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Effect of Strength and Power Training on Physical Function in Community-Dwelling Older Adults

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Background. The performance of daily tasks, such as stair climbing or lifting an object, requires both muscle strength and power. Age-associated reductions in strength and power can affect an older adult's ability to complete daily tasks such as stair climbing and lifting a child.

Methods. The purposes of this study were to determine whether power training was more efficacious than strength training for improving whole-body physical function in older adults and to examine the relationship between changes in anaerobic power and muscle strength and changes in physical function. Thirty-nine men and women (mean age ± SD = 72.5 ± 6.3 years) with below-average leg extensor power were randomly assigned to control (C, n = 15), strength-training (ST, n = 13) or power-training (PT, n = 11) groups. The ST and PT groups met 3 days per week for 16 weeks; the C group maintained usual activity and attended three lectures during the course of the study. Primary outcome measures included the Continuous Scale Physical Functional Performance test, maximal strength, and anaerobic power.

Results. After baseline was controlled for, the Continuous Scale Physical Functional Performance test total score was significantly greater for the PT group than for the ST (p = .033) and C (p = .016) groups. Maximal strength was significantly greater for the ST group than for the C group (p = .015) after the intervention. There was no significant difference between groups for peak anaerobic power.

Conclusions. Power training was more effective than strength training for improving physical function in community-dwelling older adults.

THE performance of daily tasks requires muscle strength and power, though both may be compromised because of age-associated changes in the neuromuscular system (1). Inadequate strength may make it difficult to lift a grandchild, and stair climbing may be difficult with reduced leg power. Loss of anaerobic power, needed for physically demanding tasks and serial task performance, can also impose limitations on older adults. These age-associated changes are largely due to a reduction in muscle mass, which is mediated by the loss of type II fibers (2). Numerous studies of older adults have demonstrated the ability of strength-training programs to attenuate these losses (3–5).

Whereas strength training incorporates a heavy resistance moved at a moderate to slow velocity, power training often utilizes a light resistance moved at a fast velocity. Participation in a strength-training intervention has been shown to significantly improve strength (3,6) and some functional tasks in older adults (3), but older adults who train for muscle power are more powerful than those who do not (7–9). Because power has been highly related to functional task performance (10–12), these individuals may have a greater ability to rise from a chair, climb stairs, and possibly avoid a fall.

Power training may improve physical function beyond that of traditional strength-training intervention because it involves a high velocity of movement. High-velocity movements can improve the motor-unit firing rate, synchronization of discharge, and levels of muscle activation more than strength training can (13–15).

Both strength and power training improve anaerobic power (16,17) and physical function (16,18,19); however, studies comparing the effects of power and strength training on physical function and anaerobic power are limited. The purposes of this study were to determine whether power training was more efficacious than strength training for improving whole-body physical function in older adults and to examine the relationship between changes in anaerobic power and muscle strength and changes in physical function.

Methods

Subjects and Procedures

Sixty-five men and women between the ages of 65 and 90 with leg extensor power less than 140 W for women and 210 W for men were recruited from the Athens, GA community. This level of leg extensor power was chosen because it corresponded to a low level of physical function (Continuous Scale Physical Functional Performance test total score < 55). Exclusion criteria included the following: poorly controlled or unstable cardiovascular disease or diabetes, recent unhealed bone fracture (within the past 12 months), severe hypertension (>160/90 mmHg) while resting quietly in the supine position, leg or arm amputation, excessive alcohol intake (more than three drinks per day), a classic anterior compression fracture, neuromuscular disorders, being nonambulatory, or having recent (<6 months) involvement in a strength-training or running or jogging program. All subjects signed a written informed consent approved by the Human Subjects Institutional Review Board at the University of Georgia.

