# Exercise Training in the Debilitated Aged: Strength and Functional Outcomes

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ABSTRACT. Meuleman JR, Brechue WF, Kubilis PS, Lowenthal DT. Exercise training in the debilitated aged: strength and functional outcomes. Arch Phys Med Rehabil 2000;81: 312-8.

**Objective:** Resistance and endurance training result in gains in fitness in the aged. It is unclear whether the debilitated elderly can perform moderate-intensity training and whether such training results in short-term improvements in strength, endurance, and function in this population.

**Design:** Randomized, controlled trial.

**Settings and Patients:** Subjects were from a Veterans Affairs nursing home and rehabilitation unit and a community nursing home. They were older than 60yrs with impairment in at least one physical activity of daily living. Seventy-eight subjects volunteered and 58 (mean age, 75yrs; 9 women, 49 men) completed the intervention and initial posttest. Only one subject withdrew because of injury or disinterest.

**Intervention:** Thrice-weekly resistance training (using an isokinetic dynamometer) and twice-weekly endurance training for 4 to 8 weeks.

**Main Outcomes:** Isometric strength in dominant arm and leg, heart rate response to timed endurance test, and activities of daily living score.

**Results:** The mean change in isometric strength across the muscle movements tested was 32.8% in the training group and 10.2% in the control group (difference, 22.6%; 95% confidence interval, 6.2% to 39.0%). No change in heart rate during exercise was seen in the training group. Trained subjects tended to have a greater improvement in functional activity than control subjects, which was statistically significant ($p = .04$) for those subjects who at enrollment were most dysfunctional (ie, activities of daily living score less than 13 [maximum score 26]).

**Conclusion:** This group of debilitated elderly patients effectively performed resistance training and increased their strength, with the most impaired gaining the most function. Few in the group could effectively perform endurance training.



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LOSS OF MUSCLE FUNCTION in the elderly contributes greatly to problems with ambulation, falling, and functional dependence. Muscle weakness of the legs is frequently found to be a risk factor for falls.[1-5] Studies of exercise training in older individuals have shown large, relatively rapid improvements in strength,[6] but most work has been in the healthy elderly.

Because the functional benefit of exercise may well be greatest in the dysfunctional elderly population with compromised health, in recent years there have been several studies of exercise in physically impaired elders. Some of these have been uncontrolled[7] or used a minimally progressive stimulus, with no resulting consistent increase in strength.[8] Five controlled studies using progressive resistance training have each found significant increases in strength, but in four of these all subjects were ambulatory,[9-12] and in one only 10% used a wheelchair to ambulate.[13] The effectiveness of exercise training in more severely impaired elders as might be found in a subacute unit, acute rehabilitation facility, or nursing home is unclear.

The principal hypothesis tested in this study was that debilitated nursing home or geriatric evaluation and management unit (GEM) patients who trained would have short-term improvements in strength, endurance, and functional state. Secondary objectives were (1) to determine these subjects' ability to participate in a program of moderate-intensity training; (2) to determine whether any improvements were sustained during a 12-month period; and (3) to examine the effect of training on survival and hospitalization in the ensuing year.

## METHODS

This randomized, controlled study was conducted at the Gainesville Veterans Affairs (VA) Medical Center, with study enrollment between May 1994 and April 1996. The protocol was approved by the hospital's research review committee. Informed consent was obtained from the subjects or a surrogate (five subjects).

### Study Sample

Subjects were recruited from the VA nursing home and GEM and a community nursing home. The GEM provides rehabilitative care to veterans transferred from the acute medical or surgical service. All GEM patients receive one session of physical therapy 5 days each week. Fifty percent of the VA nursing home subjects received maintenance physical therapy (two or three times per week). The percentage of the community nursing home subjects receiving physical therapy was unavailable.

Subjects were screened for participation if they were aged 60yrs or older and had an impaired functional status that was thought to have a potential for improvement. Impaired functional status was defined as need for help with one or more Physical Activities of Daily Living (PADL).[14] Potential for improvement was a subjective judgment of the principal investigator (JRM), made on the basis of baseline functional status, duration of current disability, and coexistent medical problems. Recruitment and decision as to subject eligibility were done by the principal investigator, who was familiar with all patients at the VA nursing home and GEM. Subjects from the community nursing home who in the judgment of nursing and physical therapy staff met study entry criteria were referred to the principal investigator for determination of study eligibility.

