Progressive Resistance Muscle Strength Training of Hospitalized Frail Elderly

ABSTRACT


Objective: To determine whether frail elderly patients recuperating from acute illnesses could safely participate in and gain appreciable improvement in muscle strength from progressive resistance muscle strength training.

Design: Muscle strength (one repetition maximum), functional abilities (sit-to-stand maneuver and 20-sec maximal safe gait speed), and body composition were measured before and at the conclusion of a 10-wk program of lower limb progressive resistance muscle strength training. The nonrandomized study was conducted in a 30-bed geriatric rehabilitation unit of a university-affiliated Veterans Affairs hospital and a 28-bed transitional care unit of a community nursing home. Participants included 19 recuperating elderly subjects (14 male, 5 female; 13 ambulatory, 6 nonambulatory) >64 yr (mean age, 82.8 ± 7.9 yr).

Results: The one repetition maximum increased an average of 74% ± 49% (median, 70%; interquartile range, 38%–95%), and an average of 20 ± 13 kg (P = 0.0001). Sit-to-stand maneuver times improved in 15 of 19 cases (79%). Maximum safe gait speeds improved in 10 of 19 cases (53%). Four of the six nonambulatory subjects progressed to ambulatory status. No subject experienced a complication.

Conclusions: A carefully monitored program of progressive resistance muscle strength training to regain muscle strength is a safe and possibly effective method for frail elderly recuperating from acute illnesses. A randomized control study is needed to examine the degree to which progressive resistance muscle strength training offers advantages, if any, over routine posthospital care that includes traditional low-intensity physical therapy.

Key Words: Geriatrics, Physical Therapy, Weight Lifting, Exercise
As a consequence of illness or major surgery, many hospitalized elderly patients become profoundly debilitated. Even with conventional physical therapy and the reestablishment of adequate nutrient intake, recovery of lost muscle mass and strength is often very slow. Supervening complications frequently occur during this period of recovery and often lead to further clinical deterioration or death. Because complication rates during periods of postillness disability are high and protein and energy stores and muscle strength replete slowly using current treatment modalities, alternate therapies, progressive resistance muscle strength training (PRMST) using weight-lifting machines holds great promise. When used alone or in combination with nutritional supplementation, PRMST has been shown to be a safe and effective means of increasing muscle mass and strength and improving functional status in frail elderly subjects residing in the community and in long-term care facilities. However, there is very little experience using such an approach to treat frail elderly hospitalized patients who are in the recuperative phases of acute illnesses.

To investigate this issue further, we conducted a nonrandomized, 10-wk study to determine the following: (1) whether frail elderly patients in the recuperative phases of acute illnesses could safely participate in exercise programs of PRMST at least 3 times per week; and (2) whether the interventions would produce appreciable improvements in muscle strength. The study focused on leg extension exercises because knee and hip extensors are essential for performing independent activities, such as walking, stair climbing, and rising from a chair. A secondary objective was to determine whether improved strength correlated with a change in functional performance. The ultimate objective was to build the foundation for further randomized, controlled studies.

METHODS

Patient Accrual

The study was conducted at a 30-bed geriatric rehabilitation and recuperative care unit of a university-affiliated Veterans Administration hospital and a 28-bed transitional care unit of a community nursing home. All subjects were initially recruited as inpatients from one of the two sites. Inclusion criteria included age >64 yr, recent and potentially reversible functional decline secondary to surgery or medical illness, and the ability to give informed consent. Prospective subjects were excluded from the study if they had documentation of a near-terminal medical disorder (including advanced heart, lung, kidney, or liver failure resistant to medical management), an unresolved malignancy (with the exception of nonmetastatic skin cancer or prostate cancer), treatment with chemotherapy or a pharmacologic dose of steroids, severe cognitive impairment (Mini-Mental State Exam score <10 or otherwise judged unable to understand and comply with the treatment protocol), disabling arthritis or irreversible neurologic disease that made the goal of independent ambulation unrealistic (patients with hip or knee prostheses had to be cleared by their orthopedic surgeon), unstable cardiovascular disease (i.e., unstable angina), and/or untreated hypo- or hyperthyroidism.

In accordance with the ethical standards of the Department of Veterans Affairs and the Human Research Advisory Committee of the University of Arkansas for Medical Sciences, all subjects received oral and written explanations of the study, including possible risks involved, and signed informed consent documents before entering the study.

