Muscle CSA, Force Production, and Activation of Leg Extensors During Isometric and Dynamic Actions in Middle-Aged and Elderly Men and Women


Forty-two healthy men and women in two age groups (40 and 70 years) were examined for muscle cross-sectional area (CSA), maximal voluntary bilateral isometric force, force-time characteristics, maximal concentric 1 RM, and power performance of the leg extensors in a sitting position, squat jump, and standing long-jump. The results suggested that the decline in maximal strength with increasing age is related to the decline in muscle CSA; however, particularly in older women, the force/CSA ratio may also be lowered. Explosive force seems to decrease with increasing age even more than maximal strength, suggesting that muscle atrophy with aging is greater in fast-twitch fibers. The voluntary activation of the agonist and antagonist muscles seems to vary depending on the type of muscle action and/or velocity and time duration of the action in both age groups but to a greater extent in older people. There appears to be an age-related increase in antagonist coactivation, especially in dynamic explosive movements.

Key Words: aging, muscle atrophy, muscle strength, explosive force, activation, agonists, antagonists

It has been well documented that muscle mass and strength decline with increasing age, especially after age 50 (Doherty, Vandervoort, Taylor, & Brown, 1993; Frontera, Hughes, Lutz, & Evans, 1991; Häkkinen, Pastinen, Karsikas, & Linnamo, 1995; Häkkinen et al., 1996b; Larsson, 1978; Narici, Bordini, & Cerretelli, 1991; Vandervoort & McComas, 1986; Viitasalo, Era, Leskinen, & Heikkinen, 1991...
1985; Young, Stokes, & Crowe, 1984). These age-related declines are not surprising, since aging is associated with alterations in hormone balance (e.g., Håkkinen & Pakarinen, 1993) and often also with a decline in the quantity and intensity of physical activity (e.g., Mälkiä, Impivaara, Heliövaara, & Maatela, 1994). The age-associated decline in muscle mass is thought to be mediated by a reduction in the size and/or number of individual muscle fibers, especially fast-twitch fibers (Aniansson, Grimby, Hedberg, & Krotkiewski, 1981; Essen-Gustavsson & Borges, 1986; Larsson, Sjödin, & Karlsson, 1978; Lexell, Henriksson-Larsén, Winblad, & Sjöström, 1983; Lexell, Taylor, & Sjöström, 1988; Porter, Myint, Kramer, & Vandervoort, 1995). The rate of decline of explosive strength appears to be even greater than that of maximal strength, whether determined using dynamic actions (Bassey & Harries, 1987; Bassey et al. 1992; Bosco & Komi, 1980; Larsson, Grimby, & Karlsson, 1979) or as a slowing of the maximal rate of isometric force production (Clarkson, Kroll, & Melchionda, 1981; Håkkinen & Håkkinen, 1991; Håkkinen et al., 1995, 1996b; Vandervoort & McComas, 1986). Muscle strength and the ability of the leg extensor muscles to develop force rapidly are important factors contributing to the successful performance of several tasks of daily life such as climbing stairs, walking, and prevention of falls and trips (Bassey et al., 1992).

Whether age-related decreases in maximal and/or explosive strength are explained solely by structural changes in the muscle or to what extent decreased strength characteristics may also be associated with age-related changes in voluntary neural drive to the muscles is difficult to interpret conclusively (Håkkinen et al., 1995; Porter et al., 1995). Although some findings indicate that aging does not necessarily impair a person’s ability to maximally activate some muscle groups (Enoka, Fuglevand, & Barreto, 1992; Vandervoort & McComas, 1986), decreases in muscle mass, maximal strength, or explosive strength may vary between the different muscle groups (Håkkinen et al., 1995). Moreover, muscle activation may also differ in relation to age or sex depending on the type of muscle contraction, the complexity of motion, and time or velocity characteristics of action. It should also be within both scientific and practical interests to examine, in addition to activation of agonists, the extent to which antagonist coactivation during various isometric and dynamic actions may be influenced by aging and by gender.

The purpose of this study was therefore to examine age-related changes in muscle cross-sectional area, and maximal and explosive force production characteristics of the leg extensor muscles during various isometric and dynamic actions in middle-aged and elderly men and women. Second, we were especially interested in examining possible differences in the quantity of muscle activation between various maximal and explosive actions by recording electromyographic activity from not only the agonist but also the antagonist muscles.