To be eligible for participation, subjects had to have an expected length of stay of at least 4 weeks, which eliminated approximately 50% of patients admitted to the GEM. Participants could not have uncontrolled hypertension, unstable angina pectoris, or other medical conditions that would interfere with the safety of the training protocol. Subjects had to be able to follow simple commands, so those with severe dementia were excluded. Subjects in wheelchairs had to be able to transfer with at most moderate assistance. Subjects were not eligible who had had a stroke in the previous 3 weeks. Subjects with a pacemaker or chronic atrial fibrillation were excluded from the endurance training because of the inability to assess the effect of training on change in heart rate with exercise. Subjects who could perform resistance exercise but could not conduct endurance training because of dyspnea or hemiplegia were still eligible to participate.

### Intervention

Training group subjects received resistance and endurance training that was conducted in groups of two and supervised by a physical therapist and aide. Training sessions were held in the physical therapy department at the Gainesville VA Medical Center. Community nursing home subjects were transported to the exercise site. The control group received no study-provided intervention.

Strength exercises consisted of resistance training of both knees, shoulders, elbows, and ankles. An isokinetic dynamometer (KIN-COM 125E[a]) was used to test the peak isokinetic concentric force for each joint. This device was chosen for safety reasons (ie, the lever arm will not drop down if upward force is reduced) and because once seated, subjects complete all resistance training without moving to different stations. On Mondays, Wednesdays, and Fridays, participants then used the dynamometer to perform one set of 15 repetitions (concentric and eccentric) at 30°/sec for each muscle group. A certain force (minimum load) had to be exceeded to move the machine's lever arm forward. This minimum resistance was initially set at 40% of the subject's peak concentric force and progressively adjusted each session so that the last repetitions were performed with visible difficulty.

Endurance training took place Tuesdays and Thursdays using either an upper extremity ergometer, a stationary cycle, or a recumbent stepper. Subjects initially operated these devices for 10min at an effort sufficient to achieve a heart rate of 50% of their maximum (estimated to be 220 minus their age in years). Once subjects progressed to 30min of endurance exercise, resistance on the ergometer or stepper was increased so as to achieve a heart rate of 65% of predicted maximum. A Rating of Perceived Exertion (RPE) scale was used in those participants receiving beta-blockers to guide effort.[15]

Exercise sessions continued until the patient was discharged from the GEM or nursing home or for a maximum of 8 weeks. Only training group subjects who completed at least 10 resistance sessions in a 4-week period were considered to have completed the intervention. Training group subjects were not given any instructions for continued exercise at the termination of the intervention.

### Outcome Measures/Target Sample Size

The primary outcome variables were isometric strength, endurance, and functional status. Strength was measured in the dominant arm and leg using the isokinetic dynamometer. Subjects with a history of stroke were tested on the unaffected side. Isometric torque recorded was the peak during a 5sec contraction. Subjects also performed isokinetic tests until two curves with similar peak torques were obtained, and the average of these two peaks was recorded. All measurements were corrected for limb weight. We performed endurance testing by means of a timed test using for each subject the same modality as training and same rate of movement and resistance for the preintervention and postintervention tests. We analyzed heart rate 6min into the endurance test to assess cardiovascular fitness. Functional status was measured using a six-item PADL and seven-item Instrumental Activities of Daily Living (IADL) scale.[14] Whenever possible, the subject's primary nurse was interviewed to provide information for the PADL and IADL scales. Each item was scored as follows: 0, unable to perform; 1, performs with help; or 2, performs without help.

In terms of secondary outcomes, psychological status was assessed using the Geriatric Depression Scale.[16] Mobility was evaluated through measurement of self-selected walking speed over a 20-foot distance.[17] Hospital information systems were accessed to determine the number and duration of admissions to the Gainesville VA Medical Center during the 12-month period after study enrollment. Because of inability to obtain accurate data, non–VA hospital admissions were not tabulated.

All the above measures were assessed at the time of study enrollment. For the training group they were repeated at the time of termination of the exercise training. For the control group they were repeated at the time of GEM or nursing home discharge (as long as at least 4 weeks had elapsed since enrollment) or 8 weeks after enrollment, whichever came first. Subjects who were able to return were reassessed 6 and 12 months after study enrollment.

