Training for Muscle Power in Older Adults: Effects on Functional Abilities

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Abstract/Résumé

The purpose of this study was to determine the influence of simple, progressive lower body exercise training, focusing on strength and power, on functional abilities in frail older adults. Twenty-five residents of a long-term care facility (75–94 yrs) participated in this randomized controlled trial of 10-wks duration. The exercise group (Ex, n = 18) underwent simple, progressive lower body resistance exercises, specifically aimed at improving muscle power, 3 times/wk; the control subjects (Con, n = 7) maintained their usual daily activities. Knee extensor strength and power were measured on an isokinetic dynamometer (180 °/s), and functional performance was assessed from a 6-m walk timed test, a 30-s chair stand, and an 8-ft up-and-go timed test, before and after the 10-wk intervention period. Significant increases were found in the Ex group for eccentric (44%) and concentric (60%) average power ($p < 0.05$), and improvements were seen on each functional test: the 8-foot up-and-go, chair stand, and walk time improved by 31%, 66%, and 33%, respectively ($p < 0.05$). No significant change occurred in the Con group. In conclusion, simple progressive exercise training, even in the 10th decade, increases muscle power and is associated with an improved performance of functional activities using the trained muscles.

Le but de cette étude est d'établir les effets d'un simple entraînement physique progressif du bas du corps sur les aptitudes fonctionnelles de personnes âgées et frêles; cet entraînement est constitué surtout d'exercices de force et de puissance. Vingt-cinq résidents d'un

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établissement de soins de longue durée (75 à 94 ans) sont répartis aléatoirement dans deux groupes. Le groupe expérimental (Ex, n = 18) s'entraîne à améliorer sa puissance musculaire au moyen d'exercices du bas du corps, à raison de 3 séances par semaine durant 10 semaines; le groupe de contrôle (Con, n = 7) maintient ses activités quotidiennes ordinaires. Avant et après cette période de 10 semaines, les aptitudes fonctionnelles sont évaluées au moyen d'un test de marche chronométré sur 6 m, un test d'alternance assis-debout sur 30 s, un test de lever-marcher sur une distance de 2 m 44 (8 pieds) ainsi que la force et la puissance musculaires des extenseurs du genou, au moyen d'un dynamomètre isokinétique (180 °/s). Chez le groupe Ex, la puissance moyenne au cours d'actions pliométriques et miométriques augmente de façon statistiquement significative (p < 0,05): 44% et 60%, respectivement; les aptitudes fonctionnelles aux tests de lève-toi et marche, d'alternance assis-debout et de marche chronométrée s'améliorent aussi de façon statistiquement significative (p < 0,05): 31%, 66%, et 33%, respectivement. Chez le groupe Con, il n'y a aucune variation significative. En conclusion, un simple programme d'entraînement physique, même au cours de la dixième décennie, améliore la puissance musculaire et contribue à de meilleures aptitudes fonctionnelles de la part des muscles sollicités.

Introduction

The loss of muscle strength and power leading to a decline in functional status is generally considered to be an inevitable consequence of aging. Compared with the vast number of studies examining the age-related declines in muscle strength, however, relatively few studies have focused on changes in muscle power with age (Bassey et al., 1992; Jozsi et al., 1999; Skelton et al., 1995). This is rather surprising, since many basic activities of daily living such as walking, climbing stairs, or simply standing from a seated position are not only dependent on muscle strength but also on the ability to generate force at high velocity, or muscle power. Since muscle power is the product of force and velocity, it may be more sensitive to age-related declines, as both force and velocity of shortening are dependent on fast-twitch muscle fibres which are known to decrease in both area and number with aging (Lexell et al., 1988; Murray et al., 1985). Furthermore, the neural processes associated with high-speed contractions (e.g., motor unit firing rate, conduction velocity) may be affected by aging. Cross-sectional comparisons support the prediction that greater declines in muscle power may be expected with aging; an estimated 3.5% per year decline in muscle power, compared with a 1.5% annual decline in muscle strength, has been reported from ages 65 to 89 (Metter et al., 1997; Skelton et al., 1994).