Methods

SUBJECTS

Forty-two subjects volunteered for the study. They were divided into four different groups according to age and sex: 10 middle-aged men in the 40-year-old age group (M40) (mean age 42, range 39–45), 11 middle-aged women in the 40-year-old age group (W40) (mean age 39, range 35–45), 11 elderly men in the 70-year-old age
group (M70) (mean age 72, range 69–78), and 10 elderly women in the 70-year-old age group (W70) (mean age 67, range 62–71). The physical characteristics of the four subject groups are presented in Table 1. Each subject signed a written informed consent form prior to participation in the study. The study was conducted according to the declaration of Helsinki and was approved by the Ethics Committee of the University of Jyväskylä, Finland.

All subjects were healthy and habitually physically active. To keep fit they took part, on average two to three times a week, in various recreational physical activities such as walking, jogging, cross-country skiing, aerobics, and biking. The four groups did not differ with regard to the quantity of recreational physical activities performed. No data were recorded with respect to qualitative aspects such as the intensity of physical activities. However, none of the subjects had any background in regular strength training or competitive sports of any kind. The subjects were taking no medication that would have been expected to affect physical performance.

TESTING

The subjects were familiarized with the testing procedures for voluntary force production of the leg muscles during several submaximal and maximal performances a few days before the measurements. During the actual testing occasion, several warm-up contractions were performed prior to the maximal tests.

Dynamic explosive force characteristics of the leg muscles were measured on

| Table 1 Physical Characteristics of Middle-Aged (40 years) and Elderly (70 years) Men and Women |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|------------------|
| Variable                        | Men 40 years    | Men 70 years    | Women 40 years  | Women 70 years  | Significance     |
|                                | (n=10)          | (n=11)          | (n=11)          | (n=10)          | of differences   |
| Age (years) Mean               | 42              | 72              | 39              | 67              | W40/M40***       |
| SD                              | 2               | 3               | 3               | 3               | W70/M70**        |
| Body height (cm) Mean          | 178             | 172             | 163             | 159             | M40/M70*         |
| SD                              | 7               | 7               | 5               | 6               |                  |
| Body mass (kg) Mean            | 83              | 80              | 62              | 66              | W40/M40***       |
| SD                              | 15              | 10              | 8               | 7               | W70/M70***       |
| Body fat (%) Mean              | 19              | 24              | 26              | 34              | W40/M40***       |
| SD                              | 4               | 5               | 6               | 3               | W70/M70***       |
|                                |                 |                 |                 |                 | M40/M70*         |
|                                |                 |                 |                 |                 | W40/W70*         |

*p < .05. **p < .01. ***p < .001.
a force platform using a maximal vertical squat jump (SJ) (from a starting position of 90° knee flexion) and a standing long jump (SLJ). For the SJ, the height was calculated and power was analyzed from the vertical force–time curve. Bosco and Komi (1980) successfully used this test to examine elderly men and women. For the SLJ, distance was calculated using a tape measure. Three maximal jumps were recorded in both cases, and the best reading was used for further analysis. If needed (on rare occasions), one or two more jumps were recorded until the subject was unable to improve his or her performance.

Isometric force–time curves, maximal isometric force (MIF), and maximal rate of isometric force development (RFD) of the bilateral leg extensor muscles were measured on an electromechanical dynamometer similar to that reported earlier by Komi (1973). For this test, the subjects were in a sitting position so that the knee and hip angles were 107 and 110°, respectively. The subjects were instructed to exert maximal force as fast as possible during a period of 2.5 to 4.0 s. A minimum of three trials were completed for each subject, and the best performance trial with regard to maximal peak force was used for the subsequent statistical analysis. However, if needed (on rare occasions), one or two more test contractions were recorded until the subject was unable to improve his or her maximum, as described previously (e.g., Häkkinen & Häkkinen, 1991; Häkkinen et al., 1995). A David 210 dynamometer (David Fitness and Medical Ltd.) was used to measure maximal bilateral dynamic force production of the leg extensors. The subject was in a seated position so that the hip angle was 110°. On verbal command, the subject performed a concentric leg extension starting from a flexed position of about 70° trying to reach a full extension of 180° against the resistance determined by the loads chosen on the weight stack. In testing the maximal load, separate 1 RM (repetition maximum) contractions were performed. After each repetition, the load was increased until the subject was unable to extend the legs to the required position. The last acceptable extension with the highest possible load was determined as 1 RM (e.g., Häkkinen et al., 1996b).