Strength tests were repeated on two consecutive days at study enrollment, at the initial posttest, and whenever possible at the 6- and 12-month reassessments, with the maximum of the two replicates used as the observed value. The assessor was blinded to the subjects' group assignments (training or control).

The sample size calculations were performed for strength and functional status. To detect a 25% improvement in knee extension strength (assuming premeasures and postmeasures correlation of .55, power = 80%, $\alpha = .05$ 1-tail, and 30% dropout rate), 20 subjects per group would be needed. Forty-three subjects per group would be needed to detect a 2-point differential in the PADL score (assuming power = 80%, $\alpha = .05$ 1-tail, and 30% dropout rate).

### Statistical Analyses

An intention-to-treat approach was not incorporated into the plan for statistical analysis because most subjects who dropped out were not available to be tested at the end of the intended period because of discharge home or deterioration of health. Though isometric tests of each muscle group were performed at four joint angles, changes in strength were similar across all angles. We post hoc chose one of the middle-range angles for our data analysis. Covariate balance between the groups was assessed by using the $\chi^2$ test or Fisher exact test to compare proportions, and the independent-sample *t* test or Wilcoxon rank sum test to compare means or rank sums.

To determine composite joint strength scores, the percent change in torque relative to the pretest was computed for each muscle group, and the median percent change among all muscle groups was considered as the subject's composite response. Subjects were included only if at least six muscle groups were evaluable. The independent-sample $t$ test and the Wilcoxon rank sum test were used to compare means and rank sums between study arms.

Mean within-subject change in individual muscle group strength and in ADL scores was compared between treatment groups using analysis of covariance (ANCOVA). Interactions between treatment group effect and other covariates of interest were also evaluated using ANCOVA. Endurance data were analyzed by contrasting the within-subject change in heart rate after 6min of aerobic exercise between pretest and initial posttest in the treatment groups using ANCOVA.

Number of hospital admissions and length of stay were compared using the independent-sample $t$ test and the Wilcoxon rank sum test. The square root transformation was used to transform number of hospital admissions to stabilize variances. Mortality was evaluated by estimating Kaplan-Meier survival curves and comparing them using the log-rank test. All analyses were performed using SAS 6.11 for Windows.[b]

### Assignment

The randomization scheme for the VA participants was determined by a computer algorithm stratified by site of care (GEM or nursing home). Assignments to the study groups were concealed in sealed envelopes that were opened after the pretest was completed. Transportation logistics precluded more than two subjects from the community nursing home from training at any given time. As a result, the randomization scheme for these subjects was done using a coin flip every time two subjects had completed the pretest. Though the assessor was blinded to the subjects' group assignment, the assessor was not questioned to ascertain the success of the blinding.

## RESULTS

### Participant Characteristics

The profile of subject participation is depicted in figure 1. Three subjects dropped out during testing. Two of these found the tests overly exhausting, and one had an apraxia and could not perform the exercise tests. Twenty dropped out after testing but before they could be retested 4 to 8 weeks later. Ten subjects (6 training, 4 control) dropped out because they were discharged home before 4 weeks had elapsed. Nine of the 10 were

