The Effect of Single Set Resistance Training on Strength and Functional Fitness in Pulmonary Rehabilitation Patients

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- **PURPOSE:** The primary goal of pulmonary rehabilitation (PR) is for patients to achieve and maintain their maximum level of independence and functioning in the community. Traditional PR uses a predominantly aerobic/endurance approach to rehabilitation with little or no inclusion of exercises to increase strength. Few studies have investigated the impact of resistance training on PR despite growing evidence supporting its efficacy to improve physical function (functional fitness) in both healthy individuals and those with chronic disease. The purpose of this study was to investigate the effect of single-set resistance training on strength and functional fitness outcomes in PR patients.
- **METHODS:** Twenty PR patients, 60 to 81 years old, were randomly assigned to an 8-week endurance-based PR program (ET) or an ET plus resistance training program (RT).
- **RESULTS:** Strength increased in RT ($P < .05$) and decreased in ET for both upper and lower body. Functional fitness improved ($P < .05$) in 5 of 7 tests for RT compared with 2 tests for ET.
- **CONCLUSIONS:** Single set RT can elicit significant improvements in both strength and functional fitness, which is not obtained by traditional PR alone. Our results are comparable to other studies with similar outcomes using multiple-set RT protocols. These findings may have important implications for program design, application, and adherence in PR.

KEY WORDS

independence

physical function

resistance training

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INTRODUCTION

The primary goal of pulmonary rehabilitation (PR) is to achieve and maintain each individual's maximum level of independence and functioning in the community.[1] The National Center for Health Statistics and the Centers for Disease Control and Prevention have identified 2 components of physical function: *functional impairment*, defined as a limitation in mobility, and *physical disability*, defined as difficulty performing activities of daily living (ADL).[2] Rickli and Jones[3] have proposed an additional construct, "functional fitness," defined as the "physiological capacity to perform normal everyday activities safely and independently without undue fatigue." Designed to assist clinicians and researchers to assess physical parameters associated with functional ability, it consists of a battery of 6 tests of upper and lower body strength, endurance, agility, balance, and flexibility. Functional fitness (FF) is clearly important for persons with chronic obstructive pulmonary disease (COPD) who have skeletal muscle weakness, particularly of the lower extremities, which contributes to impaired functional health and increased use of health-care services.[4] It has been shown to be highly correlated with strength,[3,5] and furthermore, in community, living adults can be improved with resistance training (RT).[6,7]

Although RT has been recommended as safe and effective for both cardiac[8] and COPD patients[9] even at higher intensities,[10] it has received little attention in PR. In a recent systematic review, O'Shea et al[9] reported only 9 empirical studies that included RT as an intervention in PR and, with the exception of walking and cycling tasks, no FF outcomes were examined that could be regarded as impacting participants' "maximum level of independence and functioning in the community."[1] Furthermore, among studies not included in the review of O'Shea et al,[9] we found only 2 that addressed ADL-specific outcomes (ie, FF task performance) after the addition of RT to a conventional PR program. One of these reported improvements[11] and the other reported no change[12] in ADL performance.

Most RT programs implemented in a COPD population have used 3 sets of strength exercises performed 3 times per week.[9] However, such an approach is both time and staff intensive. In contrast, training protocols using only 1 set have been reported as improving both strength[13–15] and FF.[6,7] To date no RT studies have been reported that investigate the impact of single-set training on either strength or FF outcomes in individuals with COPD.

Purpose

The purposes of this study were (i) to evaluate the effect of a traditional endurance-based PR program on strength and FF in older individuals with COPD and (ii) to evaluate the complementary effects of a single-set RT program on these outcomes.

METHODS

Design

After completion of informed consent and collection of baseline measurements, participants were randomized into 1 of 2 groups: (*i*) the traditional endurance-based PR program (ET) or (*ii*) the ET program plus RT.

Participants

Twenty-four patients, aged 60 to 81 years, were recruited after initial referral to PR by their pulmonary physician due to a recent hospitalization, worsening of respiratory status, or forced expiratory volume in 1 second below 60% of predicted value. Inclusion criteria were a diagnosis of COPD, functional ability to participate in the resistance exercises, and willingness to accept random assignment to either the ET or RT group. Two individuals met inclusion criteria but were excluded from participation by physician recommendation due to unstable angina and a history of multiple inguinal hernia repairs. One participant was enrolled but was disenrolled from the PR program after week 4 due to generalized weakness and so was dropped from the study. Another participant withdrew due to the discovery of a lung mass presumed to be cancerous.