Maintaining independent function in activities of daily living is of primary importance to older adults. The ability to stand from a seated position is considered by some to be one of the most important measures of physical function (Kelly et al., 1976; Rodosky et al., 1989). A number of variables have been determined to influence the ability to rise from a chair and perform other daily activities, such as walking and stair-climbing. These include balance (Schenkman et al., 1990), upper and lower extremity strength (Hughes et al., 1996), and muscle power (Bassey et al., 1992; Skelton et al., 1995). Given the age-related decline in muscle power, and the necessity in elderly populations of possessing muscle power for performing daily habitual activities, it is important to know the extent to which this can be increased with training.

Unfortunately, the few studies that have focused on training for power in older adults have used sophisticated (and costly) training equipment such as Keiser pneumatic resistance machines (Jozsi et al., 1999), have trained subjects at a special facility (Skelton et al., 1995), or have used exercises that were not similar or relevant to basic functional tasks (Skelton et al., 1995). Frail elders living in a residential facility may not have access to expensive equipment and may not be capable of leaving their place of residence to take part in training sessions. Therefore, the purpose of the present study was to examine the effect of an on-site and simple progressive lower body training program, designed to improve muscle power, on functional abilities in frail older adults.

Methods

SUBJECTS

A total of 30 individuals (6 M, 24 F), who were residents in a long-term care facility, volunteered to participate in this study. Inclusion criteria were the ability to follow directions and walk across a room (with or without an assistive device), and no recent history of cardiovascular, cerebrovascular, respiratory, systemic, muscular, or uncontrolled metabolic disease. None of the subjects were presently involved in any physical activity programs, nor did they have any recent exercise history. Subjects were randomly assigned (≈1:2 ratio), in a lottery format, to either a control group (Con, n = 10; ages 75–87 yrs) or an exercise group (Ex, n = 20, ages 76–94 yrs). The use of ambulatory aids per group (walker, cane, wheelchair) and other subject characteristics are outlined in Table 1. This investigation carried the approval of the Human Ethics Research Board at McMaster University, and each subject gave his or her written informed consent to participate.

Table 1 Physical Characteristics of Subjects

Group	Age (yrs)	Gender	Ht (cm)	Wt (kg)	# Using ambul. aids
Exercise	84.9	5 M, 13 F	156.9	60.7	10
(n = 18)	±4.8		±8.9	±11.3	
Control	80.6	1 M, 6 F	159.3	70.0	2
(n = 7)	±4.6		±7.0	±13.4	

ASSESSMENT OF LEG EXTENSOR STRENGTH AND POWER

A Biodex® multi-joint testing and exercise dynamometer (Biodex Corp., Shirley, NY) was used to measure isokinetic knee extension contractions at an angular velocity of 180 °/s. Peak torque (PT) and average power (AP) were calculated by the on-line microsystem inherent to the dynamometer.

During testing, subjects were seated on the Biodex chair and straps were secured around the waist and thigh for stabilization. Subjects were instructed on how to perform both eccentric (Ecc) and concentric (Conc) contractions; to minimize fatigue, the nondominant leg was used for testing of Ecc contractions and the dominant leg for Conc contractions. Subjects were allowed to practice each trial before it was recorded, and verbal encouragement was given. A total of three test repetitions were completed on each leg and the best recorded torque and power output for each leg was used for subsequent analysis. We have previously determined the reliability of these measures in the older population and found test-retest reliability coefficients for peak torque and average power measures (at 180 °/s) to be .82 and .91, respectively (Hruda, unpublished observations).

FUNCTIONAL FITNESS TESTS

Three functional ability tests (Bassey et al., 1992; Rikli and Jones, 1999) were chosen for a probable relationship with strength or power. The assessor explained and demonstrated all tests before they were performed by the subjects.

8-Foot Up-and-Go Timed Test. The subjects were asked to rise as fast as possible from a seated position, walk around a marker 8 feet away, then return to sit on the chair. Subjects could use assistive devices if needed. The test was performed twice and the fastest time, recorded with a stopwatch to the nearest 0.1 second, was recorded.