Fifty older adults were stratified by sex and randomized into one of three groups: strength training (ST, n = 17), power training (PT, n = 18) or attention control (C, n = 15). Subjects were evaluated on physical function, maximal strength, and anaerobic power at baseline and after 16 weeks. Subjects in the ST and PT groups met 3 days per week for 16 weeks. Meanwhile, subjects in the C group maintained their usual activity without engaging in any strength training or beginning a new exercise program during the study. They also met for an educational presentation three times during the 16 weeks. At the conclusion of the 16 weeks, these subjects had the opportunity to participate in a strength-training program.

Strength training.—The following three upper- and lower-body exercises were performed for three sets of six to eight repetitions: seated row, chest press, triceps extension, leg press, leg extension, and seated leg curl (Keiser Inc., Fresno, CA). Biceps curls, plantar flexion, and squats were also performed. Each session began with a 5-minute dynamic warm-up utilizing the major joints and muscles to be exercised that day. Muscle-specific stretches were performed after each set. The intensity progressed from 50% to 70% of the one-repetition maximum (1RM) by week 8, and then remained at 80% of the 1RM for weeks 9–16. The 1RM was retested every 4 weeks so that the resistance could be adjusted properly. The concentric action was performed in approximately 4 seconds, and the eccentric action was slow and controlled.

Power training.—The power-training program consisted of the same eight exercises as the strength-training program; however, jump squats were performed instead of squats. Because research suggests building a strength base prior to power training (20), the first 8 weeks were the same as in the strength-training program. After 8 weeks, the program was altered to increase muscle power. Each subject performed three sets of six to eight repetitions at 40% of the 1RM value as fast as possible. The concentric action was performed in approximately 1 second, and the eccentric action was performed in approximately 2 seconds.

Anthropometric Measures

Percent fat was estimated from the sum of three skinfold measurements, using sex-specific generalized equations (21,22). Skinfold measurements were taken with Lange calipers (Cambridge, MA) and measured to the nearest 1 mm. Lean thigh volume (LTV) was estimated by using anthropometric procedures according to Jones and Pearson to normalize anaerobic power (23). Each circumference and skinfold site was recorded twice, and the average value was calculated.

Physical Function

The Continuous Scale Physical Functional Performance (CS-PFP) test was used to measure physical function. The CS-PFP test is a valid functional test that consists of a battery of 16 everyday tasks measured by the distance moved, the time to complete each task, and/or the amount of weight carried (24). The CS-PFP test yields a total score and five physical domain scores: lower-body strength (LBS), upper-body strength (UBS), upper-body flexibility (UBF), balance and coordination (BALC), and endurance (END). Each task is adjusted to a scale of 0 to 100 (25). The CS-PFP total is the average of all adjusted scores, and the domain scores are the average of the tasks in that domain. A detailed description of the tasks performed has been reported previously (24) and is available online (http://www.coe.uga.edu/cspfp/).

Maximal Strength

The 1RM, the maximal amount of weight that can be lifted once through the full range of motion while holding to good form (26), was measured for the chest press (Cemco Physical Fitness Products, S. El Monte, CA) and leg press (Chattanooga Group, Inc., Hixson, TN) exercise. One warm-up set of approximately four to six repetitions was performed. Resistance was gradually increased until the subject reached a maximal value. No less than 3 minutes was allowed between each trial. Each subject performed two familiarization trials before the 1RM test.

Anaerobic Power

The Wingate anaerobic cycle test is a 30-second maximal cycle sprint against a constant resistance. This is a valid test of anaerobic power (27) that quantifies peak (the highest average power in any 5-second interval) and mean power (the average power over the total 30 seconds). The pedal resistance was based on a percentage of the subject's lean body mass (LBM), using the following equation (12):

$$\text{Load (kg)} = [(57.4/\text{LBM}) \times 0.085] \times \text{BM}.$$

A 12-lead electrocardiogram recording was taken during rest, throughout the test, and for 3 minutes posttest. A physician supervised the electrocardiogram to monitor any signs of cardiovascular insufficiency. A 5-minute warm-up on a Monarch cycle ergometer (Model 814E, Varberg, Sweden) interspersed with four brief sprints was performed in order to familiarize the subject with the protocol. After a 7-second countdown, the subject proceeded to pedal as fast as possible for 30 seconds. The subject or the physician was able to terminate the test if he or she determined it unsafe. Upon completion of the test, the subject remained seated on the bike and pedaled at a low resistance (0.5 kg) until heart rate returned to baseline. During the test, an optical sensor was used to determine the number of revolutions of the cycle flywheel from the reflective markers on the flywheel. This sensor was interfaced with computer software (Sports Medicine Industries, St. Cloud, MN) to calculate mean and peak power.

