The Effect of Strength Training on Functional Fitness in Older Patients with Chronic Lung Disease Enrolled in Pulmonary Rehabilitation

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The purpose of this study was to compare the effects of a strength training–enhanced program and a traditional pulmonary rehabilitation (PR) program on functional fitness (FF) in older patients with chronic obstructive pulmonary disease (COPD), using the Senior Fitness Test. Twenty patients were recruited from an outpatient PR program. After completing baseline measures, including muscular strength and the Senior Fitness Test, patients were randomly assigned to the strength training program (TR+ST, n = 10) or traditional PR program (TR, n = 10). Patients completed 16 exercise sessions that were conducted twice a week for 8–10 weeks, after which patients repeated outcome measurements. Independent t tests were conducted to determine whether groups differed between measures. Both the TR+ST and TR groups improved on all FF measures. Moderate effect sizes were found for two of the FF measures when the groups were compared. The addition of strength training to PR may have a favorable impact on FF in older patients with COPD.

KEY WORDS

chronic obstructive pulmonary disease
functional fitness
older adults
pulmonary rehabilitation
resistance exercise
strength training

Exercise training has long been an established component of pulmonary rehabilitation (PR) for people with chronic obstructive pulmonary disease (COPD) (ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel, 1997). This training plays an important role in accomplishing the central goal of PR, which is helping patients achieve and maintain the highest possible level of independence and functional status (ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel). Functional status is related to patients' physiological capacity (e.g., muscular strength, aerobic capacity) to perform activities of daily living (ADLs) such as getting out of a chair and lifting objects (Larson & Leidy, 1998). The physiological capacity to perform ADLs has been called functional fitness (FF) and correlates well with the goal of helping patients attain higher levels of independence and functional status (Rikli & Jones, 1999).

In patients with chronic lung disease, exercise training—both aerobic and strength—has been shown to favorably affect FF (ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel, 1997). In traditional PR programs, aerobic training generally receives greater emphasis than strength training. Although aerobic training significantly benefits FF (e.g., improved capacity for ambulation), it has recently been suggested that strength training may also complement aerobic training and significantly improve FF (ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel). Celli (1995) suggested that upper extremity strength training might considerably improve PR patients' ability to perform ADLs because they require upper extremity strength. In addition, because lower body strength is necessary for performing ADLs (Rikli & Jones, 1999), it follows that lower extremity strength training may be important for improving independence and FF in patients with COPD. Several studies have demonstrated that the significant effects of strength training on the FF of healthy and frail older adults who experience physiological deficits (e.g., decreased muscle mass and strength, decreased aerobic capacity) are similar to those of patients with COPD (Chandler, Duncan, Kochersberger, & Studenski, 1998; Davis, Ross, Preston, Nevitt, & Wasnich, 1998; Hunter et al., 1995; Mihalko & McAuley, 1996; Phillips, Broman, Burkett, & Swan, 2004). However, despite the potential benefits of strength training to the FF and independence of patients with COPD, only a handful of studies have examined the effects of strength training in this population (Phillips, Benton, Wagner, & Riley, 2006; Storer, 2001).

Recently, Rikli and Jones (1999) developed a comprehensive FF test for older adults (60 years and older) to assess the physiological components (e.g., agility, aerobic endurance, muscular strength, balance) important for performing ADLs. This objective test, known as the Senior Fitness Test (SFT), is appropriate for older PR patients because they have physical deficits (e.g., decreased strength and mobility) similar to those of older adults. The SFT may provide a more comprehensive understanding of how strength training affects the FF of older PR patients, thus potentially allowing PR practitioners to better evaluate whether the goals of improved independence and functional status are being met. The purpose of this study was to compare the effects of a strength training–enhanced program and a traditional 8-week PR exercise program on FF in older patients with COPD using the SFT (Rikli & Jones, 1999).

Method

Study Participants

Participants (11 women, 16 men) were recruited from the Banner Baywood Heart Hospital Pulmonary Rehabilitation program in Mesa, AZ, a multidisciplinary program consisting of education, breathing retraining, exercise conditioning, and psychosocial support. The patients were first-time attendees of PR and were referred to the program by their pulmonary physician. Entry criteria, as determined by the pulmonary physician, were a forced expiratory volume in 1 second below 60% of predicted forced expiratory volume in 1 second based on the patient's height, age, sex, etc., a recent hospitalization, or a decline in COPD symptoms. Also, patients did not have any medical, physical, or cognitive impairment that would preclude their participation in the evaluation and training protocols. The research protocol for the study was approved by the Banner Health Institutional Review Board.