30-s Chair Stand Test. The subjects were asked to rise up as fast as possible from a chair (seat ht = 42 cm) placed against a wall and then return to a seated position before repeating the sequence. If necessary, subjects could push off from the arm rests of the chair or hold on to the arm handles of their walkers as they repeated the chair stand for the 30-s period. If they were more than halfway up at the end of the 30 seconds, it counted as a full stand. Subjects only performed this test once, as it was very exhausting for most of them.

6-m Walk Timed Test. The subjects were instructed to walk a distance of 6 metres as fast as they could, using assistive devices if needed. Each subject was timed for two walks, to the nearest 0.1 second, and the faster of the two times was used for analyses.

TRAINING INTERVENTION

No active or placebo intervention was prescribed for the Con group. They were asked to perform no more or no less activity than accustomed to on a daily basis. Subjects in the Ex group attended exercise classes in their residential facility three times a week for a total of 10 weeks. Each class began with a 10-min warm-up and stretch of the main muscle groups of the lower limbs being trained. The strengthening component of the class utilized both seated and standing exercises, focusing on the lower body muscle groups. For example, seated exercises included leg crosses, hip rotations, ankle rotations, and rising from a seated position. Standing exercises included heel raises, squats, leg lifts, and hamstring curls. Initially subjects used their own body weight as resistance, but Therabands® were gradually introduced into the program to increase the resistive component.

Following a typical progressive resistance protocol, subjects initially performed each exercise as one set of four to eight repetitions, with body weight, and later with therabands for resistance (they were instructed on how to hold and use the therabands). As the subjects completed the repetitions and one set of exercises more easily, both were progressively increased. As well, any exercises that included a speed component were gradually performed more quickly so as to focus on muscle power. At the end of the exercise session there was a 10-min cool-down component which resembled the warm-up. The duration of exercise class was 20-min initially, progressing up to one full hour over the course of the 10-week study.

STATISTICAL ANALYSIS

Each dependent variable was first analyzed with a two-factor (Group × Time) between-subjects ANOVA with repeated measures on the time factor. To control for baseline differences between groups, change score data (pre/post) were analyzed with analysis of covariance (ANCOVA), with baseline measures used as the covariate. Correlations between functional tests and muscle strength or power were assessed by calculating Pearson's product moment r. Statistical significance was established at $p < 0.05$. Unless otherwise stated, all results are expressed as means ± standard deviations.

Results

After randomization, there were no significant baseline differences in age, height, or body weight between groups, although there was a very strong trend ($p = 0.052$) for subjects in the Con group to be younger than those in the Ex group (Table 1).

BASELINE MEASURES

At baseline there were no statistically significant differences in Conc or Ecc peak torque or Ecc average power between groups, but the Con group had significantly greater Conc average power (Table 2). In the functional tasks the Con group had significantly better performance in the 8-ft up-and-go timed test and the 30-s chair stand test (see Table 3). There was no significant difference between the Ex and Con groups for the 6-m walk timed test at baseline.

Table 2 Isokinetic Measurements of Knee Extensor Peak Torque and Power Pre- and Post-Intervention

	Exercise Group (n = 18)			Control Group (n = 7)		
	Pre	Post	% Change	Pre	Post	% Change
Ecc PT (Nm)	68.1 ±22.7	81.9* ±23.3	29.5 ±48.8	76.3 ±20.1	71.0 ±22.2	–7.1 ±14.4
Ecc AP (W)	44.9 ±22.0	57.5 ±24.0	41.5* ±73.5	54.9 ±32.9	47.8 ±32.5	–19.6 ±23.1
Conc PT (Nm)	29.4 ±12.1	35.8* ±14.0	25.1 * ±24.2	33.3 ±14.8	30.1 ±14.7	–17.7 ±13.7
Conc AP (W)	34.4** ±20.6	46.3* ±23.2	59.7* ±65.8	48.6 ±17.2	45.3 ±14.6	–3.9 ±14.4

Note: Ecc = Eccentric; Conc = Concentric; PT = Peak torque; AP = Average power. *Signif. different from control (baseline adjusted); **Signif. different from control.