Explosive force characteristics of the leg extensor muscles were also tested with the David 210 dynamometer using a load of 50% of each subject's 1 RM. In this case, the subjects were instructed to move the load as fast as possible. Two testing actions were recorded (but if needed, also a third trial was recorded), and the best reading (with the highest velocity) was taken for further statistical analyses.

In all tests of neuromuscular performance, strong external verbal encouragement was given for each subject. In all test conditions, the time between the maximal contractions was always 1.5 min.

The force signal was recorded on a computer (486 DX-100) and thereafter digitized and analyzed with a Codas TM computer system (Data Instruments, Inc.). Maximal peak force was defined as the highest value of the force (N) recorded during the bilateral isometric contractions. Force–time analysis on the absolute scale included the calculation of average force (N) produced from the different periods of 100 ms in duration from the start of the contraction up to 500 ms (Häkkinen, Komi, & Alen, 1985). The maximal rate of force development (RFD; N · s⁻¹) was also analyzed (Viitasalo, Saukkonen, & Komi, 1980). All of these variables have been used previously to evaluate force–time characteristics in middle-aged and elderly subjects (Häkkinen & Häkkinen, 1991; Häkkinen et al., 1995, 1996b).
Electromyographic (EMG) activity was recorded from the knee extension agonist muscles vastus lateralis (VL) and vastus medialis (VM) and from the antagonist muscle biceps femoris (BF) of the right and left legs separately during all the bilateral test actions. Bipolar (20 mm interelectrode distance) surface EMG recording (Beckman miniature-sized skin electrodes 650437, Illinois) was employed. The electrodes were placed longitudinally on the motor point areas determined by an electrical stimulator (Disa). EMG signals were recorded telemetrically (Glonner, Biomes 2000). Thereafter, the EMG signal was amplified (by a multiplication factor of 200, cut-off frequency 360 Hz 3dB -1) and digitized at the sampling frequency of 1000 Hz by an on-line computer system. EMG was full-wave rectified, integrated (IEMG), and expressed for 1 s for each muscle separately using a custom computer program. EMG was also integrated (EMG for 1 s) in the isometric actions for the periods of 100 ms up to 500 ms to obtain an IEMG time curve from the start of the contraction and for the maximal peak force phase of the isometric contractions (500–1,500 ms) to calculate maximal IEMG (Häkkinen et al., 1985). In the concentric actions of the 1 RM and with the 50% load, as well as in both jumping performances, the integration (EMG for 1 s) was performed for the entire range of motion. The average IEMG values of the agonist and antagonist muscles were calculated separately for each muscle for both the right and left legs. To record the maximum voluntary IEMG of the biceps femoris muscle acting as an agonist, the subjects were tested for maximal isometric knee flexion for both the right and left legs. A minimum of two maximal isometric knee flexion actions were recorded for both legs, and the highest IEMG value recorded for the right and the left biceps femoris muscle was taken for further analysis.

The cross-sectional area (CSA) of the quadriceps femoris (QF) muscle group (rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius) was measured with a compound ultrasonic scanner (Aloka FANSONIC, SSD-190) and a 5-MHz convex transducer. The CSA was measured at the lower third portion between the greater trochanter and lateral joint line of the knee. Two consecutive measurements were taken from the right thigh and then averaged for further analyses. The CSA of the QF was then calculated (Ryushi, Häkkinen, Kauhanen, & Komi, 1988). The percentage of fat in the body was estimated from the measurements of skinfold thickness (Durnin & Womersley, 1967).

**STATISTICAL METHODS**

Standard statistical methods were used to calculate means, standard deviations (SD), standard errors (SE), and Pearson product moment correlation coefficients. The data were then analyzed using analysis of variance (ANOVA). Probability adjusted t tests were used for pairwise comparisons when appropriate. The p < .05 criterion was used to establish statistical significance.

**Results**

The mean (±SD) value of 53.6 ± 4.7 cm² for the CSA of the QF in M40 was greater (p < .001) than that for M70 and also greater (p < .001) than that for W40, while the value of 33.7 ± 3.3 cm² in W70 was clearly the smallest (p < .001) (Figure 1).
The maximal bilateral voluntary isometric leg extension force of $2387 \pm 353$ N in M40 was greater ($p < .01$) than that recorded for M70 and greater ($p < .01$) than that for W40 (Figure 2a). The lowest value of $997 \pm 437$ N was recorded for W70.

The maximal bilateral concentric leg extension 1 RM values differed also in a similar way between the subject groups, so that the loads in M40 were greater ($p < .01$) than in M70 and in W40 were greater ($p < .01$) than in W70 (Figure 2b). The maximal 1 RM value in M40 was also much greater ($p < .001$) than in W40 and in M70 much greater ($p < .001$) than in W70.