EVALUATION

Before admission to PR, a registered nurse obtained participants' demographics and medical history, including pulmonary functioning (forced expiratory volume in 1 second). Pulmonary function tests were completed by the hospital or referring physician within 3 months of entry into the PR program. Baseline evaluation of strength and FF was conducted during the first and second rehabilitation sessions. Participants were reevaluated during the last PR session.

Strength Testing

A 1 repetition maximum (1RM) test was administered to assess maximal upper and lower body strength of all subjects. A 1RM was defined as the maximum load able to be lifted with good technique through a full range of motion. All 1RM tests were conducted twice during the first week of PR, allowing at least 48 hours rest between tests, with the higher of the 2 values taken to represent the participant's maximal strength. Testing was conducted according to a standardized protocol[16] as described in Appendix 1.

One-Repetition-Maximum Test Reliability. We have previously reported that between 1 and 3 days of familiarization with 3 trials of 1RM are optimal for testing in older adult populations, but 2 trials can be sufficient.[17] Because the PR program provided only 16 sessions per patient (2 sessions per week for 8 weeks), any time used for familiarization and baseline measures would decrease the time available for training. Therefore, it was decided to limit reliability testing to the 2 representative major muscle groups for upper and lower body strength (incline chest press and leg press) to include the familiarization for these 2 lifts within the test sessions and to conduct 2 consecutive trials of 1RM. This allowed a total of 13 sessions for training after the use of 2 sessions for baseline testing and 1 for posttesting. Lifting range of motion was standardized for all participants by commencing each lift from a right angle at the elbow (chest press) and the knee (leg press) and by encouraging the completion of the lift to full extension. Identical testing procedures and machine settings were used preintervention and postintervention. The same researchers supervised all testing protocols.

FF Testing

Functional fitness was assessed by the Senior Fitness Test,[3] a well validated battery of 6 tasks (Modified Sit and Reach, Chair Stand, Scratch Test, Up and Go, Arm Curl, and 6-Minute Walk). Although initially developed and validated for use with community-dwelling older adults, we have also found it highly appropriate for cardiac rehabilitation settings.[18,19] The "Lift and Reach" test described by King et al[20] was administered as an additional functional assessment of upper body strength.

Functional fitness assessment was completed pre-RT and post-RT during the first and last PR sessions. All tests were conducted by trained researchers except the 6-Minute Walk Test, which was conducted as part of the traditional PR program by a registered nurse, exercise physiologist, or respiratory therapist according to the procedure recommended by Guyatt et al.[21] Before functional testing, the subject warmed up on an exercise bicycle for 5 minutes. In accordance with the protocol outlined by Rikli and Jones[3] and King et al,[20] each test was described and demonstrated by one of the researchers and the participant allowed to practice before commencement of the actual trial.

Training

PR Program

The PR program consisted of exercise training, education, breathing retraining, and psychosocial support. The program was administered by an interdisciplinary team consisting of registered nurses, respiratory therapists, exercise physiologists, registered dietitians, and occupational therapists. Patients with COPD attended the program for 16 sessions, ideally 2 sessions a week for 8 weeks.

The 8-week PR training program (ET) consisted of upper and lower body aerobic, endurance-type exercises. Blood pressure, resting heart rate, and oxygen saturation of hemoglobin were assessed before, at midsession, and after exercise. In addition, participants were monitored continuously by telemetry. Ratings of perceived exertion (RPE) and ratings of perceived breathlessness (RPB) were assessed regularly during each exercise. Upper extremity training was conducted on a Monark arm ergometer (Rehab Trainer 881E, Quinton, Seattle, Wash). Lower extremity training was performed on a motor-driven treadmill (Trackmaster TM-210, Carrollton, Tex), an Air Dyne stationary cycle (Schwinn, Chicago, Ill), or a NuStep Total Body Recumbent Stepper (NuStep Inc, Ann Arbor, Mich). The training goal was to accumulate 20 to 40 minutes of aerobic exercise per session by the end of the 8-week program. Training intensity was set at approximately 3 METS to maintain RPE < 13 (somewhat hard), RPB ≤ 3 (moderate), and oxygen saturation $\geq 90\%$.

