Chronic exercise and skeletal muscle power in older men

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Abstract: We sought to determine the effects of age and chronic exercise on muscle power in older males. We examined 32 older males 60–74 years of age and grouped as sedentary (CON, n = 11), chronic endurance trained (ET, n = 10), and chronic endurance trained + resistance training (ET + RT, n = 11). Exercise history was obtained by questionnaire. Absolute strength and power measures were obtained by the one-repetition maximum method. Relative strength and power were determined by dividing the absolute measure by the muscle mass involved in the exercise. Total and regional muscle mass was measured by DXA. Absolute and relative leg power were not significantly different among the 3 groups. In contrast, absolute leg press strength was greater in ET + RT compared with CON, and relative leg press strength was greater in ET and ET + RT compared with CON. Chronic running combined with resistance training may therefore enhance absolute and relative muscle strength in older adults, but does not influence muscle power. Endurance exercise may inhibit the ability of resistance exercise to positively influence skeletal muscle power.

Key words: aging, strength, running, resistance training.

Résumé : Pour établir les effets de l'âge et de l'exercice physique assidu sur la puissance musculaire d'hommes âgés, les auteurs ont évaluée 32 hommes âgés de 60 à 74 ans et répartis en trois groupes : sédentaire (CON, n = 11), endurance chronique (ET, n = 10), et endurance chronique + entraînement à la force (ET + RT, n = 11). Un questionnaire permet de préciser le vécu sportif. Les auteurs obtiennent les mesures de force absolue et de puissance par le maximum sans répétition (1RM). Les mesures relatives de force et de puissance sont obtenues en divisant les dernières par la masse musculaire impliquée dans l'exercice. Les masses musculaires totale et régionale sont obtenues par absorptiométrie biénergétique à rayons X (DXA). Les puissances absolue et relative de la jambe ne diffèrent pas d'un groupe à l'autre. Par contre, la charge levée au développé des jambes est plus lourde dans le groupe ET + RT comparativement au groupe CON et la charge relative levée est plus lourde dans les groupes ET et ET + RT comparativement au groupe CON. L'activité assidue de course combinée à celle de la force musculaire peut améliorer les forces musculaires absolue et relative mais n'a pas d'effet sur la puissance musculaire. L'activité physique d'endurance peut inhiber les effets de l'exercice de force sur l'amélioration de la puissance musculaire.

Mots clés : vieillissement, force musculaire, course, entraînement à la force.

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Introduction

With advancing age, a gradual loss of skeletal muscle mass results in diminished strength and, to a greater extent, power (Pearson et al. 2002; Malbut-Shennan and Young 1999). This condition, referred to as sarcopenia, impairs physical function and contributes to frailty (Marcell 2003; Volpi et al. 2004). There is tremendous interest in the role that chronic exercise can play in reducing the effect of sarcopenia, including identifying the exercise mode(s) stimulating adaptation in skeletal muscle function (Hawkins et al. 2003). Whereas chronic resistance exercise clearly provides the greatest stimulus to muscle strength in older adults (Pearson et al. 2002; Klitgaard et al. 1990), there is accumulating evidence that chronic endurance training is beneficial to muscle strength in this population (Tarpenning et al. 2004; Alway et al. 1996; Sipila et al. 1991). As many older adults choose chronic endurance training as their mode of

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exercise, these findings suggest important benefits not normally attributed to this training mode.

However, muscle power may be more important than muscle strength when performing activities of daily living such as rising from a chair, climbing stairs, or crossing a street (Miszko et al. 2003; Evans 2000). Leg muscle power has been shown to be a stronger predictor of functional status than maximal voluntary strength, muscle endurance, VO_2 peak, health status, or neuropsychological status in sedentary older women (Foldvari et al. 2000). In contrast to muscle strength, muscle power is diminished with endurance exercise in older adults due in part to properties inherent at the single fiber level (Widrick et al. 1996). Conversely, older strength-trained athletes demonstrate muscle power characteristics similar to young control subjects (Porter 2001; Klitgaard et al. 1990) and acute resistance exercise increases power in older adults (Hunter et al. 2004). Therefore, it may be advantageous for older endurance-trained individuals to include resistance exercise in their training program to enhance skeletal muscle power. However, to our knowledge there are no reports describing the effect of combined strength and endurance training on muscle power in older adults.