Statistical Analysis

All statistical analyses were performed with SPSS (Chicago, IL, Version 10). An analysis of covariance was used to examine differences between population means on the postmeasure while using the pretest as the covariate.

Three pairwise comparisons were performed to test whether power training improved physical function more than strength training did. Pearson correlation coefficients were calculated to evaluate the relationship between the change in physical function, strength, and anaerobic power. Confidence intervals (CIs) were also calculated. A value of $p <$ .05 was required to establish significance.

Results

Participants

Of the 50 volunteers, 11 (22% total, 0% C, 24% ST, and 39% PT) did not complete the study because of family and/or personal medical reasons, injuries, or relocations. Six women (ST, $n = 5$; C, $n = 1$) fell during the course of the study. Fourteen participants (93.3%) in the C group participated in the strength-training program at the conclusion of the 16 weeks. There was no significant difference between groups at baseline for any physical characteristic shown in Table 1. Table 2 includes the pretest and posttest data for the outcome variables.

Physical Function

After the baseline was controlled for, the PT group was significantly greater than the ST group for CS-PFP total (p = .033; CI: PT = 60.8–69.9, ST = 54.5–62.8), BALC (p = .013; CI: PT = 57.2–69.1, ST = 47.3–58.2), END (p = .026; CI: PT = 61.9–72.1, ST = 54.3–63.7), and UBF (p = .045; CI: PT = 70.6–82.7, ST = 62.7–73.8) (Table 3). Additionally, the PT group was significantly greater than the C group for CS-PFP total (p = .016; CI: C = 54.1–61.8), BALC (p = .013; CI: C = 47.9–58.1), and END (p = .006; CI: C = 53.0–61.7). The change in physical function was not significantly correlated to the change in peak anaerobic power (r = .29) or leg press strength (r = .16).

Maximal Strength and Anaerobic Power

There was no significant difference between the two exercise groups for either measure of strength or peak anaerobic power expressed as absolute (W), relative to LTV (W l^{-1}), or relative to BM (W kg^{-1}). However, the ST group was significantly stronger on the leg press (p = .004; CI: ST = 213.1–248.8, C = 176.6–210.0) and chest press (p = 0.015; CI: ST = 70.6–80.0, C = 62.6–71.6) and had significantly more relative mean power (W kg^{-1}) than the C group (p = .032; CI: ST = 2.7–3.4, C = 2.1–2.9) on the posttest measure (Table 3).

Discussion

The major finding of this study was that power training was more effective than strength training for improving whole-body physical function on the CS-PFP test in community-dwelling older adults. The observed improvements in function support previous work that demonstrated a significant improvement in CS-PFP total following a 6-month strength-training program for older women with disability (19) and a combined-strength and endurance-training program for healthy older adults (18).

Table 1. Physical Characteristics of the Participants at Baseline

Variable	Control (n = 15)	Strength (n = 13)	Power (n = 11)
Female (%)	60	53.8	54.5
Age (y)	72.4 ± 7.2	72.8 ± 5.4	72.3 ± 6.7
Height (cm)	169.9 ± 10.0	170.9 ± 9.8	170.4 ± 11.3
Body mass (kg)	68.22 ± 13.5	80.20 ± 24.0	79.73 ± 15.7
LBM (kg)	49.8 ± 10.1	55.5 ± 13.8	56.4 ± 11.8
Body fat (%)	26.77 ± 6.2	29.23 ± 10.3	29.05 ± 7.3

Notes: Physical characteristics are means ± *SD*. LBM = lean body mass.