Study Design

After informed consent forms were completed and baseline data were collected, participants were randomly assigned to one of two groups: the traditional PR program (TR) or the traditional PR program plus strength training (TR+ST).

Exercise Conditioning

Exercise conditioning was conducted twice a week for 8 weeks, or a total of 16 sessions. To allow for absences caused by illness or PR closure on holidays, participants were permitted a maximum of 10 weeks to complete the 16 sessions. Patients failing to complete the sessions in 10 weeks were excluded ($N = 3$) from the study.

Before, during, and after exercise, a registered nurse or respiratory therapist assessed patients' blood pressure, resting heart rate, and oxygen saturation of hemoglobin. Patients were monitored throughout each exercise session by telemetry.

Traditional Exercise Training

Aerobic exercise consisted of upper and lower extremity endurance training. Upper extremity training was performed on a calibrated Monark arm ergometer (Rehab Trainer 881E, Quinton, Seattle, WA). Lower extremity training was performed on a motor-driven treadmill (Trackmaster TM-210, Carrollton, TX), an Air Dyne stationary cycle (Schwinn, Chicago, IL), and a NuStep Total Body Recumbent Stepper (NuStep Inc., Ann Arbor, MI). The patients' aerobic training protocol was individualized and planned at baseline with a registered nurse. Goals were set to meet each patient's conditioning needs. Training goals consisted of achieving a combined (e.g., using all aerobic equipment) duration of 20 to 40 minutes by the end of 8 weeks or 16 sessions. The exercise intensity goal was three metabolic equivalents. The intensity of each exercise session was determined by one or all of the following: an exercise heart rate of 20–40 beats above resting heart rate, rating of perceived breathlessness of 1–5, and rating of perceived exertion of 11–13. The duration of aerobic exercise was increased before the intensity of training was increased.

In addition to the aerobic exercise training in the traditional program, patients performed low-intensity upper extremity strength training using handheld dumbbells to perform the following exercises: arm curl, lateral torso bend, lateral arm raise, wrist curl, standing triceps extension, and upright row. One set of 8–15 repetitions was performed for each exercise. The intensity depended on the patient and ranged from 1 to 10 pounds. Intensity was determined by self-reported ratings of perceived breathlessness and exertion.

Strength Training

The TR+ST participants performed the strength-training protocol immediately after their regular TR exercise session (i.e., two times a week) for half of the PR program (eight sessions) and at the beginning of PR for the other half of the program (eight sessions).

Strength training, performed according to the American College of Sports Medicine (1998, 2000) guidelines for older adults, consists of a single set of 12 repetitions of the following five exercises: incline bench press, seated leg press, lateral pulldown, cable triceps pushdown, and cable bicep curl. Intensity of the first two lifts was determined by a one-repetition maximum (1 RM) assessed at baseline. Intensity for the remaining exercises was determined empirically, ensuring that patients reached fatigue or a rating of perceived exertion of 11–13 to avoid excessive strain (American Association of Cardiovascular and Pulmonary Rehabilitation, 1999). During the first week, participants exercised with a load that was 50% of 1 RM for the exercises in which 1 RM was assessed. For the remaining exercises, participants used a low-intensity load to enable proper familiarization with equipment before increasing intensity. Increases in intensity or resistance load were based on the successful completion of more than 12 repetitions for two consecutive training sessions. Loads increased in 3- to 5-pound increments. All strength exercises were performed using Universal Dynamic Variable Resistance (Cedar Rapids, IA) strength-training equipment.

Evaluation

Before participants were evaluated, their demographic information and medical history, including pulmonary function (e.g., forced expiratory volume at 1 second), were obtained by a registered nurse. Participants were then evaluated during the first and second rehabilitation sessions and on the last session of PR.

Muscular Strength Measurements

Muscular strength was assessed using the 1 RM test to determine upper and lower body strength. The safety of 1 RM testing in patients with COPD has recently been confirmed (Kaelin et al., 1999). Because of logistical and time constraints, 1 RM testing was limited to one upper body (incline bench press) and one lower body (seated leg press) exercise. A brief warmup set was performed before each test to help participants familiarize themselves with the exercise. To assess the reliability of the 1 RM values, two 1 RM tests (separated by at least 48 hours) were conducted at baseline. The higher of the two values was used to represent the participants' true maximal load lifted.