Along with other patients in the unit, all study subjects received standard nutritional care and continued their participation in the customary rehabilitation program of functional, goal-directed treatments. Subjects who were released from the hospital before the study was completed remained in the program on an outpatient basis.

Overview of Protocol

Subjects trained 3 days per week for 10 wk. As described below, warm-up exercises preceded each training session to loosen muscles and joints. Subjects then performed three sets (eight repetitions per set) of leg presses on a hip extension–leg press chair (Body Solid Leg Press, Spirit Direct, Jonesboro, AR). The rate at which a subject performed successive repetitions was adjusted as necessary to prevent the pulse rate from increasing to >110 beats per minute. Subjects rested 3–5 min between sets. The exercise supervisor monitored every session to make certain that each subject performed the exercises using correct techniques. Each subject’s pulse and blood pressure (BP) were checked at the end of every one or two sets. Trainers were told to terminate sessions immediately if a subject experienced chest pain, severe shortness of breath, lightheadedness, an increase in the pulse to >140 beats per minute, sustained elevation in BP of >200/110, or a drop in BP of >20 mm Hg. Subjects were also encouraged to terminate a session whenever they felt too weak or too ill to continue. These criteria were developed by an expert panel of three geriatricians and a cardiologist and were designed to minimize aerobic cardiovascular stress.

Schedule

Week 1. The first week of the protocol involved very low intensity training.
During this period of the study, each subject became familiar with the protocol, received instructions on the proper techniques for using the weight-lifting equipment including the correct breathing method, and completed the following series of functional tests and body composition measurements. Sit-to-stand maneuver—subjects were instructed to stand as rapidly as possible from a seated position in a locked wheelchair, while keeping their arms folded across their chests. The events were recorded using a handheld stopwatch to the nearest 0.1 sec beginning at the command to start and ending at the moment the subjects were fully erect. The average of three trials was used. If they could not complete the testing in this manner, they completed a second test in which they were allowed to use their arms to push off from the arm rests. Both methods were highly reliable, with test-retest correlation coefficients of 0.97 or better (\( P < 0.001 \)) for both methods. The same observer performed all functional testing throughout the study. Maximal safe gait speed—subjects were instructed to walk as rapidly as possible, while maintaining their balance and avoiding undue fatigue. If they were unable to ambulate independently, they were given an alternate test in which they were allowed to walk behind a wheelchair or walker. The distance to the nearest foot that the subject could walk within 20 sec was recorded. The best of two trials was used with a test-retest correlation coefficient of 0.98 or better (\( P < 0.001 \)) for each of the methods. Body composition—measurements of weight and height, plus a bioelectrical impedance analysis, were taken from which total body water and lean and fat mass were calculated.

**Week 2.** The first session was dedicated to testing to determine the maximal weight that could be lifted correctly in a single repetition (i.e., one repetition maximum (IRM)). During this session, the subject was attached to a continuous monitoring electrocardiogram and had BP checks every 4–5 min. Starting at a weight that the subject could easily lift, additional weight was added in small increments (1–5 kg), with 30-sec rests between lifts, until the maximum weight the subject could fully lift was reached. Test-retest reliability was evaluated in 15 subjects who either entered or were eligible to enter the study. Testing was completed at baseline and again 3 days later with a test-retest correlation coefficient of 0.99 (\( P < 0.001 \)). The IRM served as the basis for setting the exercise training resistance for subsequent sessions. For the last two sessions of the week, subjects worked out at 50% of their IRM. At the start of each of these sessions, the patient warmed up by completing one set at 25% of their IRM.

**Weeks 3–10.** At the first session of week 3, training resistance increased to 80% of IRM. For all remaining sessions, workout resistance was increased after each set as tolerated by the subject. If a subject could not complete a set, the weight was returned to the prior level. At the start of each session (weeks 3 through 10), subjects warmed up by completing one set at approximately 30% and a second set at 60% of their IRM.

**Week 10.** Body composition measurements and functional and strength testing were repeated at the last session of week 10.