As part of the traditional PR program, patients also performed low-intensity RT using handheld dumbbells. Initially, 2- or 3-lb weights were used to complete 8 to 10 repetitions for 6 exercises (arm curl, lateral torso bend, lateral arm raise, wrist curl, standing triceps extension, and shoulder abduction with arms flexed). Participants were encouraged to increase the number of repetitions (2–3) each session as long as RPE remained ≤ 13. Training load was increased when the participant could complete 16 to 18 repetitions without distress, at which time the number of repetitions was decreased to 8 to 10. At the end of 8 weeks, training weights for this part of the PR program averaged 5 to 8 lb for the ET group and 5 to 10 lb for the RT group.

Resistance Training

Resistance training consisted of 5 exercises (incline chest press, seated leg press, lat pulldown, cable triceps pushdown, and cable biceps curl). All exercises were performed using Universal Dynamic Variable Resistance training equipment (Cedar Rapids, Iowa). Training intensity of the chest and leg press exercises was determined by 1RM values assessed at baseline. Participants exercised initially with a load that was set at approximately 50% of 1RM. For the remaining 3 exercises, participants commenced with light loads sufficient to allow appropriate familiarization with equipment and lifting technique. For subsequent sessions, increases in resistance load were determined by successful completion of 10 repetitions of an exercise. When this occurred, the load was increased at the next session by 5% to 10% as tolerated. The RT group performed their exercises immediately preceding or after their regular endurance-based PR program as determined by the PR staff, who were responsible for integrating the RT program into PR with the least disruption possible. Of the 16 PR sessions, 13 were used for RT, and the remaining 3 sessions were used for pretesting (2 sessions) and posttesting (1 session).

Statistical Analysis

All data collected were analyzed using the SPSS7® program for Windows™ (SPSS, Inc, Chicago, Ill). Baseline participant characteristics were compared using descriptive statistics. All prescores and postscores were reported as mean ± SE. A multiple linear regression analysis was used to examine posttest differences between groups in maximal strength and FF. Paired *t* tests were used to assess significant changes within groups. Although multiple comparisons were made, a post hoc Bonferroni was not used in the analysis.[22] The alpha level for all tests was set at $P \leq .05$.

RESULTS

A total of 20 participants completed the 8-week rehabilitation program. One member of the RT group developed low back pain between weeks 2 and 3 of the study period and chose not to continue in the RT group. This participant entered the ET group, continued with the regular PR program, and completed the posttests for strength and FF at the end of the 8-week study period. Another participant in the ET group with a history of bilateral hip surgery complained of hip pain during week 2 of the study. This participant chose to continue in the ET group but was not posttested for 1 strength measure (1RM leg press) or 1 FF measure (chair stand). Finally, one member of the ET group was excluded from the analysis as an outlier due to anomalous changes in strength measurements (chest press = 15 lb, leg press = 82 lb), which were >2 SDs from mean values (7 and 12 lb, respectively). Participants in both groups who were oxygen dependent completed all tests and training with oxygen intact. Compensation was made during testing by having research or PR staff members provide assistance to carry or manipulate oxygen containers.

Characteristics of both groups were similar at baseline for gender, age, and body mass index (Table 1). Because of randomization in group assignment, the ET group included 6 participants who used oxygen during exercise, whereas 3 members of the RT group used oxygen. However, pulse oximetry was used to verify adequate gas exchange while exercising, and no negative respiratory or cardiovascular outcomes occurred during either testing or training. Blood pressure and heart rate changes were well tolerated, with no clinically important differences between groups in mean or maximal values during exercise sessions (Table 1). Values of RPB and RPE were not different between groups, and RPE did not exceed moderate intensity (Table 1). Attendance for the RT sessions was 100%. Although members of the RT group were given the option of participating only in the traditional PR program at each session, there were no sessions at which a participant chose this option.

Strength Outcomes

Strength significantly increased in the RT group for chest press and leg press and decreased for both of these exercises in the ET group. There were significant posttest differences between groups for both chest press and leg press (Table 2).

Reliability. Test-retest values for baseline 1RM were highly correlated for chest press ($r = 0.99$, $P < .05$) and leg press ($r = 0.97$, $P < .05$). In addition, a paired *t* test found no significant differences between the 2 baseline 1RM trials for chest press. A significant difference was found between the 2 baseline trials for leg press ($P < .01$).

FF Outcomes

Functional fitness improved significantly in the RT group for all measures except the 2 flexibility tests (Modified Sit and Reach and Scratch test). Although the ET group also improved in all FF measures, only the Arm Curl and 6-Minute Walk tests reached significance. Finally, significant differences between groups were found for the Lift and Reach (Table 3).