Key Practice Points

1. Among chronic lung disease patients, both aerobic and resistance exercise have shown to positively affect patients' ability to perform activities of daily living or functional fitness; however, resistance exercise may have a greater impact on functional fitness due to the nature of many activities of daily living.
2. Using a single-set resistance training program among older pulmonary rehabilitation patients may require an increased rate of intensity progression than in a normal, healthy population to maximize functional and strength gains.
3. The effective use of resistance exercise among older pulmonary rehabilitation patients may be lacking because of insufficient information regarding the proper prescription of such exercise; therefore, further research is needed to establish evidence-based practice related to resistance exercise prescription.
4. Appropriate and accurate assessment of maximal strength using a one-repetition maximum protocol requires more than a single trial because of the potential learning effect, which naturally occurs when performing repeated trials.

Functional Fitness Measurements

Senior Fitness Test. The SFT was designed to assess patients' physiological characteristics associated with the performance of ADLs, including lower body strength (chair stand), upper body strength (arm curl), lower body flexibility (chair sit and reach), upper body flexibility (back scratch), and agility and dynamic balance (8-foot up and go). These test items have been proven valid and reliable; specifically, test–retest reliability and content, criteria, and construct validity have been demonstrated (Rikli & Jones, 1999). Each test represents a specific fitness component (Rikli & Jones).

Additional Functional Fitness Measures. In addition to the SFT items, two additional FF tests were completed: one for upper body strength and endurance (lift and reach) and one for ambulation (6-minute walk [6MW]). The lift-and-reach test was recently developed and has been validated (King, Pruitt, Phillips, Rodenburg, & Haskell, 2000). The 6MW is safe and reliable and is often used as a measure of functional ambulatory capacity in PR programs (Guyatt et al., 1985; Redelmeier, Bayoumi, Goldstein, & Guyatt, 1997).

Before testing, participants performed an aerobic warmup (e.g., cycle, treadmill, NuStep) for 5–10 minutes. Test items were counterbalanced to control for an order effect. Each item was explained and demonstrated by the researchers before testing. Participants were allowed to practice each test item (excluding the 6MW) just before scoring began to ensure that participants were familiar with the tests and that they were being performed correctly. The SFT items were administered according to the procedures previously outlined by Rikli and Jones (2000). Trained researchers conducted all test items except for the 6MW, which was conducted according to standardized procedures by trained PR staff (e.g., registered nurse, exercise physiologist, respiratory therapist; Guyatt et al., 1985).

Statistical Analysis

Baseline patient characteristics for the two groups were compared using independent *t* tests. Reliability of the strength measurement (1 RM) was assessed under the procedures outlined by Batterham and George (2000). Independent *t* tests were then used to evaluate within- and between-group pretest and posttest differences on all dependent variables. To determine the magnitude and meaningfulness of findings, effect size (ES) was also calculated for each of the dependent variables (Cohen, 1988). Statistical significance was set at $p < .05$.

Results

Seven participants (five in the TR+ST group and two in the TR group) did not complete the program because they dropped out for personal reasons ($n = 2$), failed to complete the program within the required 10 weeks ($n = 3$), sustained rib fractures caused by excessive coughing ($n = 1$), and experienced new-onset hypertension ($n = 1$). Baseline characteristics of the remaining 20 participants (14 men, 6 women; 69 ± 9 years) are listed in **Table 1.** Seven men and three women were in each study group. No changes occurred during the study period for any of the baseline characteristics, including pulmonary function measures.

Effect of Exercise Training on Muscular Strength

Reliability data for comparison of 1 RM trials are presented in **Table 2.** The bench press trials were not significantly different ($p = .16$); however, the seated leg press trials were significantly different ($p = .03$).

At the end of the training period, the TR+ST group experienced a 2.1% and 5.4% increase in seated leg press 1 RM and incline bench press 1 RM, respectively, which were not statistically significant. The TR group decreased by 1.8% in seated leg press 1 RM and increased by 9.4% in bench press 1 RM; these changes in muscular strength were not statistically significant. In addition, no significant differences were found between the TR+ST and the TR groups in changes in muscular strength (**Table 3**).

Effect of Exercise Training on Functional Fitness Measures

FF values, including mean changes from PR, for the TR+ST and TR groups are given in **Table 4.** ESs for the FF and muscular strength values are presented in **Table 5.** After analysis, there was no significant difference between groups on changes from exercise training in any of the FF measures. Moderate ESs were found for the chair-stand test ($p = .24$, ES = .55) and the up-and-go test ($p = .24$, ES = .57). All other ESs were low, ranging from .09 to .36.