### Functional Test Scores

Because some of the subjects were unable to perform the functional tests at the beginning of the study, percent change in functional performance times could not be determined. Instead, ordinal performance scales were developed to objectively assess improvement. Both functional tests were scored on a three-point scale. Points were assigned for each task as follows: 0 = cannot complete task without the physical support by another person; 1 = needs Assistive device to complete task (e.g., use of arms for standing or device for walking); 2 = completes task independently. After retesting at the end of the study, individual scores were considered significantly improved if a subject advanced at least one level (e.g., from 0 to 1) or if a subject’s initial score was 2 and the individual test performance improved by >25%.

### Statistics

Tests of hypotheses between results taken at the beginning and at the end of the study were declared significant at the 0.05 level. A paired \( t \) test was used to test whether strength differences over time were significantly different than 0. Variables that had skewed distributions were log transformed before analysis (e.g., leg strength was expressed on a logarithmic scale, with differences expressed as percent change). Correlates of strength improvement of >20% were identified using a non-paired \( t \) test. For each functional test, subjects were classified as to whether their performance significantly improved between the start and end of the study. No subject experienced a significant deterioration in function. The relation between change in leg strength (IRM) and “significant improvement” was evaluated using a nonpaired \( t \) test. The data were analyzed using SAS Institute software. 23

### RESULTS

A total of 19 subjects (14 male, 5 female) were included in the study. They ranged in age from 69 to 97 yr (mean, 82.8 ± 7.9 yr), and all had experienced a recent decline in their level of physical functioning. At study entry, two subjects lacked adequate strength to walk, four subjects could
only walk short distances (<20 feet) with significant physical support of another person, and two subjects ambulated <50 feet with the aid of a walker. Although their strength was limited, the remaining subjects could ambulate >50 feet independently or with the aid of a cane. On average, the subjects were taking six medications and had 3.2 active and 5.9 stable medical problems. Although all of the subjects had multiple active medical problems that contributed to their hospitalizations, the most common primary diagnostic categories included congestive heart failure (five subjects), bronchitis/emphysema (six subjects), serious infections (six subjects), and diabetes (two subjects). Eight of the subjects had protein-energy undernutrition listed as a problem. All were listed as being debilitated.

The results of the initial and final functional and strength (1RM) testing are presented in Table 1 and Figure 1. On initial testing, six subjects were unable to rise from the chair and two subjects could only do so using their hands to push off. As mentioned previously, six subjects could not complete the timed walk test without physical support by another person. On final testing, all subjects could rise from a chair, although three subjects could do so only when using their hands to push off. All but two subjects were able to complete the final test of ambulatory function without the physical support of another person. Both of the subjects who remained nonambulatory had severe pulmonary disease (methotrexate-induced pulmonary fibrosis or advanced chronic obstructive pulmonary disease). Overall, 15 subjects (79%) met our criteria for

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Results of initial and final functional and strength (one repetition maximum) tests</th>
</tr>
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<tbody>
<tr>
<td>Leg Strength</td>
<td>Sit-to-Stand Maneuver</td>
</tr>
<tr>
<td>Patient No.</td>
<td>Initial (kg)</td>
</tr>
<tr>
<td>1</td>
<td>18.2</td>
</tr>
<tr>
<td>2</td>
<td>47.7</td>
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<td>3</td>
<td>13.6</td>
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<td>4</td>
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<td>5</td>
<td>47.7</td>
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<td>6</td>
<td>22.7</td>
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<td>7</td>
<td>3.2</td>
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<td>8</td>
<td>37.3</td>
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<td>9</td>
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<tr>
<td>18</td>
<td>22.7</td>
</tr>
<tr>
<td>19</td>
<td>77.3</td>
</tr>
</tbody>
</table>

aSit-to-stand maneuver score: U = unable (cannot perform maneuver without human assistance); H = hands (can perform maneuver only by pushing on arms of chair with hands), I = independent (can perform maneuver unassisted).

bP = 25% improvement (unassisted performance time improved by >25% over initial test).

cSignificant improvement was defined as either a subject advancing at least one level (e.g., from U to H) or if a subject’s unassisted performance time improved by >25% (see text for details); Y = Yes, N = No.

dMaximal safe gait speed score: U = unable (cannot perform exercise without human assistance), W = walker (can only perform maneuver using aid of walker or wheelchair), I = independent (can perform exercise unassisted).

eP = 25% improvement (distance walked unassisted increased by >25% over initial test).