Table 3 Functional Performance Measurements Pre- and Post-Intervention

	Exercise Group (n = 18)			Control Group (n = 7)		
	Pre	Post	% Change	Pre	Post	% Change
8-ft Up-and-go (s)	20.7**	14.4	–32.4*	15.5	16.3	3.3
	±7.1	±6.5	±15.7	±17.3	±18.9	±14.5
30-s Chair stand (#)	6.8**	10.0	66.2*	10.8	10.5	–1.1
	±3.1	±3.1	±77.5	±3.1	±2.3	±10.6
6-m Walk (s)	11.2	7.7*	–36.1*	11.9	13.4	–1.1
	±4.7	±3.9	±13.5	±6.9	±9.4	±19.8

*Significantly different from control (baseline adjusted); **Significantly different from control.

Table 4 Pretraining Correlation Coefficients Between Strength, Power, and Functional Performance

	8-ft Up-and-go	Chair stand	6-m Walk time
Ecc PT	–0.47 (p < .05)	0.31 (p = .14)	–0.37 (p = .08)
Ecc AP	–0.26 (p = .24)	0.38 (p = .07)	–0.39 (p = .06)
Conc PT	–0.51 (p < .05)	0.46 (p < .05)	–0.36 (p = .10)
Conc AP	–0.59 (p < .05)	0.56 (p < .05)	–0.54 (p < .05)

Note: Ecc = Eccentric; Conc = Concentric; PT = Peak torque; AP = Average power.

RELATIONSHIP BETWEEN LEG EXTENSOR STRENGTH/POWER AND FUNCTIONAL PERFORMANCE

Prior to training, the relationship between knee extensor strength/power and performance on the functional tasks was assessed in the study population, and the data from the 25 subjects who completed the study are presented in Table 4. As can be seen from the table, all three functional tasks were most strongly correlated with Conc average power (r = –0.59, 0.56, and –0.47, for the 8-ft up-and-go, 30-s chair stand, and 6-m walk test, respectively). These data are shown in Figure 1.

EFFECTS OF TRAINING

Of the original 30 subjects, 5 (2 Ex, 3 Con) dropped out due to health reasons. The remaining 25 subjects (18 Ex, 7 Con) all completed the 10-wk study period. The average number of training sessions attended by each subject in the Ex group was 21 out of 30, representing a 71% adherence rate.