The individual values of the CSA of the QF correlated significantly ($p < .05$) with the corresponding individual values of maximal leg extension 1 RM values both in women ($r = .64$ and .56 for W40 and W70) and in men ($r = .56$ and .76 for M40 and M70). These individual values are plotted together for the whole sample of women (W40 + W70, $r = .73$, $p < .001$) and for all men (M40 + M70, $r = .80$, $p < .001$) in Figures 3a and 3b. The individual values of the CSA correlated in a similar way also with the individual values of maximal isometric leg extension force for all men ($r = .75$, $p < .001$), while the corresponding correlation coefficient was lower for all women ($r = .36$, NS).

The maximal bilateral 1 RM values per CSA of the QF were $3.19 \pm 0.41$, $2.87 \pm 0.45$, $3.02 \pm 0.46$, and $2.61 \pm 0.42$ kg $\cdot$ cm$^2$ for M40, W40, M70, and W70, respectively ($p < .05$ for M70 vs. W70). The maximal bilateral isometric force values per CSA of the QF were $44.60 \pm 5.91$, $30.71 \pm 14.44$, $40.55 \pm 10.56$, and $29.84 \pm 13.10$ N $\cdot$ cm$^2$ for M40, W40, M70, and W70, respectively ($p < .01$ for M40 vs. W40 and $p < .05$ for M70 vs. W70).

The jumping height in SJ and the distance in SLJ differed between the groups, such that both values were greater ($p < .001$) in M40 than in M70 and greater ($p < .001$) in W40 than in W70 (Figure 4). These values were also greater ($p < .01$ and .001) in M40 than in W40 and greater ($p < .05$ and .001) in M70 than in W70.

The shapes of the average bilateral isometric force–time curves in absolute values differed also between the groups. Both maximal RFD and the force produced during the early (up to 500 ms) portions of the curve were greater in M40 ($p < .05$ and .01) than in M70 and slightly greater in W40 (NS) than in W70 (Figure 5). The
Figure 2. Mean (±SE) maximal voluntary bilateral isometric force (a) and bilateral concentric 1 RM (b) of the leg extensor muscles in middle-aged (40 years) and elderly (70 years) men and women (**p < .01, ***p < .001).

differences in these values between M40 and W40 as well as between M70 and W70 were also significant (p < .05-.001).

In both older groups, maximal strength correlated significantly (p < .05-.01) with dynamic explosive force values (1 RM with SLJ in W70, r = .58, and in M70, r = .73; and 1 RM with SJ in M70, r = .78, and MIF with SJ in M70, r = .54). Also, in both older groups maximal strength correlated significantly (p < .05-.001) with explosive isometric force values (MIF with RFD in M70 and W70, r = .67 and r = .79; 1 RM with RFD in M70 and W70, r = .59 and r = .65; MIF with F500 and 1 RM with F500 in M70, r = .80 and .97 and r = .67 and .68, respectively). In the total sample of subjects, explosive isometric force values correlated significantly (from r = .55 to .71, p < .001) with explosive dynamic force production values.

Figure 6 presents the maximum IEMG activity of the vastus lateralis muscle in the jumping performances of SJ and SLJ, during the maximal bilateral isometric and maximal concentric 1 RM actions, during the explosive isometric action of force produced in 500 ms, and during the concentric power performance with the 50% load of the 1 RM performance. In W40 + M40, the IEMG values did not differ significantly between the first five actions, while the IEMG during the power performance with the 50% load was much lower (p < .001) than those recorded during the other actions both in the right and left leg. The corresponding IEMG values in W40 + M40 during the power performance were also the lowest (p < .001) for the vastus medialis muscle of both legs. In W70 + M70, the IEMG of the vastus
lateralis during the power performance was also the lowest ($p < .01$ and $p < .001$) for both the right and left legs. However, the IEMGs in SLJ, maximal isometric 1 RM, maximal concentric 1 RM, and explosive isometric action were also lower ($p < .05$–$p < .001$) than in SJ for the right and/or left leg. The corresponding IEMG results of the vastus medialis muscle in W70 + M70 were similar to those recorded for the vastus lateralis for both the right and left leg.

