessing neuromuscular functional capacity in the elderly (1990) ICSSPE, International Council of Sport Science and Physical Education, workshop on fitness tests (abstract). Tampere. Available from UKK Institute, Tampere, Finland, p 39

Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ (1990) High-intensity strength training in nonagenarians. JAMA 263:3029–3034

Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, Evans WJ (1988) Strength conditioning in older men: skeletal muscle hypertrophy and improved function. J Appl Physiol 64:1038–1044

Komi PV, Bosco C (1978) Utilization of stored elastic energy in leg extensor muscles by men and women. Med Sci Sports 10:261–265

Kuta I, Parizkova J, Dycka J (1970) Muscle strength and lean body mass in old men of different physical activity. J Appl Physiol 29:168–171

Larsson L (1978) Morphology and functional characteristics of the ageing skeletal muscle in man. Acta Physiol Scand [Suppl] 457:1–37

Larsson L (1982) Physical training effects on muscle morphology in sedentary males at different ages. Med Sci Sports Exerc 14:203–206

Lexell J, Henriksson-Larsen K (1983) Distribution of different fiber types in human skeletal muscles: effects of aging studied in whole muscle cross section. Muscle Nerve 6:588–595

Lexell J, Taylor C, Sjöström M (1988) What is the cause of ageing atrophy? Total number, size and proportion of different fiber types studied in whole vastus lateralis muscle from 15- to 83-year-old men. J Neurol Sci 84:275–294

Montoye HJ, Lamphiear DE (1977) Grip and arm strength in males and females, age 10 to 69. Res Q 48:109–120

Moritani T, DeVries H (1980) Potential for gross muscle hypertrophy in older men. J Gerontol 35:672–682

Murray MP, Duthie EH, Gambert SR, Sepic SB, Mollinger LA (1985) Age-related differences in knee muscle strength in normal women. J Gerontol 40:275–280

Nie NH, Hull CH, Jenkins JG, Steinbrenner K, Bent DH (1975) Statistical package for social sciences. McGraw-Hill, New York

Pérusse L, Lortie G, Leblanc C, Tremblay A, Thériault G, Bouchard C (1987) Genetic and environmental sources of variation in physical fitness. Ann Hum Biol 14:425–434

Rikli R, Busch S (1986) Motor performance of women as a function of age and physical activity level. J Gerontol 41:645–649

Sipilä S, Suominen H (1991) Ultrasound imaging of the quadriceps muscle in elderly athletes and untrained men. Muscle Nerve 14:527–533

Suominen H, Heikkinen E, Liesen H, Michel D, Hollmann W (1977a) Effects of 8 weeks' endurance training on skeletal muscle metabolism in 56–70-year-old sedentary men. Eur J Appl Physiol 37:173–180

Suominen H, Heikkinen E, Parkatti T (1977b) Effects of eight weeks' physical training on muscle and connective tissue of the m. vastus lateralis in 69-year-old men and women. J Gerontol 32:33–37

Suominen H, Heikkinen E, Parkatti T, Forsberg S, Kiiskinen A (1980) Effects of "lifelong" physical training on functional aging in men. Scand J Soc Med [Suppl] 14:225–240

Suominen H, Rahkila P, Era P, Jaakkola L, Heikkinen E (1989) Functional capacity in middle-aged male endurance and power athletes. In: Harris R, Harris S (eds) Physical activity, aging and sport, vol 1. Scientific and medical research. Center for the Study of Aging, Albany, pp 213–218

Vandervoort AA, Hayes KC (1989) Plantar flexor muscle function in young and elderly women. Eur J Appl Physiol 58:389–394

Viitasalo J, Komi P, Karvonen MJ (1977) Physical health and performance capacity, and physical activity habits in conscripts in the beginning of service at Air Force Communications School. Research Reports from the Department of Biology of Physical Activity no. 22, University of Jyväskylä

Viitasalo J, Era P, Leskinen A-L, Heikkinen E (1985) Muscular strength and anthropometry in random samples of men aged 31–35, 51–55 and 71–75 years. Ergonomics 28:1563–1574

Viljanen T, Kujala U, Viitasalo J (1990) Isometric trunk extension and flexion strength of Finnish urban women and men aged 25–55-years. In: Telama R, Laakso L, Pieron M, Ruoppila I, Vihko V (eds) Physical education and life-long physical activity. Reports of Physical Culture and Health no. 73, Jyväskylä, pp 550–559

Wickham C, Walsh K, Cooper C, Parker D, Margetts B, Morris J, Bruce S (1989) Dietary calcium, physical activity, and risk of hip fractures: a prospective study. Br Med J 299:889–892