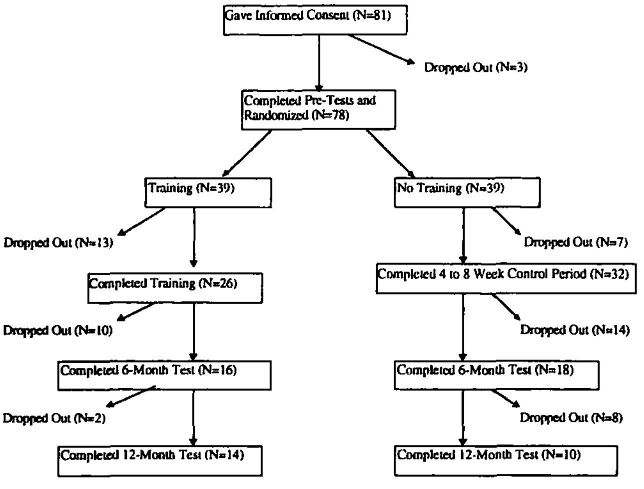


**Fig 1. The profile of subject participation.**

**Table 1: Characteristics of Study Participants Completing Initial Posttest**

| Characteristic at Time of Pretest | Training Group ($n$ = 26) | Control Group ($n$ = 32) |
|---|---|---|
| Mean age, yrs (range) | 74.1 (60-90) | 76.9 (60-97) |
| Women, $n$ (%) | 2 (7.7) | 7 (21.9) |
| Mean body mass index (kg/m$^2$) | 24.1 | 22.9 |
| Mean mini-mental status examination score | 23.9 | 23.0 |
| Mean combined activities of daily living score | 10.7 | 12.4 |
| Mean number of scheduled medications | 3.8 | 4.3 |
| Mean number of chronic medical conditions | 3.9 | 4.4 |
| Primary medical problem ($n$) | | |
| Disability from cerebrovascular accident | 12 | 7* |
| Postsurgical | 6 | 6 |
| Dementia | 2 | 6 |
| Miscellaneous diagnoses | 6 | 13 |
| Site of residence ($n$) | | |
| Geriatric evaluation and management unit | 9 | 9 |
| Veterans Affairs nursing home | 12 | 16 |
| Community nursing home | 5 | 7 |
| Usual mode of ambulation | | |
| Wheelchair | 22 | 26 |
| Walker | 2 | 1 |
| Cane/no assistance | 2 | 5 |

* $p = .05$ by $\chi^2$.

GEM patients who had finished their rehabilitation. Five subjects (4 training, 1 control) dropped out because they became ill or medically unstable. Four subjects (2 training, 2 control) died before 4 weeks had elapsed. In none of the training group subjects who dropped out because of illness or death did the illness or death have any apparent relation to the efforts of training. One training group subject dropped out because of a slight shoulder strain. No other adverse events occurred as a result of training. One subject could not train for 4 weeks because of illness and was treated as a new trainee when exercise resumed. The 58 subjects who completed the initial posttest comprise the study population for all subsequent analyses.

The two groups were similar in terms of various characteristics at the time of the pretest (table 1). A significantly higher percentage of training subjects had as their primary medical problem disability from cerebrovascular accident ($p = .05$), though only 2 of the 19 subjects had their stroke within 2 months of study enrollment.

### Training Sessions/Reliability of Testing

The 26 training subjects completed a mean of 19.8 resistance sessions (range, 10 to 24). Twenty subjects participated in endurance training, completing a mean of 14 sessions (range, 6 to 22). The initial load, load at end of training, and percent increase in load are given in table 2.

All muscle groups showed good reliability on consecutive testing days except shoulder flexion and elbow extension, which had intraclass correlation coefficients for which the 95% lower bound was between .40 and .60 for all three strength measures (isometric, concentric, eccentric).

The second reliability question was whether subjects in the training group might achieve a higher strength score because of

Table 2: Change in Training Load Between First Resistance Session and Last

| Exercise | Subjects (n) | Mean Load (N*) | | % Increase |
|---|---|---|---|---|
| Knee extension | 26 | Initial | 129 | 78% |
| | | Final | 230 | |
| Knee flexion | 26 | Initial | 63 | 181% |
| | | Final | 177 | |
| Shoulder extension | 26 | Initial | 80 | 166% |
| | | Final | 213 | |
| Shoulder flexion | 26 | Initial | 44 | 161% |
| | | Final | 115 | |
| Elbow extension | 26 | Initial | 55 | 165% |
| | | Final | 146 | |
| Elbow flexion | 26 | Initial | 42 | 107% |
| | | Final | 87 | |
| Dorsiflexion | 25 | Initial | 25 | 268% |
| | | Final | 92 | |
| Plantarflexion | 25 | Initial | 84 | 226% |
| | | Final | 274 | |

* N = Newton; 1N = .22lb.

their greater familiarity with the dynamometer. The intraclass correlation coefficients between the 2 days of posttesting were very similar for the training and control groups.

## Primary Outcomes

***Strength outcomes.*** To establish overall group change we calculated the median and mean of each subject's composite change for the eight muscle groups (table 3). Both isometric and isokinetic concentric strength increased more in the training group between the pretest and the initial posttest. At the 6- and 12-month posttests, no significant differences from baseline were seen between groups in the composite change.