Figure 1. Change in leg strength (one repetition maximum) over 10-wk study period.
significant improvement in the sit-to-stand maneuver and ten subjects (53%) did so for the 20-sec maximal-safe gait speed test.

Compared with baseline, leg strength (1RM) increased by an average of 74% ± 49% (median, 70%; interquartile range 38%–95%; average, 20 ± 13 kg; \(P = 0.0001\)). All but two subjects improved their leg strength by >20%. Compared with the other subjects, the two subjects who did not improve had less body fat (32.4% ± 9.9% vs. 9.5% ± 7.8%; \(P < 0.01\)), smaller midarm circumference (26.6 ± 4.5 cm vs. 19.6 ± 0.1 cm; \(P < 0.001\)) and thigh skinfold thickness (21.6 ± 14.4 cm vs. 5.2 ± 2.6 cm; \(P = 0.001\)), and a somewhat lower body mass index (23.9 ± 5.2 vs. 18.5 ± 7.8; \(P = 0.19\)). Change in strength, when expressed in absolute terms or as percent improvement over baseline, did not correlate with significant improvement in either functional test (\(P > 0.5\) for all analyses). There was a weak (although nonsignificant) correlation between strength gain expressed as a percentage of body weight and significant improvement in maximal safe gait speed. The subjects whose gait speed improved had the greater strength gains compared with the remaining subjects (39.4% ± 16.8% of body weight vs. 29.0 ± 14.0% of body weight; \(P = 0.17\)).

The median weight gain during the study was 1.3 kg (range, -5.5 to 7.4 kg). Based on the bioelectrical impedance analysis measurements, the median change in lean body mass was 0.8 kg. However, lean body mass change ranged from a loss of 7.9 kg to a gain of 10.8 kg, suggesting that much of the change may have been secondary to fluctuations in total body water. There was no correlation between percent strength gain and change in either body weight or lean body mass (\(P > 0.4\) for both analyses).

Two subjects (12 and 15) experienced problems with BP control during the time they participated in the study. For each subject, it was necessary to cancel two different exercise sessions because the subject’s BP was >200/110 before initiating the warm-up exercises. After their antihypertensive medications were adjusted, both subjects completed the study without further incident. No subject experienced any other cardiovascular- or joint-related problems while participating in the study. It was not possible to monitor BP response during each lift. Based on measurements taken between sets, no subject developed a dangerous rise or fall in BP during an exercise session. The amount of time between each lift and between sets was adjusted as necessary to keep each subject’s pulse rate from exceeding 110 beats per minute. Several subjects had to be reminded frequently to slow down because they had a tendency to rush through the exercises, which precipitated rises in their heart rates. Whenever this occurred, several subjects increased their frequency of premature ventricular complexes, and one subject developed multiple three-beat runs of ventricular tachycardia. In all cases, the arrhythmias resolved completely when the subjects slowed down their rate of exercise.

**DISCUSSION**

The purpose of this study was to establish the safety and feasibility of using PRMST as an adjunct to traditional physical therapy among frail elderly patients who are in the recuperative phases of recent acute illnesses. This is the first evaluation of PRMST among this patient population. Although prior studies have established the effectiveness of this therapeutic modality in improving the strength and functionality of older individuals residing in the community or in long-term care institutions,\(^\text{15–19}\) it is not necessarily valid to extrapolate these results to recuperative care patients whose recent acute illnesses and consequential functional decline distinguish them from the other groups.

Elderly patients admitted to recuperative care units present a unique rehabilitation challenge. Even with conventional physical therapy, which usually does not include high-intensity weight training, older patients’ recovery from the debilitating effects of recent illnesses or surgeries is often slow and incomplete.\(^\text{4,5,7,10,11,24}\) While on the recuperative care units, supervening complications occur frequently (between 33% to 40% of cases in recent series) and often negate any gains made toward functional recovery.\(^\text{10,24}\) Up to 13% of these patients reportedly die before discharge.\(^\text{10,24}\)

Part of the reason for these poor outcomes may relate to the fact that conventional physical therapy, even in combination with an aggressive program of nutritional repletion, often does not adequately restore lost muscle mass or strength.\(^\text{5–7}\) Failure of elderly recuperative care patients to completely recover to preillness levels of physical function may be causally related to an increased risk for other adverse outcomes. Whether PRMST is more effective than conventional physical therapy in improving outcomes in this high-risk population remains to be determined.