The IEMGs in the antagonist muscle of the biceps femoris during the agonist actions were from 20 to 40% of the maximal voluntary IEMG of the biceps femoris recorded during the maximal isometric knee flexion (Figure 7). The antagonist IEMG values during the maximal 1RM and power performances were greater ($p < .05$–$p < .001$) than the corresponding antagonist activation recorded during the isometric actions for both in W40 + M40 and in W70 + M70.

### Discussion

The present study was conducted using a limited number of subjects, but the strength data in Figures 2a and 2b support the concept of an age-related decrease in maximal strength. Maximal bilateral isometric force of the leg extensor muscles in M70 was 25% lower than in M40 and in W70 was 26% lower than in W40. The
differences in the maximal bilateral concentric leg extension 1 RM performance between the two age groups were also of about the same magnitude. As one could expect, the two male groups differed clearly from the two female groups in absolute strength, in both isometric and concentric strength actions, with the bilateral strength values of W40 of 57% and 66% of M40 and W70 exhibiting 56% and 67% of the strength values recorded for M70, respectively. These values are very consistent with male–female strength comparisons reported earlier for younger (Laubach 1976), middle-aged, and elderly subjects (Häkkinen et al., 1996b; Mäkkiä, 1993), indicating that aging does not appear to alter this relationship.

The results presented in Figure 1 indicate an age-related loss of muscle mass, with the CSA of QF muscle in M70 clearly smaller than in M40 and the CSA of W70 also much smaller than in W40. The differences in the CSA between the genders of the same age groups were also remarkable. The individual values of the CSA of the QF correlated significantly with the corresponding individual values of maximal bilateral strength in the total group of men and women (Figures 3a and 3b). These findings support the concept that the decrease in muscle mass with increasing age is accompanied by a parallel decline in maximal strength in both men and women. However, the correlation coefficient between the CSA and maximal 1 RM was somewhat lower in the total group of women, especially in the older women. Furthermore, when the individual values of maximal force were related to the individual values of the CSA, the force per CSA in the women was significantly lower than in the men, with W70 exhibiting the lowest values.
Figure 5. Mean (±SE) maximal voluntary rate of force development and mean (±SE) voluntary explosive force produced in 500 ms of the bilateral isometric leg extension action in middle-aged (40 years) and elderly (70 years) men and women (*p < .05, **p < .01, ***p < .001).

These findings indicate that in addition to a decrease in muscle mass, a decline in maximal strength, especially in older women, might also be due in part to a decrease in maximal voluntary neural input to the muscles and/or in "qualitative" characteristics of the muscle tissue itself (Häkkinen & Häkkinen, 1991; Häkkinen et al., 1996b; Ryushi et al., 1988). However, it is possible that the amount of intramuscular fat and connective tissue may reduce the validity of the ratio between muscle CSA and force in women, especially in older women. Second, the present results should be treated with caution, because the force recorded did not exactly represent the contribution of the knee extensor muscles alone but also the other muscles involved with bilateral extension of the lower extremities. Furthermore, CSA was measured only for the right leg. Nevertheless, the results do not exclude the possibility that in addition to age-related muscle atrophy, a decrease in muscle strength in aging may be accompanied by a decrease in voluntary neural drive to the muscles (Häkkinen et al., 1995, 1996b).

Aging is known to be associated with decreases in the ability of the neuromuscular system to produce force rapidly so that the decline in explosive strength seems to take place to an even greater degree than the decline in maximal strength of the same muscle group. The values recorded for the heights in SJ and the distances in SLJ shown in Figure 4 indicate that dynamic explosive force production of the lower extremities decreases greatly in aging people, both men and women. The mean
Figure 6. Mean (±SE) integrated electromyographic activity (IEMG in relative [%] values) for the vastus lateralis muscle of the right and left leg during the dynamic explosive performances of SJ and SLJ, maximal voluntary bilateral isometric force and concentric 1 RM actions, maximal voluntary explosive bilateral isometric action (force produced in 500 ms), and the power performance with a load of 50% of 1 RM in a total group of middle-aged (40 years) women and men and in a total group of elderly (70 years) women and men (*p < .05, **p < .01, ***p < .001).
values in SJ for W70 were as much as 53% lower than those for W40, and for M70 were 46% lower than for M40. Similarly, in SLJ the mean values for W70 were 41% lower than for W40, and for M70 34% lower than for M40. These differences in dynamic explosive strength capability were much greater than the differences observed in maximal strength between the present age groups of both genders.