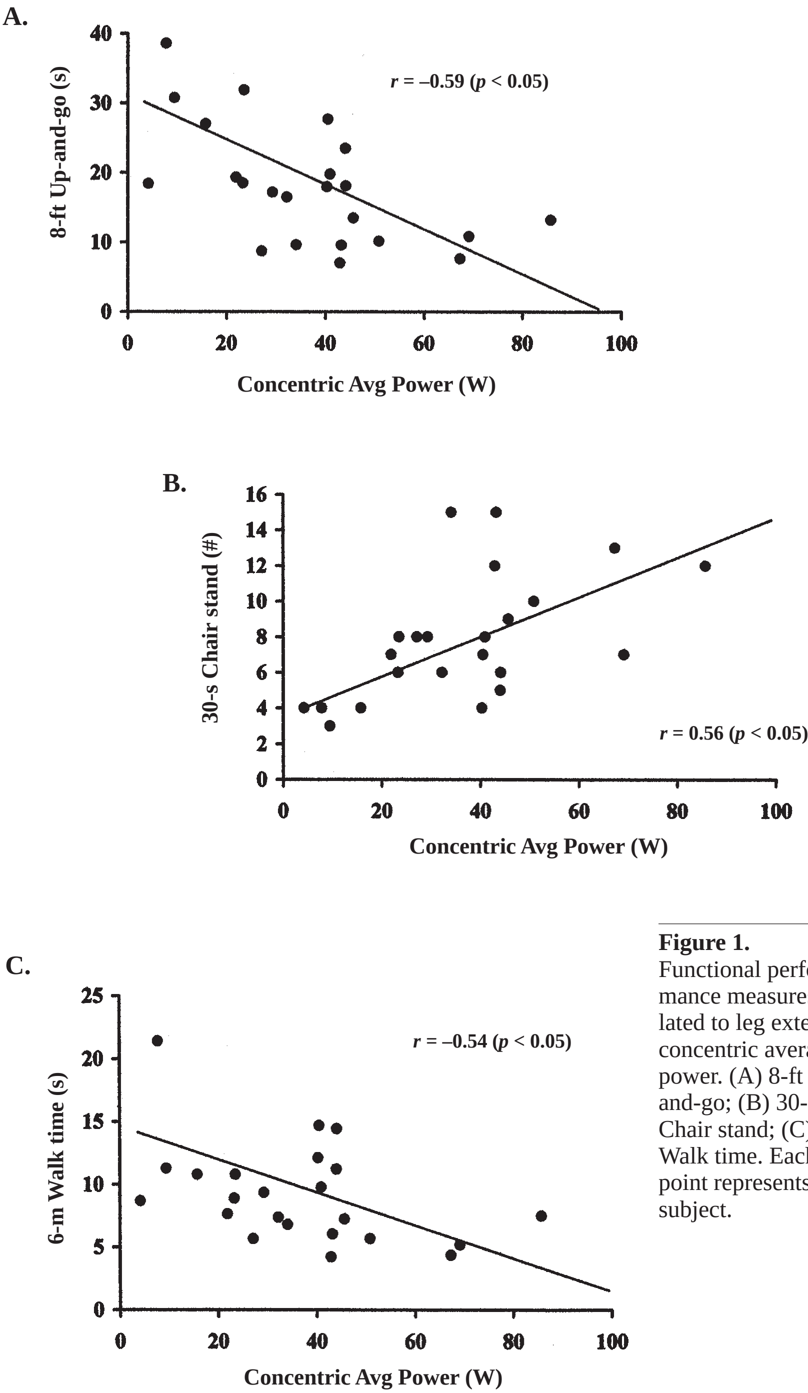

Figure 1. Functional performance measures related to leg extensor concentric average power. (A) 8-ft Up-and-go; (B) 30-s Chair stand; (C) 6-m Walk time. Each point represents one subject.

ISOKINETIC MEASUREMENTS OF STRENGTH AND POWER

Controlling for baseline differences in isokinetic peak torque and power, ANCOVA analyses revealed significant improvements in Conc and Ecc peak torque and Conc average power in the Ex group; the change in Ecc average power showed a strong trend toward a significant improvement ($p = 0.08$). Expressing these changes in percentages, the Ex group had changes ranging between 25 and 60% in knee extensor peak torque and average power ($p < 0.05$), with no significant change occurring in the Con group (Table 2).

FUNCTIONAL TESTS

Repeated-measures ANOVA revealed significant Group × Time interactions for each functional performance task, with only the Ex group showing significant training-induced improvements. The two groups differed at baseline, however, in two of the performance tests (8-ft up-and-go and chair stand test). ANCOVA analyses revealed that while all subjects in the Ex group improved their performance in each functional test after training (except for 2 subjects in the 30-s chair stand test), when the baseline differences were controlled for, only the change in 6-m walk time was significantly different between groups. These results are depicted in Table 3. When expressed as a percent change from baseline, the Ex group's improvement in performance in the 8-ft up-and-go timed test, the 30-s chair stand test, and the 6-m walk test were 31%, 66%, and 33%, respectively ($p < 0.05$).

The changes in each functional performance task were correlated with the changes found in knee extensor peak torque and average power (Table 5). While all correlation coefficients were in the expected direction, the only significant relationships found were between the change in concentric average power and both the change in 8-ft up-and-go ($r = –0.47$, $p < 0.05$) and change in 6-m walk time ($r = –0.42$, $p < 0.05$). These relationships are depicted in Figure 2.