Interestingly, the PT group performed less absolute total work than the ST group during each exercise session, yet the PT group improved physical function more than the ST group. This suggests that significant changes in physical function are not dictated by the amount of absolute total work performed. These data indicate that the velocity of movement and intensity of exercise had a greater influence on the improvement in physical function than total work performed.

Physiological and functional adaptations are specific to the type of training performed (28,29). The ability of older adults to lift small objects was greater after participation in a strength-training program than a power-training program (16) and athletic performance improved in young adults after power training more so than after strength training (30). In the current study, the PT group performed individual tasks faster after participating in the power-training intervention, whereas the ST group carried more weight after participating in the strength-training intervention. Other researchers have suggested that power training results in greater neural activation than strength training (13–15). This may help explain the observed improvement in timed-task performance by the power-training group.

Results indicated that both programs were equally effective for improving maximal strength. The ST group was significantly stronger than the C group following training; however, there were no significant differences between the exercise groups. These results support past research that has demonstrated a lack of difference between the groups (7,8,31). Findings for anaerobic power were also nonsignificant between the groups.

The observed improvement in physical function without an improvement in anaerobic power suggests that training adaptations did occur; however, the lack of significant findings for anaerobic power may be due to factors unrelated to the strength- and power-training programs. Because many older adults do not cycle regularly, inadequate familiarity with cycling may have confounded the results on the Wingate test. Because blood lactate was not measured, there was no direct physiological measure to ensure that anaerobic metabolism was elicited on either the pretest or posttest Wingate. However, we have previously demonstrated a significant increase in blood lactate in older adults after they perform the Wingate test (12), and Jozsi and coworkers (4) demonstrated a significant increase in relative mean anaerobic power (13%) after 9 months of strength and power training. In young adults, power training

Table 2. Descriptive Data for Outcome Variables

Variable	Control (n = 15) Before	Control (n = 15) After	Strength (n = 13) Before	Strength (n = 13) After	Power (n = 11) Before	Power (n = 11) After
1RM strength						
Chest press (kg)	29.36 ± 12.2	29.18 ± 13.6	30.25 ± 15.8	34.62 ± 17.7	31.01 ± 12.9	34.81 ± 14.6
Leg press (kg)	75.61 ± 38.9	79.71 ± 37.5	85.61 ± 45.2	105.27 ± 53.1	95.45 ± 33.2	107.65 ± 32.2
Anaerobic power						
Peak power (W)	263.0 ± 81	248.4 ± 83	262.2 ± 117	294.5 ± 117	310.2 ± 105	334.7 ± 137
Peak power (W l^{-1})	88.04 ± 32.3	83.01 ± 27.1	68.90 ± 22.6	81.84 ± 26.5	91.49 ± 35.6	91.45 ± 34.0
Mean power (W)	199.8 ± 64	176.0 ± 54	216.7 ± 100	234.1 ± 107	233.1 ± 80	247.5 ± 119
Mean power (W l^{-1})	66.31 ± 24.9	58.71 ± 17.0	57.02 ± 20.1	65.38 ± 26.6	68.36 ± 25.0	66.49 ± 27.6
Physical function						
CS-PFP total	55.5 ± 14	57.0 ± 18	55.5 ± 10	57.7 ± 10	58.2 ± 13	67.1 ± 13
LBS	47.9 ± 17	50.7 ± 5	49.8 ± 10	50.8 ± 13	54.1 ± 16	61.3 ± 16
UBS	64.3 ± 15	66.0 ± 4	62.8 ± 13	67.9 ± 13	70.7 ± 16	74.6 ± 4
UBF	67.5 ± 15	69.3 ± 11	66.3 ± 13	68.1 ± 13	65.7 ± 15	76.3 ± 3
BALC	52.4 ± 15	52.6 ± 19	53.4 ± 13	53.2 ± 11	52.9 ± 11	63.2 ± 4
END	56.2 ± 14	57.3 ± 18	55.5 ± 11	58.2 ± 11	57.4 ± 12	68.0 ± 14