Although no muscle biopsy samples were taken in the present study, the findings support the concept that age-related decreases in explosive dynamic and isometric strength actions may be explained, especially at older ages, by selective atrophy and/or a loss of fast-twitch muscle fibers (Essen-Gustavsson & Borges, 1986; Lexell et al., 1983, 1988). However, the present data do not exclude the possibility that the maximal rate of voluntary neural activation of the muscles may also decrease with increasing age (Häkkinen et al., 1995). The latter phenomenon has been suggested to take place especially with regard to rapid activation of the leg extensor muscles during isometric actions (Häkkinen et al., 1995). The present findings in Figure 6 support this suggestion, since the IEMG in W70 + M70 during
the first 500 ms of the rapid isometric action was lower than in the strength performances or in SJ.

The correlational data also suggest that, in the older groups, a low level of maximal strength (both isometric and concentric) may be related to a reduced capacity for explosive force production, whether determined isometrically or dynamically. In the middle-aged groups, the corresponding correlation coefficients were lower than those calculated for the older groups. When the data of all groups were combined, the correlation coefficients between explosive isometric and explosive dynamic actions reached a statistically significant level.

We were especially interested in examining possible age- and gender-related differences in activation of agonist and antagonist muscles during various dynamic and isometric actions. The EMG data presented in Figure 6 show that, in the middle-aged subjects, the quantity of neural activation of the agonist muscles was about the same in all of the dynamic and isometric actions except for the power performance with the load of 50% of 1 RM, in which lower IEMG values were recorded in comparison to the other performances. The elderly groups demonstrated the lowest IEMG values in this power performance. It is unclear to what extent this finding in both age groups could be partially explained by the submaximal load itself or by the “unnatural” sitting position used to produce explosive bilateral leg extension movements. The finding may also be explained, in part, by the changing conditions in the force/knee angle relationship contributing to the load becoming more submaximal throughout the extension in comparison to the beginning of the extension.

In contrast to the middle-aged groups, both elderly groups demonstrated the second lowest muscle activation levels in the rapid isometric action. As suggested, this finding indicates that the ability for rapid recruitment of motor units may decrease with increasing age, at least during the bilateral isometric action of the leg extensor muscles (Häkkinen et al., 1995). The data in Figure 6 also show that in SLJ, the elderly groups produced lower IEMG values than the middle-aged subjects. These findings indicate that the amount of skill and motor coordination required to perform the SLJ may also be influenced by the aging process and by possible differences in the history of physical activity between older and younger people. On the other hand, all subject groups produced rather high EMG activity in SJ. This finding is consistent with previous observations of younger adults (Viitasalo, 1984) and of athletes (Häkkinen, Komi, & Kauhanen, 1986), in which a high contribution of motor units was needed to produce sufficient force to raise the body from an almost seated position with subsequent explosive force production of the lower extremity muscles in order to reach the highest possible jumping height. Therefore, it seems possible to reach higher muscle activation during the SJ performance than during various other explosive or maximal dynamic and/or isometric actions independent of age and gender. Because no IEMG/force ratios were recorded, we cannot determine the extent to which the actions studied differed possibly with regard to muscle action efficiency.

The EMG data showed that activation of the antagonist (flexor) muscles during the corresponding agonist action (extensors) ranged in both age groups, in general, between 20 and 40% of the maximal muscle activity. This finding is consistent with the presence of an inhibitory mechanism to protect the musculoskeletal system from injury when the muscles become fully activated (Eloranta & Komi, 1981; Westing, Cresswell, & Thorstensson, 1991). However, during the
dynamic actions studied (1 RM and power), the IEMGs of the antagonists were significantly higher than during the isometric actions. Second, in the power performance in the elderly groups, antagonist muscle activity was greater than that recorded for the middle-aged groups. These results indicate that the degree of coactivation of the antagonist may be increased by aging, which may limit the full force production potential of the agonist muscles, especially in dynamic explosive types of movements requiring rapid neural activation of the lower extremity muscles.

In summary, the present findings indicate that the decline in maximal strength with increasing age, both in men and women, seems to be related to the decline in the CSA of the muscle, while in older women the force/CSA ratio may also be lowered. The finding that explosive force production of the neuromuscular system decreases with increasing age even more than maximal strength indicates that the atrophying effect of aging may be greater on fast-twitch fibers and/or that the rate of rapid neural activation of the muscles may also be influenced by aging. Activation of the agonist and antagonist muscles seems to vary depending on the type of muscle action, the velocity, or the time duration of the action in question in both middle-aged and older people of both genders. Finally, there is an age-related increase of antagonist coactivation especially during dynamic explosive types of movements.

References


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