DISCUSSION

Strength Changes

This is the first study to report the impact of single-set RT on both strength and FF in patients with COPD. After the 8-week program, strength significantly increased ($P < .05$) by 14% for chest press and 9% for leg press in the RT group and decreased by 2% and 4%, respectively, in the ET group. The reliability of the baseline

Table 1 · PARTICIPANT CHARACTERISTICS

	ET (n = 9)	RT (n = 10)
Baseline Measures		
Gender (F/M)	8/1	6/4
Age, y	70 ± 2	71 ± 1
BMI, kg/m^2	26.1 ± 1.3	28.5 ± 1.8
O_2 dependent	6	3
FEV_1, L	0.74 ± 0.15	1.11 ± 0.14
FEV_1 (% predicted)	32.8 ± 6.2	42.0 ± 3.2
FEV_1/FVC	39.0 ± 3.9	52.2 ± 4.9
Mean resting HR, bpm	89 ± 3	89 ± 5
Mean resting SBP	120 ± 3	126 ± 2
Mean resting DBP	67 ± 2	66 ± 2
Training Session Measures		
Absolute maximal HR, bpm	126 ± 3	136 ± 6
Mean maximal HR, bpm	113 ± 3	118 ± 5
Mean maximal SBP	144 ± 4	145 ± 3
Mean maximal DBP	76 ± 3	73 ± 2
Mean RPE	11 ± .3	12 ± .2
Mean RPB	2 ± .2	3 ± .2

ET indicates endurance-based pulmonary rehabilitation program; RT, resistance training.; F, female; M, male; BMI, body mass index; FEV_1, forced expiratory volume in 1 second; FEV_1/FVC, ratio of forced expiratory volume in 1 second to forced vital capacity; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; RPE, Rating of Perceived Exertion (6-20 scale); RPB, Rating of Perceived Breathlessness (0–10 scale).
Data are presented as means ± SE.
No significant differences were found between groups ($P \leq .05$).

Table 2 · STRENGTH OUTCOMES

Outcome	Pre-ET (SE)	Post-ET (SE)	ET Change (SE)	ET % Change	Pre-RT (SE)	Post-RT (SE)	RT Change (SE)	RT % Change
1RM chest press, lb	52 (6)	51 (6)	−1 (2)	−2%	63 (8)	72 (8)	9*† (1)	14%
1RM leg press, lb	174 (19)	167 (19)	−7 (4)	−4%	204 (29)	224 (28)	20*† (6)	9%

ET indicates endurance-based pulmonary rehabilitation program; RT, resistance training; 1RM, 1 repetition maximum.
Data are presented as means ± SE.
*Significant within groups ($P < .05$).
†Significant between groups ($P < .05$).

1RM for chest press was high ($r = 0.99$, $P < .05$). The leg press 1RM showed a similarly high correlation ($r = 0.97$, $P < .05$) but also showed a significant difference between trial 1 and trial 2 at baseline. The implication of this is that our baseline leg press 1RM may have been underestimated, resulting in an overestimation of the "true" strength gains in this study. However, our research[17] and that of others[23] report that differences between the second and third trials, when conducted, are likely to be too small to be meaningful and/or nonsignificant. In addition, a smaller reported increase in strength would only serve to strengthen the relationship between strength and FF measures.

Although the RT group included a larger percentage of men than did the ET group, this was not felt to bias the outcome. Fiatarone et al[24] found no difference in strengths gains between elderly men and women as a result of an 8-week RT protocol. Furthermore, Hakkinen et al[25] found that although gender differences existed in baseline strength, both men and women increased strength equally and proportionately as a result of RT.

Strength gains in our study are somewhat lower than the 20% to 36% increases in upper and lower body, which have typically been reported in PR programs.[11,26–30] Such disparities are perhaps to be expected because of differences in frequency, intensity, and duration of training. Our study frequency (twice per week) and duration (8 weeks) are among the lowest reported in the literature,[9,11,12] and we are the only published study to date that has used a single-set protocol.