We evaluated sedentary and chronically physically active older males participating in either endurance running only or endurance running with resistance exercise for maximal bilateral leg press strength and maximal unilateral leg extension power. Values for muscle performance measures were expressed in absolute values and relative to the muscle mass of the limb(s) involved in producing the movement. We hypothesized that chronic endurance runners would not demonstrate greater skeletal muscle power than sedentary age-matched men, but that the addition of resistance training to their excercise regimen would enhance muscle power in chronic runners. The purpose of this investigation was to compare the effects of chronic endurance training alone or in combination with resistance training (RT) on muscle power in a group of active older men.

Materials and methods

Subjects

Thirty-two older adults (age range 60–74 y) were studied after providing informed written consent in accordance with the guidelines established by the Institutional Review Board of the University of Southern California Health Sciences Campus (Los Angeles, Calif.). The chronically active subjects (n = 21) were selected from a larger cohort of subjects participating in a 20 y longitudinal study previously described in Wiswell et al. (2001). The subset was selected based on age and complete data sets for muscle performance measures, body composition, and training histories. The sedentary subjects (n = 11) were age matched, healthy, community-dwelling older men participating in other studies in our laboratory. Reported values for the sedentary subjects reflect pretesting values (Table 1). The subjects were grouped according to physical activity: sedentary (CON), chronic endurance trained (ET), and chronic endurance trained + lower extremity RT (ET + RT).

Body composition assessment

Total-body 3-compartment (bone, fat, and lean mass) body composition was determined by dual-energy X-ray absorptiometry (DXA) during a whole-body scan using a Hologic QDR 1500 (Hologic, Inc., Bedford, Mass.). As the whole-body scan allows for regional assessment of body segments of interest, relative strength was expressed as a function of the right lower extremity (leg) lean mass for leg power and bilateral lower extremity (leg) lean mass for leg strength. A single member of the research team performed blinded analysis of the region of interest according to specifications of the manufacturer. Reproducibility of the whole-body scan equaled 0.8% between 10 repeat tests in the laboratory. The coefficients of variation for lean mass obtained by DXA were 0.1%, right lower extremity 2.0%, and bilateral lower extremity 1.7% in our laboratory.

Assessment of muscle performance

Before determination of muscle strength and power, subjects warmed up for 5 min on a cycle ergometer. Subjects were given a demonstration of proper form and were familiarized with the testing procedures for each test. Verbal encouragement was provided during each effort. Test order was randomized to reduce the influence of fatigue. The same investigator performed all muscle performance assessments.

Leg press strength

Bilateral leg strength was assessed by the one-repetition maximum (1RM) method in accordance with the National Strength and Conditioning Association's guidelines (Baechle et al. 2000), and was performed on a seated leg press using pneumatic resistance (Keiser Sport, Fresno, Calif.). Subjects were positioned with both feet firmly placed on the footplate and the seat adjusted to produce a knee flexion angle of 90°. Subjects were instructed to extend their knees through the full range of motion (i.e., from 90° of flexion to full extension and back) with control. Rest periods between each trial were 1 min and the highest value achieved was recorded in Newtons (N). The coefficient of variation for this device in our laboratory is less than 4%.

Leg press power

Right lower extremity leg press power was determined using a Bassey power rig (Bassey and Short 1990). This test was performed with the subject in the seated position, arms crossed over their chest, and the right foot placed on a footplate. The seat was positioned for each subject to achieve a starting position of 90° of knee flexion. The subjects were instructed to extend their knee as hard and as fast as possible. The push is transmitted by a lever and chain to spin a flywheel. Resistance to the movement is held constant by the gearing and along with velocity of the flywheel is used to calculate leg extensor power (Bassey and Short 1990). Attempts were made until each subject reached a maximum value as evidenced by their values diminishing upon repeated attempts. The highest value achieved was recorded as the maximum power in Watts (W). Peak power was achieved within 6–12 attempts. Rest periods between trials on this device were ≥ 30 s. The coefficient of variation for this device in our laboratory is 7.6%.