Table 4 presents the results of the individual muscle groups at the initial posttest. In terms of isometric torque, significant differences were seen with knee extension and shoulder extension. As for isokinetic concentric strength, the only significant difference was in plantarflexion. For eccentric strength there were no significant differences, though plantarflexion approached statistical significance. Each of these results favored the training group. At the 6- and 12-month posttests (not shown), the only significant difference was in ankle dorsiflexion at the 6-month follow-up, for which training group subjects were stronger on isometric and isokinetic eccentric testing.

Changes in strength had very weak nonsignificant correlation coefficients with six possible confounding variables: patient age, body mass index, mini-mental status examination score, site of residence (GEM or either nursing home), number of resistance sessions completed, and diagnosis of stroke.

***Functional outcomes.*** Though the scores for PADL, IADL, and the two scales combined tended to improve more by the initial posttest in the training group, the differences of 0.9, 0.6, and 1.5 were not significant ($p$ values .13, .19, and .10, respectively). When post hoc we stratified the subjects into most dysfunctional (score $<13$ [maximum score, 26]) versus less (score $\geq 13$), the 17 most dysfunctional training subjects improved their ADL score by 2.9 points at the initial posttest versus 0.2 points for the 16 most dysfunctional control subjects ($p = .042$). The initially more functional subjects (9 training, 16 control) improved similarly (0.2 and 0.7 points, respectively; $p = .623$). The relationship between change in function and group assignment was not affected by site of residence or diagnosis of stroke. At the 6- and 12-month posttests, the change in functional status scores from the pretest were not different between the two groups. Of all 13 ADL items, the one that improved the most at the initial posttest in the training versus control group was that asking "can you walk?" ($p = .021$).

As a question separate from the 13-item ADL assessment, all subjects were asked how they usually ambulated (see table 1 for mode of ambulation at the pretest). Four training subjects who were usually using a wheelchair at the time of the pretest were

Table 3: Change in Composite* Strength From Pretest

| Assessment | Group | Subjects (n) | Median (%) | p† | Mean (%) | Difference (95% CI) |
|---|---|---|---|---|---|---|
| Isometric | | | | | | |
| Initial posttest | Training | 26 | 30.0 | .009 | 32.8 | 22.6 (6.2-39.0) |
| | Control | 32 | 7.1 | | 10.2 | |
| 6-month test | Training | 16 | 20.8 | .196 | 25.0 | 16.7 (−7.3-40.8) |
| | Control | 18 | −2.1 | | 8.3 | |
| 12-month test | Training | 14 | 11.8 | .930 | 16.3 | 7.8 (−24.5-40.1) |
| | Control | 10 | 5.3 | | 8.5 | |
| Isokinetic concentric | | | | | | |
| Initial posttest | Training | 26 | 21.1 | .017 | 41.2 | 28.4 (−0.3-57.1) |
| | Control | 32 | 3.4 | | 12.8 | |
| 6-month test | Training | 16 | 33.0 | .221 | 29.6 | 19.0 (−8.2-46.2) |
| | Control | 18 | 4.5 | | 10.6 | |
| 12-month test | Training | 14 | 7.0 | .619 | 18.2 | 8.3 (−32.2-48.8) |
| | Control | 10 | −12.4 | | 9.9 | |
| Isokinetic eccentric | | | | | | |
| Initial posttest | Training | 26 | −4.1 | .748 | 7.0 | 1.3 (−13.5-16.1) |
| | Control | 32 | 0.2 | | 5.7 | |
| 6-month test | Training | 16 | 5.7 | .221 | 12.4 | 12.8 (−8.0-33.6) |
| | Control | 18 | −6.5 | | −0.4 | |
| 12-month test | Training | 14 | 0.1 | .930 | 4.9 | −2.2 (−28.7-24.3) |
| | Control | 10 | −4.7 | | 7.1 | |

Abbreviation: CI, confidence interval.
* Over the 8 muscle groups tested.
† Using rank sum.