Table 1. Participant Characteristics

	Traditional PR Program Plus Strength Training (n = 10)		Traditional PR Program (n = 10)	
Characteristic	*M*	*SD*	*M*	*SD*
Age (years)	65	8	73	9
Height (in.)	67.88	2.82	67.72	3.19
Weight (lb)	161.4	39.6	186.10	36.23
BMI	24.6	5.5	28.5	5.0
FVC (L)	2.04	0.83	2.42	0.87
FVC (% predicted)	51.6	17.8	65.8	18.1
FEV1 (L)	0.86	0.39	1.08	0.42
FEV1 (% predicted)	29.8	13.4	38.6	14.5
FEV1/FVC %	40.9	9.8	46.0	11.5

Note. BMI = body mass index (weight [kg]/height [meters]2); FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity; PR = pulmonary rehabilitation.

Table 2. Reliability of One-Repetition Maximum Strength Measurements (N = 20)

	Trial 1		Trial 2		Difference	*p*
Test	*M*	*SD*	*M*	*SD*		
Seated leg press (lb)	205.2	72.0	218.7	71.3	13.5	.03
Incline bench press (lb)	62.4	23.2	64.8	21.9	2.4	.16

Table 3. Muscular Strength Before and After Pulmonary Rehabilitation

	Traditional PR Program Plus Strength Training (*n* = 10)					Traditional PR Program (*n* = 10)				
	Pretest		Posttest		% Change	Pretest		Posttest		% Change
Measure	*M*	*SD*	*M*	*SD*		*M*	*SD*	*M*	*SD*	
Seated leg press (lb)	233	70	238	80	2.1	222	82	218	89	–1.8
Incline bench press (lb)	74	28	78	29	5.4	64	19	70	18	9.4

Note. Mean values were calculated using the highest one-repetition maximum value (in lbs) of the two trials; PR = pulmonary rehabilitation.

Table 4. Functional Fitness Before and After Pulmonary Rehabilitation

	Traditional PR Program Plus Strength Training (*n* = 10)					Traditional PR Program (*n* = 10)				
	Pretest		Posttest		% Change	Pretest		Posttest		% Change
Measure	*M*	*SD*	*M*	*SD*		*M*	*SD*	*M*	*SD*	
6MW (ft)	1,053	253	1,198	343	13.8	1,071	462	1,231	366	14.9
CS (reps)	9.3	1.9	11.0	2.4	18.3	8.3	4.1	9.3	3.7	12.0
AC (reps)	10.3	2.4	12.4	2.6	20.4	10.9	2.5	12.4	2.8	13.8
UnG (s)	7.5	0.5	6.8	0.7	–9.4	7.9	1.7	7.5	1.6	–4.9
CSR (in.)	–2.9	3.7	–2.2	3.4	24.1	–5.0	3.2	–3.4	2.9	32.0
LnR (reps)	9.1	2.6	12.0	2.4	31.8	10.3	2.6	12.6	3.1	22.3
BST (in.)	–2.5	3.0	–2.5	2.6	0	–4.6	5.2	–4.5	7.0	2.2

Note. 6MW = 6-minute walk test; AC = arm curl test; BST = back scratch test; CS = chair stand test; CSR = chair sit-and-reach test; LnR = lift and reach test; PR = pulmonary rehabilitation; UnG = 8-foot up-and-go test.

Discussion

The purpose of this study was to determine whether strength training–enhanced PR (TR+ST) was superior to traditional aerobic-based PR (TR) for improving FF in patients with COPD. In contrast to other published studies, the authors found no significant differences between groups in muscular strength or FF measures (Bernard et al., 1998; Ortega et al., 2002; Phillips et al., 2006; Troosters, Gosselink, & Decramer, 2000). In regard to muscular strength, the lack of significant improvement in the TR+ST group (2.1% and 5.4% increase in seated leg press and incline bench press 1 RM, respectively) may be related to low training volume (single set of 12 repetitions for five exercises), low frequency (2 days per week), and short duration of the program or intervention (8 weeks). However, Phillips and colleagues (2006) recently examined the effect of single-set resistance training on FF in a similar population with a similar training volume (single set), frequency (2 days per week), and duration (8 weeks) as the current study and found notable strength gains and improvements in a number of FF measures. The progression of workload intensity throughout the training period is what distinguishes the two studies. For this study, when patients were able to complete more than 12 repetitions for an exercise in two consecutive sessions, the workload was increased by 3–5 pounds. In contrast, the workload in the study conducted by Phillips and colleagues (2006) was increased 5%–10% when the patient could successfully complete the prescribed 10 repetitions. This progression method may have produced significant strength gains because of a higher training intensity. Future studies should further examine the proper training volume, frequency, and intensity to maximize strength gains for transfer to FF in this population.