Table 1. Physical characteristics of subjects involved in the study.

	CON (n = 11)	ET (n = 10)	ET + RT (n = 11)
Age (y)	67.3±2.8	65.0±4.3	66.9±4.9
Height (cm)	175.9±4.0	174.7±4.7	170.9±5.9
Mass (kg)	82.6±8.3	72.0±5.0*	69.3±5.4*
Lean body mass (kg)	56.9±4.5	58.1±3.4	58.4±5.1
% body fat	27.5±4.4	16.6±3.9*	15.1±3.5*

Note: Data are presented as mean ± SD.
*Significantly different from CON at $p < 0.05$.

Relative strength and power

Each of the above muscle performance measures was divided by the lean mass for the limb(s) involved in the movement. For relative leg-press strength, N of force produced bilaterally was divided by bilateral leg lean mass. For relative leg press power, W of power produced by the right leg was divided by the right leg lean mass.

Exercise history

Subjects' exercise history was self-reported via questionnaire. Sedentary subjects were those that reported no vigorous physical activity within the previous 2 y, defined as no RT and no aerobic activities at intensities greater than 50% $VO_{2\ max}$. Chronic exercisers were asked to report the number of years they had been training, mode(s) of training, and, as all were runners, average number of kilometers run each week. Subjects that reported RT were asked to report the year they began RT, average number of days they performed RT per week over the past year, and a sample RT week during the previous year. Values were confirmed by oral interview at the time of testing.

Statistics

Data were analyzed using the Statistical Package for Social Sciences (SPSS for Windows, SPSS Inc., Chicago, Ill.) program, version 11.0. Data were analyzed by 1-way analysis of variance (ANOVA) to determine group differences for dependent variables. When a significant F value was noted, Tukey's post hoc analysis was performed to locate differences between groups for comparisons involving all 3 groups. Data are reported as mean ± SD. Significance was predetermined at the $p \leq 0.05$ level.

Results

Physical characteristics and exercise history are presented in Table 1. While no differences existed for age or body height, the sedentary subjects (CON) had significantly greater body mass ($F = 12.8$, $p < 0.05$) and percent body fat ($F = 31.1$, $p < 0.05$) compared with the 2 chronic exercise groups. However, neither total (Table 1) nor regional lean body mass (right leg LBM (9.3 ± 0.9) vs. (9.4 ± 0.7) vs. (8.5 ± 0.9) kg; bilateral leg LBM (18.3 ± 1.8) vs. (18.6 ± 1.4) vs. (17.2 ± 1.6) kg; CON vs. ET vs. (ET + RT), respectively) were significantly different between groups. Years of training (30.9 ± 9.6 vs. 31.4 ± 10.7 y), kilometers run per week (46.3 ± 23.4 vs. 38.8 ± 14.0 km), and number of run training days per week (4.9 ± 1.6 vs. 4.9 ± 1.4 days) were not significantly different between exercise groups (ET vs. (ET + RT), respectively). All subjects in ET + RT currently performed lower extremity RT at least once each week (2 subjects performed RT once each week, 4 subjects performed RT twice each week, 4 subjects performed RT three times each week, and 1 subject performed RT four times each week) and had participated in an RT program for greater than 1 y. Seven of the 11 subjects who participated in RT performed leg-extension exercises. Six subjects performed the leg curl, 4 subjects performed the squat, 2 performed the leg press, 2 performed the dead lift, and 1 performed the clean and jerk exercise. All subjects used 2 or more of the above exercises per workout, with RT programs consisting of 1–4 sets of between 6 and 12 repetitions.

Table 2. Absolute muscle strength and power.