Table 4: Change in Strength From Pretest to Initial Posttest

| Muscle Group | Group | Subjects (*n*) | Isometric Pretest Torque* | Isometric Posttest Torque | Isokinetic Concentric Pretest Torque | Isokinetic Concentric Posttest Torque | Isokinetic Eccentric Pretest Torque | Isokinetic Eccentric Posttest Torque |
|---|---|---|---|---|---|---|---|---|
| Knee extension | Training | 26 | 130 | 165† | 97 | 131§ | 145 | 144 |
| | Control | 32 | 137 | 146† | 97 | 107§ | 144 | 142 |
| Knee flexion | Training | 26 | 55 | 75 | 45 | 72§ | 79 | 87 |
| | Control | 32 | 60 | 69 | 46 | 57§ | 77 | 86 |
| Shoulder extension | Training | 26 | 73 | 105‡ | 65 | 79 | 130 | 123 |
| | Control | 31 | 74 | 75‡ | 54 | 64 | 114 | 120 |
| Shoulder flexion | Training | 26 | 59 | 71 | 45 | 54 | 71 | 75 |
| | Control | 31 | 65 | 72 | 46 | 54 | 70 | 75 |
| Elbow extension | Training | 26 | 34 | 39 | 31 | 35 | 37 | 39 |
| | Control | 32 | 28 | 29 | 26 | 27 | 33 | 33 |
| Elbow flexion | Training | 26 | 34 | 41 | 26 | 33 | 41 | 42 |
| | Control | 32 | 34 | 36 | 26 | 28 | 39 | 39 |
| Ankle dorsiflexion | Training | 21 | 15 | 22§ | 15 | 19 | 28 | 31 |
| | Control | 29 | 20 | 20§ | 18 | 18 | 30 | 30 |
| Ankle plantarflexion | Training | 25 | 44 | 55 | 44 | 63 | 59 | 74§ |
| | Control | 32 | 36 | 42 | 47 | 51 | 61 | 64§ |

* In Newton meters.
† $p = .05$, using analysis of covariance.
‡ $p = .002$.
§ $p = .06$.
‖ $p = .014$.

using a walker by the initial posttest compared with three control subjects (difference not significant). At the posttest of walking speed, two training subjects were no lònger using the assistive device they used at the pretest, whereas all control subjects were using the same device (difference not statistically significant).

***Correlation of strength and functional outcomes.*** The Spearman correlation coefficients for change in composite strength on the initial posttest and change in combined ADL score for all 58 subjects were .32 ($p = .016$), .21 ($p = .108$), and .36 ($p = .006$) for isometric, concentric, and eccentric measures, respectively. This association of improved strength with improved activity score was the same when the groups were analyzed separately.

***Endurance outcomes.*** Six subjects who participated in endurance training could not perform 6min of endurance exercise at the time of the initial posttest. In 14 of the 20 subjects who participated in endurance training, and in 13 control subjects, we were able to assess change in aerobic fitness by measuring the difference in heart rate before exercise and 6min into exercise at the pretest and initial posttest. With exercise, the mean heart rate rose 13beats/min at the pretest in the training group and 7beats/min in the control group, with corresponding figures at the initial posttest of 14 and 10 (within-subject change not significant between groups, $p = .105$).

## Secondary Outcomes

Thirty-six subjects were able to perform the "walking speed" test (those unable to self-propel their wheelchairs were excluded), with 64% using a wheelchair or walker. Compared with the pretest, the time to cover 20 feet decreased 1.9sec in the training group and 3.0sec in the control group ($p = .166$).

Mean number of VA hospital admissions over the 12-month follow-up period was 0.2 in the training group versus 0.7 in the control group ($p = .005$ by rank sum). The mean number of days hospitalized at the VA for the training group was 2.3 versus 7.6 in the control group ($p = .005$).

Full information regarding 12-month survival was not available for three subjects from the community nursing home (one training, two control) who were discharged between 8 and 10 months after study enrollment. One of the 26 training subjects died during the follow-up period versus 10 of the 32 control subjects ($p = .009$, fig 2). Of the 11 deaths, 4 occurred in GEM subjects, 3 in VA nursing home subjects, and 4 in subjects from the community nursing home.

Depression scores were not significantly different between the two groups at either the pretest or initial posttest.