Notes: CS-PFP = Continuous Scale Physical Functional Performance test; 1RM = one repetition maximum; LBS and UBS = lower and upper body strength, respectively; UBF = upper body flexibility; BALC = balance and coordination; END = endurance. Data are means ± *SD*.

has significantly increased anaerobic power (32,33). Although other researchers have also found significant improvements in power in subjects after they go through strength and power training (4,5,7–9,16,31), the power measures from the Wingate test do not allow for a direct comparison with these studies because of the difference in metabolic demand between the different tests.

When any new exercise program is begun, the risk of injury must be minimized. This study had a 22% dropout rate (n = 11), with less than one third of that (n = 3) caused by injuries. Turning too quickly, tripping over the base of a machine, and falling backward during the downward phase of the squat caused the three falls that occurred during the exercise sessions. The other falls occurred in the individuals' homes. In the beginning of the study, one participant strained a hamstring during the leg curl exercise. This prompted a reduction in the intensity of the exercises during the first 4 weeks and a more gradual progression of the resistance.

Conclusions

There were limitations to this study. The trainer and tester were not blinded to the group assignment. To counter any bias, motivation and testing procedures were the same for all groups. Unfortunately, a post hoc power analysis revealed insufficient power to detect differences between groups for anaerobic power, thus affecting our results.

In conclusion, power training improved whole-body physical function more than strength training in community-dwelling older adults, despite the fact that it entailed performing less work, but exhibited similar anaerobic power and strength. These results suggest that functional measurements may be more sensitive than capacity measures for detecting change after an exercise intervention, because

Table 3. Results of the Planned Comparisons Adjusted for Baseline Scores

Variable	Control (n = 15)	Strength (n = 13)	Power (n = 11)	F Value
1RM strength				
Chest press (kg)	30.51 ± 1.0	34.23 ± 1.0†	33.59 ± 1.1	3.72
Long press (kg)	87.86 ± 3.7	104.98 ± 3.9†	97.59 ± 4.2	4.69
Anaerobic power				
Peak power (W)	262.5 ± 18.1	309.4 ± 16.5	302.8 ± 18.3	2.06
Peak power (W l^{-1})	78.73 ± 6.3	91.09 ± 5.8	84.64 ± 6.3	1.01
Mean power (W)	193.0 ± 15.6	233.9 ± 14.1	230.7 ± 15.6	2.20
Mean power (W l^{-1})	56.51 ± 5.4	70.20 ± 5.0	62.92 ± 5.5	1.70
Physical function				
CS-PFP total	57.9 ± 1.9	58.6 ± 2.0*	65.4 ± 2.2†	3.68
LBS	53.1 ± 2.2	51.3 ± 2.4	57.3 ± 2.6	1.50
UBS	68.0 ± 1.6	71.8 ± 1.7	70.8 ± 1.9	1.38
UBF	68.9 ± 2.5	68.3 ± 2.7*	76.6 ± 2.9	2.65
BALC	53.0 ± 2.5	52.8 ± 2.7*	63.1 ± 2.9†	4.39
END	57.3 ± 2.2	59.0 ± 2.3*	67.0 ± 2.5†	4.58

Notes: Values are reported as mean ± *SE*. CS-PFP = Continuous Scale Physical Functional Performance test; 1RM = one repetition maximum; LBS and UBS = lower and upper body strength, respectively; UBF = upper body flexibility; BALC = balance and coordination; END = endurance.

*significantly different from power training, $p < .05$; †significantly different from control.

physical function is the submaximal integration of physiological systems (24). Further evidence is needed to support the efficacy of a power-training program over a strength-training program to improve physical function, along with qualitative measures to address other outcomes related to life satisfaction.

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