Discussion

The results from this study demonstrate that older individuals living up to their 10th decade can improve muscle power and strength as a result of following a simple, structured, progressive exercise regimen employing only body weight and

Table 5 Correlations Between the Change in Strength and Power and Change in Functional Performance

	8-foot Up-and-go	Chair stand	6-m Walk time
Ecc PT	–0.30 (*p* = .17)	0.15 (*p* = .50)	–0.23 (*p* = .29)
Ecc AP	–0.06 (*p* = .79)	0.21 (*p* = .34)	–0.10 (*p* = .65)
Conc PT	–0.27 (*p* = .21)	0.25 (*p* = .24)	–0.25 (*p* = .26)
Conc AP	–0.47 (*p* < .05)	0.27 (*p* = .21)	–0.42 (*p* < .05)

Note: Ecc = Eccentric; Conc = Concentric; PT = Peak torque; AP = Average power.

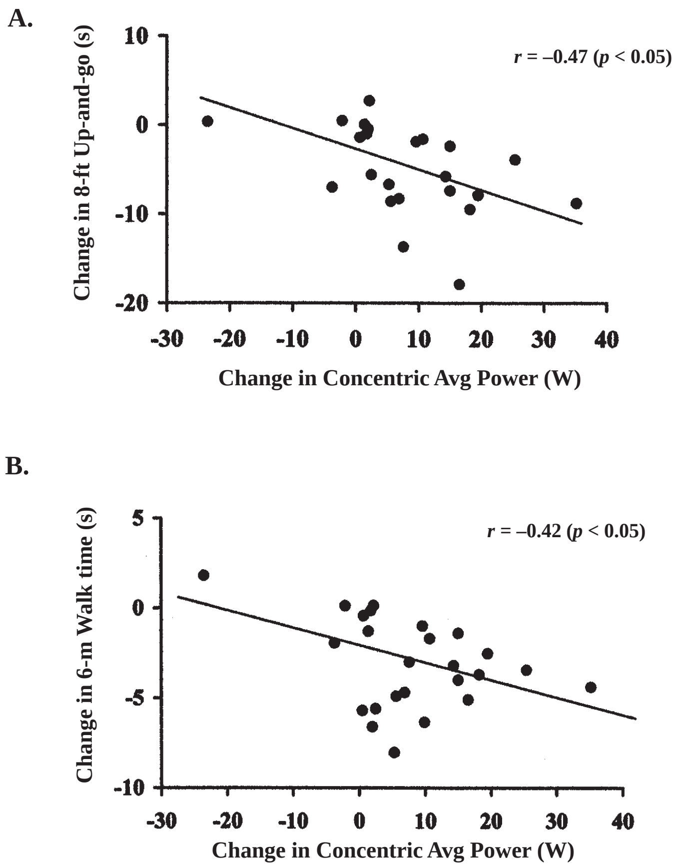

Figure 2. Relationship between change in leg extensor concentric average power and change in functional performance. (A) 8-ft Up-and-go; (B) 6-m Walk time.

Therabands for resistance. Although a number of studies have demonstrated that similar increases in strength can occur in both younger and older adults, few have examined the effects of progressive resistance exercise on muscle power in frail older adults (Jozsi et al., 1999; Skelton et al., 1995). Moreover, while some studies have addressed the question of whether a training-induced increase in muscle power or strength can translate to improved performance of functional tasks using the trained muscles (Ades et al., 1996; Lazowski et al, 1999), further studies in nursing home populations are warranted.

It has been suggested that the decline in muscle power in the older adult may be more directly related to impaired physical performance, and is a better indicator of functional potential than muscle strength alone (Bassey and Short, 1990; Bassey et al., 1992; Brown et al., 1995; Skelton et al., 1994). In support of this, the present study revealed that baseline performance on each functional test was more strongly correlated with leg extensor power, as opposed to peak torque. Significant correlations between leg extensor power and performance on similar functional tasks have been reported previously (Bassey et al., 1992), making a compelling argument for the importance of training for muscle power in the frail elderly population.