FF Changes

In the RT group, FF significantly improved ($P < .05$) in all measures except flexibility, whereas improvements in the ET group were significant only for the Arm Curl and 6-Minute Walk. Furthermore, a significant difference ($P < .05$) between the RT and ET groups was found for the Lift and Reach test (Table 3). This is an important finding because many individuals with COPD report disabling dyspnea triggered by daily activities involving the upper extremities.[31,32] Although the FF test battery reported here has not previously been used with COPD patients, it has not only been validated with community-dwelling older adults[3] but has also been successfully used to measure FF in a cardiac

Table 3 · FUNCTIONAL FITNESS TEST OUTCOMES

Test	Pre-ET (SE)	Post-ET (SE)	ET Change (SE)	ET % Change	Pre-RT (SE)	Post-RT (SE)	RT Change (SE)	RT % Change
Modified Sit and Reach, in	−3.06 (1.4)	−2.58 (1.4)	0.48 (0.52)	16%	−3.1 (0.83)	−3.25 (1.2)	−0.15 (0.83)	−5%
Chair Stand (repetitions)	11 (1)	12 (1)	1 (1)	9%	10 (1)	13 (1)	3* (1)	30%
Scratch Test, in	−3.92 (1.4)	−3.81 (1.3)	0.11 (0.75)	3%	−4.72 (1.4)	−3.95 (1.3)	0.77 (0.38)	16%
Up and Go, s	6.1 (0.28)	6.05 (0.25)	0.05 (0.13)	1%	7.44 (0.59)	6.45 (0.31)	0.99* (0.39)	13%
Arm Curl (repetitions)	10 (1)	13 (1)	3* (1)	30%	11 (1)	16 (1)	5* (1)	45%
6-min Walk, ft	951 (92)	1,154 (75)	203* (80)	21%	889 (116)	1,112 (117)	223* (53)	25%
Lift and Reach (repetitions)	12 (1)	15 (1)	3 (1)	25%	11 (1)	17 (1)	6*† (1)	55%

ET indicates endurance-based pulmonary rehabilitation program; RT, resistance training.
Data are presented as means ± SE.
*Significant within groups ($P < .05$).
†Significant between groups ($P < .05$).

rehabilitation population.[33] Test-retest reliability for all 6 tests used in this study is high, with *R* values ranging from 0.81 (arm curl) to 0.96 (scratch test).[3]

Only 2 other studies[11,12] have evaluated the effects of a concurrent RT program compared with traditional PR using ADL outcomes. After a 6-week daily exercise program, Ries et al[12] reported significant improvement in measures of muscular endurance but no improvement in 3 ADL-related tasks (dishwashing, loading grocery shelves, and simulated window cleaning). However, this was a home-based RT program and used only low resistance–high repetition upper body exercises, compared with our outpatient-based moderate-high resistance upper and lower body training program.

In contrast to Ries et al,[12] but in parallel with the findings of our current study, Panton et al[11] reported significant improvements in 8 simulated ADL tasks after RT, although there was little change in these measures after traditional PR. Outcomes included both low-level physical tasks (eg, buttoning and folding shirts) and more strenuous tasks such as a 15-meter Up and Go test (vs 8 feet in our study) and a 1-minute Chair Stand test (vs 30 seconds in our study). The authors also reported a significant 36% increase in both upper and lower body strength, notably greater than our respective 14% and 9% increases. However, these positive findings were achieved with an RT protocol considerably more strenuous and time consuming than that of our study. In the study of Panton et al,[11] RT participants performed 3 sets of 12 exercises twice a week for 12 weeks. Each session lasted 45 to 60 minutes in addition to their twice per week regular PR program. In contrast, our RT group performed 1 set of 5 exercises twice a week for 8 weeks, with the RT exercises integrated with their PR program and completed within the timeframe of their regular PR session. The 5 RT exercises took approximately 10 minutes to perform once the participants were familiarized with correct lifting technique.

Although single-set RT has been recommended as an effective approach for increasing strength in healthy adults,[13,34] multiple-set RT has been reported as producing greater strength gains.[35] However, the important consideration here may not be the absolute magnitude of the differences in strength gains between our single-set protocol and the multiple-set protocol of Panton et al,[11] but rather how these gains impact functional performance. Buchner et al[36,37] and others[38] have reported data indicating the existence of an ADL-related "threshold" of strength in older adults. For individuals at or below this threshold, an increase in strength may elicit improvements in ADL performance, whereas for those above this strength threshold, increases in strength may not elicit additional improvements in FF. The results of our study and that of Panton et al[11] fit well with this concept because both elicited analogous improvements in FF outcomes that do not seem to be differentiated by the substantial differences in training protocols or magnitude of strength gains.