In this study, there was considerable variance in individual responses to the training. Although motivation and effort are important determinants of response, other factors such as unrecognized ongoing inflammation or other metabolic derangements may also have contributed to this variance. This is suggested by the fact that all of the subjects were recuperating from a recent illness and several had a recent serious infection. This study was not funded or powered to investigate these issues. However, it may be important to investigate these factors in the future because they may effect the response of muscle to exercise.\(^\text{17,25,26}\)

The reasons for the lack of correlation between leg strength and im-
improvement in functional performance in the study are unclear. It may relate to the fact that leg strength is only one of several factors important to ambulatory ability.27 Patients may have had difficulties in other areas such as joint mobility, balance, and muscle coordination, and these important factors were not examined in this study. A study with a larger sample size is needed to investigate these relationships.

That there was no correlation in the study between improvement in muscle strength and changes in total or lean body mass is not surprising. The methods used in the study to assess body composition changes were rather crude. Most of the weight changes probably represented fluctuations in total water, a common problem in frail elderly patients during posthospitalization. These results indicate that more specific measures of muscle mass, such as nuclear magnetic spectroscopy or cross-sectional imaging of the thighs, are needed to more accurately assess changes in body composition in response to PRMST.

Weight-lifting equipment is much more expensive, less readily available, and far more difficult to transport than free weights, sandbags, dumbbells, and elastic bands. Despite these limitations, weight-lifting equipment was used in this study because the current literature suggests that it is safer and more effective than these handheld apparatuses. In a randomized study of 110 elderly subjects participating in a moderate resistance muscle strength training program using dumbbells and sandbags, 20% developed low-back or joint pain as a result of the exercises.28 Although all subjects responded to conservative management and completed the training program, resistance levels had to be lowered. In contrast, even with high-resistance training (80% of 1RM), injury rates for frail elderly trained on exercise machines were in the lower ranges of 1% to 3% and all injuries were minor.15–18 Compared with these smaller individual pieces of equipment that are often used for strength training in the elderly, a weight-lifting machine provides stabilization for the spine and pelvis, greater control of movement during each repetition, and lower potential for muscle substitution.28 Possibly for these reasons, joint, ligament, and muscle strain is less apt to occur, and there is a greater likelihood that the targeted resistance will be accepted by the patient. Therefore, the type of equipment used in PRMST for the frail elderly may be of critical importance. However, the exercise equipment may have to be modified so that it can be used effectively. Because the subjects in this study were so frail, a foot rest and a higher back to the seat had to be added and the equipment had to be raised off of the floor. Even then, some patients had to be lifted onto the unit and strapped into the chair for safety reasons.

Current literature indicates that frail elderly subjects residing either within the community or in a nursing home can safely participate in a program of progressive resistance muscle strength training.15–19 Our study demonstrates that PRMST is reasonably safe, even for recuperative care patients. There were no cases of serious injuries or cardiovascular complications among the elderly subjects who participated in this study. However, we adhered to a protocol designed to prevent excessive patient fatigue. During every exercise session, BP and pulse were monitored closely and the pace of the workout was adjusted as necessary to prevent the pulse from rising to >110 beats per minute. It is not known whether a more aggressive approach to strength training in this population would be as safe.

CONCLUSION

Progressive muscle strength training, if conducted as part of a carefully monitored protocol, is a safe and possibly effective method for frail elderly patients in recuperative phases of acute illnesses to regain appreciable muscle strength and functionality. Factors that may be important in optimizing effectiveness of the intervention while minimizing risk include inclusion of medically stable patients only, careful monitoring of vital signs during training to reduce the risk of excessive subject fatigue, performance of exercises on proper equipment such as weight-lifting machines, and slow advancement of exercise resistance to >80% of the patient’s tested maximal strength. A randomized control study is needed to examine the degree to which this technique offers advantages, if any, over routine posthospital care that includes traditional physical therapy.

ACKNOWLEDGMENTS

We acknowledge Marjorie Lacy, BA, from the Donald W. Reynolds Department of Geriatrics, University of Arkansas for Medical Sciences, Little Rock, AR, for careful review and editing.

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