There is a definite need for residents of long-term care facilities to have access to a challenging, yet feasible, regular exercise program. A study by Lazowski et al. (1999) confirms that frail, institutionalized seniors can respond positively to a challenging exercise program, using minimal equipment, through increases in strength, mobility, balance, and flexibility. The present study supports these results and has demonstrated that 10 weeks of thrice-weekly progressive lower body exercise training in frail older adults can significantly increase muscle strength and power. That our exercise group started out being somewhat older and slightly weaker than the control group should not necessarily be considered problematic; as discussed below, individuals who are the most frail to begin with have the most to gain with respect to strength training regimens.

The training-induced gains in strength and power observed in the present study were comparable to those seen in similar studies using more costly and sophisticated training equipment (Fiatarone et al., 1990; Jozsi et al., 1999; Skelton et al., 1995). It is likely that at the end of training, those in the Ex group were stronger than they had been for many years. The subjects included in the present study all lived in a residential, long-term care facility and many were dependent on assistive devices for ambulation. We excluded no volunteer on the basis of ambulation or concurrent medications, and the only requirements were the ability to walk across a room (with or without an assistive device), and to be able to follow simple directions. In this regard, our findings can be more generally applied to other frail elderly people living either independently or in long-term-care institutions.

An important purpose of the present study was to determine the extent to which training-induced improvements in muscle strength and power would translate into improved performance in functional tasks. We found that the change in concentric average power after training was significantly correlated with the change in both the 8-ft up-and-go and 6-m walk tests (r = –0.47 and –0.42, respectively). These correlation coefficients were of a similar magnitude to the relationship between change in leg strength and walking endurance (r = 0.48) reported by Ades et al. (1996) in a group of older men and women after 12 weeks of resistance training. The improvement in 6-m walk time alone could mean the difference between an older adult feeling confident in his or her ability to cross an intersection when the walk light is on, or running the risk of having the red light come on when he/she is part-way through the intersection.

While there has been a steady increase in the number of studies reporting an improvement in functional performance following strength training in older adults (Brandon et al., 2000; Chandler et al., 1998; Lazowski et al., 1999; McCartney et al., 1996; Skelton et al., 1995; Westhoff et al., 2000), the subject samples and reported improvements vary. It appears that although strength (and power) gains can be reliably reproduced in most studies employing some sort of progressive training regimen, improvements in functional tasks seem to be dependent on the initial mobility status of the participants. For example, Chandler et al. (1998) found that 10 weeks of thrice-weekly strength training had a significant impact on mobility skills, gait speed, ability to avoid falls, and chair rise performance in participants who were most impaired, but not in the less frail subjects. However, subjects in the Chandler et al. (1998) study were all active community-dwelling seniors, whereas the participants in the current study resided in a residential-care facility, were somewhat mobility-impaired, and were not regularly participating in any sort of community-based activity for seniors.

It has been suggested that there may be a strength threshold below which any further reductions may be associated with progressive decreases in functional tasks using those muscles (Westhoff et al., 2000; Young, 1986). Individuals with initial strength levels above this threshold may not show training-induced improvements in functional performance in spite of improved strength and/or power. The threshold hypothesis implies that significant improvements in the performance of functional tasks might only occur in those individuals whose initial strength is below the critical threshold.

In conclusion, this study has demonstrated that a relatively simple training regimen, utilizing no special equipment, is effective in increasing knee extensor strength and power in frail older adults. More important, improvements in the ability to perform functional activities requiring the use of the trained muscles was clearly evident, and the change in concentric muscle power was significantly related to the change in performance in the 8-ft up-and-go and 6-m walk timed tests. Functional performance is affected by many factors, two of which are undoubtedly muscle strength and power. Since both are modifiable consequences of deconditioning and aging, steps should be taken to ensure that muscle power and strength are maintained in the elderly. Our findings can be applied to other frail older adults in long-term care institutions, and opportunities should be provided for them to exercise in a way that prolongs active life and delays dependency.

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