Some improvement in FF outcomes was expected for ET as a consequence of the training effect of the traditional PR program. Other authors[39] have reported significant differences in self-reported ADL scores after a traditional PR program compared with a wait list control group. However, although in our study, improvements were found in all FF outcomes for the ET group (Table 3), some of these were very small and none reached significance apart from the Arm Curl and 6-Minute Walk. The Arm Curl is not an outcome typically reported in traditional PR programs and its improvement may be a consequence of the traditional program's inclusion of upper body exercises.

The 6-Minute Walk is a commonly reported outcome typically improved after traditional PR.[40] However, for PR studies involving RT, reported differences in 6-Minute Walk outcomes have been inconsistent. In our study, both ET (21%) and RT (25%) reported significant improvements (Table 3), with no significant additional benefit accruing to the RT group. This is in agreement with Bernard et al[28] and Spruit el al,[30] who also found improvements for both RT and ET groups. In contrast, Troosters et al[41] reported significant improvements in 6-Minute Walk for RT but not for nonexercising controls, whereas Simpson et al[26] reported no improvements in 6-Minute Walk for either RT or nonexercising controls. On review of the evidence, O'Shea et al[9] have reported only weak evidence for RT-induced improvements in walking performance in PR. Further studies need to be conducted to clarify this relationship.

CONCLUSION

In conclusion, we have shown that the addition of RT to a traditional PR program can elicit significant improvements in both strength and FF that are not obtained by traditional PR alone. Furthermore, we have demonstrated that a single-set RT protocol can produce improvements in FF that are comparable to studies using a multiple-set RT design. Single-set training enabled all participants in the RT group to comfortably complete their training within the scheduled PR session without diminishing the effectiveness of the traditional PR program. Adherence in our study was 100%, notably higher than has typically been reported for RT programs in this population.[9] It is not unreasonable to assume that this may have been a consequence of the short duration and convenience of our single-set protocol. We feel that these findings not only have important implications for program design but also highlight the importance of broadening program goals so that PR can be appreciated and evaluated as being functionally and clinically relevant.

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APPENDIX 1

Example Protocol/Script for Determination of 1RM*—Chest Press

Note: This protocol is explained and demonstrated to participants during the familiarization period and again immediately before testing.

1. Explain which muscle groups the lift primarily affects.
   "The chest press primarily affects the muscles of the chest and back of the upper arm."
   Note: Tester points to muscle locations as part of explanation.
2. Demonstrate lift with accompanying verbal explanation.
3. Position participant in basic lifting position.
   "Lie on the bench with your head toward the bar."
   "Place your feet on either side or on top of the bench, whichever is most comfortable."
   Note: Tester checks for excessive arching of back by sliding the hand under lumbar spine and adjusts feet/body position accordingly.
4. Explain and/or demonstrate correct grip.
   "Grasp the bar firmly at the positions indicated."
   Note: Hands are positioned so that a right angle is obtained at the elbow, forearms are vertical and elbows are directly beneath bar.
5. Ensure body position is correct.
   "Make sure your body is in the center of the bench and your back is flat."
   Note: Test checks for excessive arching of back and adjusts the feet/body accordingly.
6. Ensure the bar is positioned in the correct starting position.
   "Make sure the bar is directly over your mid-chest area and your elbows are vertical."
   Note: Body position is monitored and recorded by tester.
7. Adjust the starting height of bar (where appropriate).
   "For the chest press, your elbow joint should be at 90 degrees."
   Note: Bar position is noted and recorded by tester.
8. Remind participant about correct breathing technique.
   "Take a breath in to prepare for the lift and then breathe out as you push the bar steadily upward."
   "Blow the bar up."
   "Breathe in as you lower the bar steadily."
9. Perform several lifts at low or zero resistance to reestablish familiarity with movement and correct lifting technique. Encourage and monitor the technique at all times.
10. Set initial resistance at a level slightly above that of the warm-up resistance (ie, 1 or 2 blocks, 5-15 lb). This will vary between participants according to their perceived/observed effort during the warm-up.
11. Perform 1 lift with good technique.
12. Ask participants to rate how hard they perceived the lift to be (Rating of Perceived Exertion) on a scale of 6 ("very, very easy") to 20 ("the most I could possibly do").
    Note: Test monitors' difficulty of lift by observing the speed/effort at which it is performed by the participant.

*A 1RM is defined as the maximum amount of weight that can be lifted one time with good form.