	CON (n = 11)	ET (n = 10)	ET + RT (n = 11)
Leg press strength (N)	1334±218	1598±314	1711±364*
Leg press power (W)	235±41	226±58	231±28

Note: Data are presented as mean ± SD.
*Significantly different than CON, $p < 0.05$.

For muscle performance measures, absolute and relative leg press power (W) were not significantly different between groups (Table 2; Fig. 1). In contrast, absolute leg press strength (N) was significantly greater in ET + RT compared with CON ($F = 5.1$, $p < 0.05$) (Table 2). Moreover, relative leg press strength was significantly greater in ET and ET + RT compared with CON ($F = 9.4$, $p < 0.05$; Fig. 2).

Discussion

The most important finding from this study was that absolute and relative leg press power were similar in older adult men regardless of exercise history. Specifically, sedentary older men had the same ability to generate muscle power as older men who chronically endurance trained or supplemented chronic endurance training with RT. In contrast, older chronic runners who performed RT demonstrated greater absolute and relative leg press strength compared with sedentary older men.

We did not expect the long-term endurance runners who did not perform RT to have greater muscle power than sedentary controls. Chronic endurance exercise has been demonstrated to reduce power production at the single-fiber level in older men (Widrick et al. 1996), possibly because of impairment of anabolic hormonal status (Izquierdo et al. 2004). Moreover, endurance running does not alter the fiber type transition towards slow muscle with aging (Trappe et al. 1995). The preferential loss of type II fibers and fast myosin

Fig. 1. Mean ± SD. Relative leg press power was determined as right leg power (W) divided by right leg lean mass (kg).

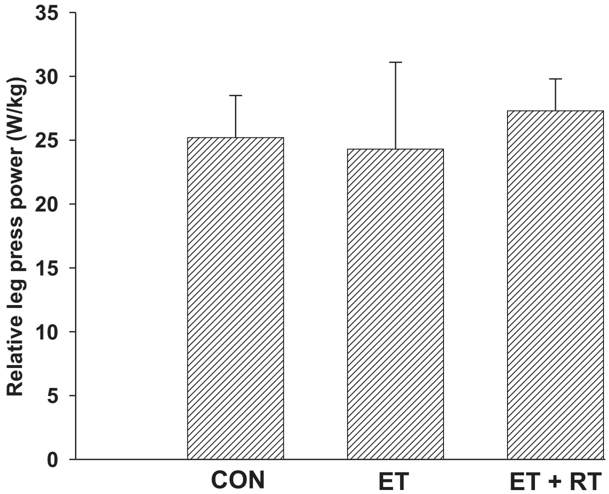
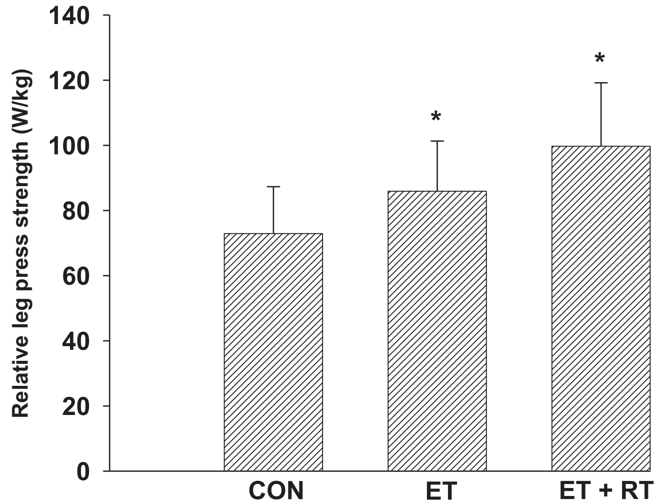


Fig. 2. Mean ± SD. Relative leg press strength was determined as bilateral leg force (N) divided by bilateral leg lean mass (kg). Asterisk indicates significant difference from CON at $p < 0.05$.