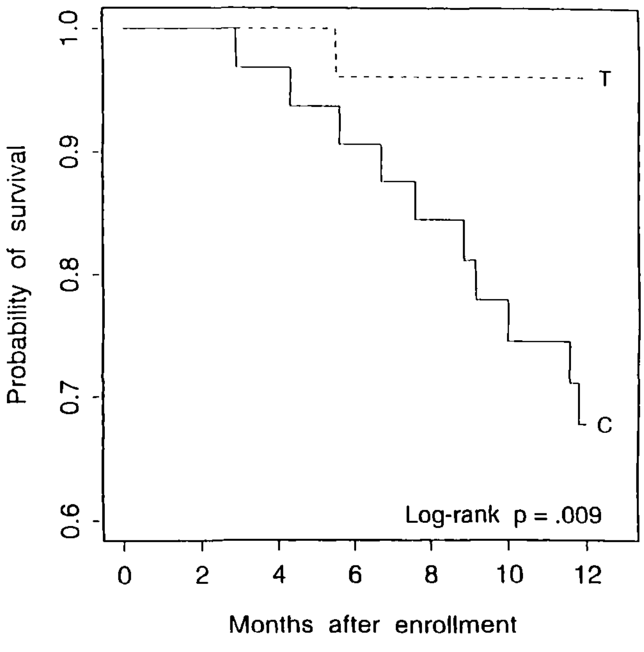


**Fig 2. Kaplan-Meier survival curves for the control (C) and exercise training (T) groups for 12 months after study enrollment. The survival curves differ significantly from one another (log-rank *p* = .009).**

## DISCUSSION

### Major Findings/Mechanisms

In this study of debilitated elders, a large majority who volunteered were able to participate in a program of progressive resistance exercise. Resistance training led to significant increases in strength, which were associated with improvements in function, particularly in those who were initially most dysfunctional. Endurance training led to no demonstrable improvement in aerobic fitness. Though the effects of resistance training on strength tended to wane in those subjects assessed 12 months after enrollment, training subjects had fewer VA hospitalizations and deaths during this period.

Data in young adults have long suggested that large gains in strength are seen only in response to moderately high loads (greater than 40% of maximum).[18] Though routine physical therapy in frail elderly patients has traditionally used only low-intensity weight training, two recent studies in the elderly each found that a low-intensity stimulus with minimal progression leads to no consistent increase in strength.[8,19]

High-intensity training is usually defined as that performed at 80% of the one repetition maximum versus 50% to 60% for moderate-intensity training and 40% or less for low-intensity training.[20] Though our use of an isokinetic dynamometer obviates the measurement of a one repetition maximum (as obtained with free weights), our training would be considered as at least moderate in intensity because we increased the load during each training session so that the last repetitions were performed with difficulty. The gains seen in function with relatively modest increases in strength may be explained by the nonlinear relationship between lower extremity performance and strength in elders who have less than normal strength.[21]

For many of our subjects, the performance of eccentric exercise was problematic. After completing a concentric contraction, they were to continue that contraction as the machine forced them in the opposite direction. Instead, many pushed along with the machine, causing a cutoff of the dynamometer's motion. It may well be, therefore, that the eccentric training did contribute to the observed gains in strength but that measurement of eccentric strength was inaccurate in this group.

Six of our subjects did not perform endurance training because of dyspnea, hemiplegia, or nonsinus cardiac rhythm. Of those who could do endurance exercise, six performed it at such a low intensity that they couldn't complete the 6-min endurance posttest. Because of the limited endurance training used, any changes seen in our various outcomes are likely to be secondary to the resistance training, which our frail subjects were able to perform much more successfully. Though our outcome measure (change in heart rate after 6min of exercise) is an indirect measure of endurance, few of our subjects could perform a formal test of aerobic capacity.

The lack of reliability of strength measurements for shoulder flexion and elbow extension is likely because subjects often rotated their upper bodies to attain additional leverage, despite the use of straps across the torso. The similar correlation coefficients between the training and control groups during the 2 days of posttesting suggest that the training group's greater familiarity with the dynamometer did not significantly influence performance on the strength tests.