The nonsignificant increases found in 1 RM tests compared with other studies in this population may also have resulted from differences in test reliability, which is rarely reported for 1 RM testing, especially in older adults (Phillips, Batterham, Valenzuela, & Burkett, 2004; Rikli, Jones, Beam, Duncan, & Lamar, 1996). This study is one of the first to conduct 1 RM reliability assessments to maximize confidence in the test's findings. Failure to determine the reliability of strength measurements through familiarization or multiple (≥ 2) 1 RM tests ignores the potential for systematic error (nonrandom trial-to-trial differences,

Table 5. Effect Sizes for Between-Group Comparisons on All Outcome Measures

Measure	*t*	*p*	Effect Size	Power
6-minute walk	–0.21	.84	0.09	0.08
Chair stand	1.2	.24	0.55	0.29
Arm curl	0.00	1.00	0	0
Up and go	–1.2	.24	0.57	0.29
Chair sit and reach	0.80	.44	0.36	0.16
Lift and reach	–0.48	.64	0.21	0.11
Back scratch	0.84	.41	0.25	0.10
Seated leg press	0.48	.64	0.23	0.10
Incline bench press	0.68	.51	0.33	0.16

Note. Effect size = (M1 – M2)/SD, where M1 = mean for experimental group, M2 = mean for control group, and SD = pooled standard deviation (Thomas, Salazar, & Landers, 1991).

generally resulting from learning effects) (Batterham & George, 2000). Systematic error may erroneously inflate strength gains and thus misrepresent the true effect of a strength-training intervention on muscular strength (Rikli et al., 1996). After a brief familiarization set and two baseline 1 RM tests, no systematic differences were found between trials for the incline bench press ($p = .16$). However, significant differences were found between trials for the seated leg press ($p = .03$), which suggests a need for greater familiarization or more baseline tests for assessing lower body 1 RM. Phillips and colleagues (2006) found similar results when assessing reliability between 1 RM tests.

In addition to systematic error, participant variability (random error) may have been a limiting factor in this population secondary to their disease state. During this study, it was not uncommon for participants to report a decline in their physical and psychological conditions as a result of increased humidity, rainy conditions, allergies, or other upper respiratory distress. Such variability is difficult or impossible to control for and may have decreased participants' motivation and ability to perform testing or exercise training sessions. Thus, in studies of a clinical population, such as patients with COPD, factors contributing to random error should be addressed. Increasing sample size or standardizing or controlling for conditions and environmental factors may help minimize variability.

Other known limitations may have influenced the results of the current study and its generalizability to other populations with COPD. Small sample size is a common limitation in clinical research because of the variability of patients' health, and, as mentioned previously, increasing the sample size in future research studies may increase the chances of detecting significant differences between groups. In addition, because participants were taken from a convenience sample, the generalizability of the findings to other populations with COPD may not be warranted. Future research in this area should involve multiple-site recruitment to include participants with varying demographics.

The ES is an important yet underreported value that helps indicate whether research findings are meaningful (Cohen, 1988; Thomas, Salazar, & Landers, 1991). The ES represents the magnitude of the differences between an experimental (TR+ST) and a control (TR) group, which allows for a more informative interpretation of findings. Cohen (1988) suggested the following scale for correctly understanding ES: .2 represents small differences between groups, .5 moderate differences, and .8 large differences. Thus, despite non–statistically significant differences, moderate ESs were found for the chair-stand test ($p = .24$, ES = .55) and the 8-foot up-and-go test ($p = .24$, ES = .57), suggesting that strength training had a meaningful effect on these outcome measures and helped increase functional leg strength, agility, and balance (Rikli & Jones, 1999).

In conclusion, although nonsignificant differences in strength-induced FF benefits were found between the TR+ST and TR groups, ES suggests that the addition of strength training to traditional PR may improve participants' strength and their ability to perform FF tasks closely related to ADLs. However, because findings remain limited in the current literature, further research is needed to determine solid clinical practice guidelines for the application of strength training to PR. Rehabilitation nurses are encouraged to further explore and, if possible, conduct research trials to help clarify the role strength training plays in PR. For example, the following research questions could be addressed: "Will single- or multiple-set strength-training programs provide greater strength gains and improved FF among older patients with COPD?" and "Given program length and staffing limitations, if single-set strength training is used, what is the ideal progression of training intensity (e.g., load) and concomitant training volume during a program?" If strength training is a viable and necessary addition to PR, the most appropriate exercise prescription in regard to type, intensity, volume, frequency, duration, and progression must be explored to help patients with COPD achieve and maintain the highest possible level of independence and functional status (ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel, 1997).

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