(Hameed et al. 2002; Lexell 1995) with aging explains the greater reduction in muscle power compared with muscle strength, as type II fibers are capable of producing 4 times greater power than type I fibers (Faulkner 1986). However, we expected that RT in addition to endurance training might lead to higher levels of muscle power in older men, as RT has been reported to enhance skeletal muscle power characteristics in this population (Trappe et al. 2000; Klitgaard et al. 1990). Preservation of muscle power with aging is of critical importance, as power has been demonstrated to be a key predictor of physical function in older adults (Evans 2000) and has been suggested to decline at twice the rate of muscle strength in healthy adults (Malbut-Shennan and Young 1999).

Several potential explanations exist for the lack of effect on muscle power observed in the RT athletes. It has been reported that RT must be high velocity to maximize the effect on muscle power in older adults (Fielding et al. 2002); in fact, several studies have reported that RT produced blunted or no effect on muscle power in older adults in spite of significant strength gains with training that did not appear high velocity (Skelton et al. 1995; Fiatarone et al. 1994). Perhaps the RT regimen undertaken by these athletes did not use high-velocity movements to enhance muscle power. Secondly, concurrent endurance training and RT has been suggested to impair strength development (Hunter et al. 2004) and, more importantly, rate of force development (Hakkinen et al. 2003) in older adults. Although concurrent training limited to 3 d/week does not appear to limit adaptations in muscle power (Hunter et al. 2004), our athletes averaged 5 d running/week; therefore, it is possible that functional responses in to the RT muscle were attenuated. In fact, we did not measure significant differences in muscle strength between the running groups, supporting the notion that chronic running of the frequency reported by our runners diminishes the training effect of RT.

A second important finding from our study was greater absolute strength in the runners who added RT to their training regimen compared with controls, as well as greater relative muscle strength in both groups of chronic exercisers compared with the sedentary men. RT would be expected to improve muscle strength in comparison with sedentary subjects, and several previous studies have reported improved absolute (Sipila et al. 1991) and relative (Tarpenning et al. 2004; Alway et al. 1996; Klitgaard et al. 1990) muscle strength in endurance-trained older men. Although this is not a universal finding in relation to endurance training (Harridge et al. 1997), improved muscle strength relative to lean body mass would provide a significant advantage in performing various functional movements (Barry and Carson 2004). These findings support others suggesting important benefits not normally attributed to endurance training (Tarpenning et al. 2004; Alway et al. 1996; Sipila et al. 1991; Klitgaard et al. 1990).

Our data support a previous contention that chronic exercise of any type has limited benefits for preservation of muscle power (Jones et al. 2004). However, this study cannot rule out the possibility that chronic RT alone could demonstrate different outcomes for muscle power in older men. Klitgaard et al. (1990) demonstrated that muscle characteristics reflecting power-generating capacity (maximal torque, speed of movement, myosin and tropomyosin isoforms) in older strength-trained subjects were identical to young controls. In addition, elite master weightlifters, while experiencing identical age-related decrements in muscle power compared with healthy controls, maintained an approximate 20 y advantage in absolute muscle power (Pearson et al. 2002).

Several limitations exist to these data. While we ensured that the sedentary subjects did not engage in any vigorous physical activity, we cannot rule out the possibility of regular moderate physical activity by these subjects. It is possible that participation in physical activity not traditionally classified as exercise (e.g., yard work, etc.) by our sedentary group might explain the finding of no differences in muscle power noted in this study. Additionally, we did not measure anabolic hormone concentrations in this study. Up to 1/3 of men over 60 y are clinically hypogonadal, defined as free T index less than 0.153 nmol/nmol (Harman et al. 2001). The muscle performance measures could be affected if the number of hypogonadal men varied among the 3 groups. Moreover, chronic endurance exercise has been correlated with reduced concentrations of total and free testosterone (Maimoun et al. 2003); if chronic exercise contributed to hypogonadism among our subjects, our measures of strength and power might be confounded.

In conclusion, chronic running combined with resistance training may enhance absolute and relative muscle strength in older men, but does not influence muscle power. Moreover, chronic running appears beneficial to relative muscle strength in older men. However, chronic endurance exercise may inhibit the ability of resistance exercise to positively influence skeletal muscle power in this population.

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