### Previous Studies

Our subjects were more impaired than the elders in other resistance training studies, yet increases in strength have been seen across the spectrum of debility in the aged. In the work of Fiatarone and colleagues,[13] only 10% used a wheelchair to ambulate versus 83% of our subjects. In four recent studies of frailty and exercise, the elderly subjects were all ambulatory,[9-12] yet in each, the increase in strength was very similar to that seen in our study. Buchner and associates[10] found that training subjects had fewer outpatient clinic visits and fewer hospital costs of more than $5,000 during an 18-month follow-up period. Neither these studies nor that of Fiatarone[13] documented the survival of subjects who received exercise training, or reevaluated subjects after cessation of training.

The low injury rate in our subjects is consistent with the experience of Coleman and coworkers.[22] These findings contrast with those of Judge and colleagues,[9] who found a 20% incidence of musculoskeletal complaints during a training program conducted in small groups utilizing sandbags and resistance machines. It is likely that Coleman's and our experiences were associated with minimal injuries because of the use of weight training machines with a one-on-one instructor.

### Limitations

There are several limitations to our methodology. Because control subjects received no extra activity as a result of their participation, the training intervention could have provided stimulation that resulted in a nonspecific benefit to the training group subjects. Direct assessment of some IADL items was limited by the institutional setting and was based on the best judgment of the primary nurse.

More patients dropped out of the training group than the control group, but the use of in-subject change as the means of analysis minimizes any effect of selective attrition. Fifty percent of dropouts were from early discharges to home. Because an intention-to-treat approach was not utilized in the analysis, this study provides insight into the efficacy of the intervention rather than its effectiveness.

We acknowledge that insight into generalizability would be enhanced if we could document how many elders meeting entrance criteria who were asked, actually agreed to participate. This cannot be provided because some prescreening was performed by the nursing home nurses whom we relied on for referrals. Of those subjects whom the principal investigator asked, only seven refused to participate.

That subjects were recruited from heterogenous sites (GEM vs nursing home) is a limitation, but the primary outcomes did not differ by site. Lack of accounting for non–VA hospital admissions limits the strength of the finding that hospitalizations were reduced in the training group.

Though the length of training was relatively brief, previous work shows that a training effect can be observed in the elderly in as little as 6 to 8 weeks.[7,23-26] Nevertheless, data[27] suggest that an intervention appreciably longer than ours may have yielded even more impressive findings. The length of our intervention was chosen because it approximates the time many patients spend in an acute rehabilitation facility.

The lack of significant differences in strength at the 6- and 12-month follow-up tests is of note. We had hypothesized that the training subjects' gain in strength would facilitate a higher level of daily activity that would sustain some of their strength improvements, but we did not use physical activity monitors to quantitate this. Though the lack of significant results at the 6- and 12-month posttests may be related to the drop-off in subjects tested because of an inability to return for testing or death, there likely is a role for maintenance training in physically impaired elders who have completed a period of moderately intense exercise.

As for the impact on survival, we acknowledge that our study was not planned to rigorously examine this outcome. One possible explanation for our finding of better survival in the training group is that control subjects were sicker. We examined various measures of medical frailty and found that the number of medical problems, patient age, and number of medications used were not significantly different between the groups, though each was slightly higher in the control group. In distinction, the baseline ADL score of the control group was better than that of the training group. The average pretest strength of the groups was similar. Therefore, we have no evidence that either group was sicker at the time of our pretest.

Another possible explanation for the differential survival relates to the unequal drop-out before the initial posttest because of illness (four training, one control) or injury (one training). One of the ill training subjects was discharged with no follow-up information available and may well have died within the follow-up period. Of the other four ill subjects, two survived 12 months and two died (one training, one control). The injured subject was alive 12 months later. It therefore does not appear that differential drop-out of sick patients during training accounted for much of the apparent survival advantage of the training group. We do not know the cause of death for those who died. The apparent effect of exercise training on survival certainly needs replication in studies that are designed more specifically to address this issue.

## CONCLUSION

The results presented in this study show that debilitated elders meeting our eligibility criteria who initiated a supervised exercise program of moderately intense resistance training obtained an increase in strength and, for some subjects, an improved quality of life. Additional research is needed to confirm these short-term results and to clarify the role of a maintenance program. Because implementation of this recommendation would require a large investment in personnel and equipment, there is need to perform more formal cost-benefit and survival analyses than were performed in this study.

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### Suppliers

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