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Effects of a Group Exercise Program on Strength, Mobility, and Falls Among Fall-Prone Elderly Men

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Objectives. This randomized controlled trial studied the effects of a low- to moderate-intensity group exercise program on strength, endurance, mobility, and fall rates in fall-prone elderly men with chronic impairments.

Methods. Fifty-nine community-living men (mean age = 74 years) with specific fall risk factors (i.e., leg weakness, impaired gait or balance, previous falls) were randomly assigned to a control group ($n = 28$) or to a 12-week group exercise program ($n = 31$). Exercise sessions (90 minutes, three times per week) focused on increasing strength and endurance and improving mobility and balance. Outcome measures included isokinetic strength and endurance, five physical performance measures, and self-reported physical functioning, health perception, activity level, and falls.

Results. Exercisers showed significant improvement in measures of endurance and gait. Isokinetic endurance increased 21% for right knee flexion and 26% for extension. Exercisers had a 10% increase ($p < .05$) in distance walked in six minutes, and improved ($p < .05$) scores on an observational gait scale. Isokinetic strength improved only for right knee flexion. Exercise achieved no significant effect on hip or ankle strength, balance, self-reported physical functioning, or number of falls. Activity level increased within the exercise group. When fall rates were adjusted for activity level, the exercisers had a lower 3-month fall rate than controls (6 falls/1000 hours of activity vs 16.2 falls/1000 hours, $p < .05$).

Discussion. These findings suggest that exercise can improve endurance, strength, gait, and function in chronically impaired, fall-prone elderly persons. In addition, increased physical activity was associated with reduced fall rates when adjusted for level of activity.

THERE are encouraging data that exercise programs can improve strength (1–5), gait (2,6,7), balance (1,8), and perhaps decrease falls (9–14) among healthy, nonimpaired older adults. However, individuals most at risk for falls—those with gait impairments, weakness, chronic musculoskeletal or neurologic impairments—have been excluded from most exercise studies. Consequently, there is little evidence about the benefits and risks of including individuals at highest risk for falls in structured group exercise.

We conducted a randomized controlled trial to measure effects of an exercise intervention on muscle strength, gait, balance, and endurance among elderly men with risk factors for falls. Secondary aims were to measure effects of exercise on actual fall rates, self-reported health measures, and activity levels.

Methods

The study, conducted at the Sepulveda VA Ambulatory Care Center, was targeted to ambulatory men aged 70 years or older who had at least one of the following key fall risk factors: lower extremity weakness (manual muscle score of $\leq$4/5 in $\geq$1 leg flexor or extensor muscle); impaired gait (score <10/12 on the gait subscale of the Performance Oriented Mobility Index [POMI]) (15); impaired balance (score <14/16 on the POMI balance subscale); or >1 fall in the previous 6 months (not resulting from a violent blow, loss of consciousness, paralysis, or seizure) (16).

Individuals were excluded if they exercised regularly or had severe cardiac or pulmonary disease, a terminal illness, severe joint pain, dementia, medically unresponsive depression, or progressive neurologic disease (e.g., Parkinson's disease).

The subject recruitment process is described in Figure 1. Participants were randomized using a randomly generated sequence of cards in sealed envelopes. Groups of 16–20 men were randomized together at 3–6-month intervals to ensure exercise groups of manageable size. The research protocol was approved by the institutional review board, and informed consent was obtained from each participant.

The intervention consisted of three 90-minute sessions per week for 12 weeks, led by exercise physiology graduate students. The exercise protocol is outlined in Table 1. Control subjects were asked to continue their usual activities during the 12-week control period.

Outcome measures were obtained prior to randomization (baseline) and within one week of the completion of the in-

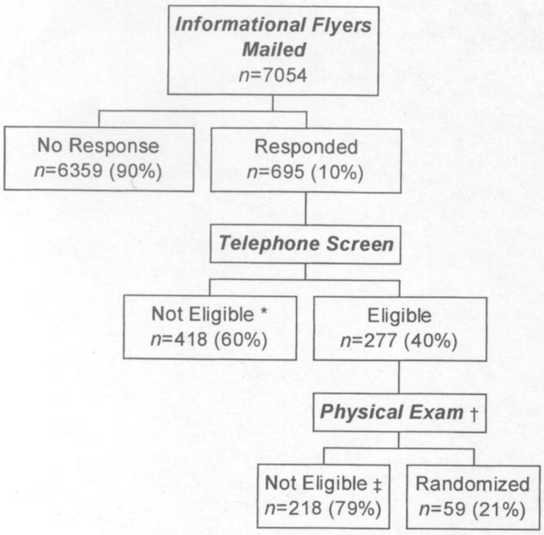

Figure 1: Subject recruitment process. *Of subjects not eligible after the telephone screen, 206 (49%) had no risk factors, 128 (31%) were too ill, and 84 (20%) refused to be randomized. †The physical examination was conducted by a physician assistant and physical therapist and included: quantitative neurologic assessment; postural pulse and blood pressure measurements; manual muscle and range of motion testing; foot evaluation; observational gait analysis (15); mental and functional status testing (17,18); and medication review. ‡Of subjects not eligible after the physical examination, 113 (41%) had no risk factors, 88 (32%) were too ill, and 17 (6%) refused to be randomized.

tervention period. Isokinetic strength of the hip, knee and ankle was assessed with a CYBEX 330 System.

Physical performance tests used to assess strength, endurance, gait, and balance included a sit-to-stand test (19), a 6-minute walk test (20), an indoor obstacle course (21), the POMI (15), and a 15-second one-leg standing balance test. A physical therapist (PT) masked to subject assignment rated videotaped performance on the obstacle course and the POMI. Inter-rater reliability with a physician on a sample of subjects ($n = 32$) was 0.96 ($p < .001$, weighted Kappa).

Three subscales of the RAND 36-item Health Survey (SF-36) (22) were used to measure physical functioning, role limitations, and general health perceptions. Physical activity was measured with the Yale Physical Activity Survey (23). Number of falls and injuries sustained during the 12-week intervention period were obtained by questioning participants every 2 weeks either by telephone (controls) or at the exercise classes.

Repeated measures two-way analysis of variance (ANOVA) was performed on outcome variables. Significant interactions were examined (Tukey's test) to determine if effects were greater in the exercise or control group. Difference in fall rates was tested using a z test based on Poisson distribution.

Results

Baseline characteristics of the 59 randomized subjects are shown in Table 2. Post-testing was completed by 90% of exercise subjects and 96% of controls. Exercise subjects attended 84% of the exercise sessions. Subjects who completed post-testing attended 91% of the sessions. Overall,

Table 1. Protocol for Exercise Intervention

Exercise	Position	Resistance	Progression*	
			Week 1—Minimum	Week 12—Maximum
Strength Training				
Hip flexion	Standing	Ankle weights	2 lbs	12 lbs
Hip extension	Standing	Ankle weights	2 lbs	12 lbs
Hip abduction	Seated	Elastic band	1 extra heavy	2 super heavy
Hip adduction	Seated	12" rubber ball	Moderately deflated	Slightly deflated
Knee flexion	Standing	Ankle weights	2 lbs	12 lbs
Knee extension	Seated	Ankle weights	2 lbs	12 lbs
Squats	Standing	Waist weights	No weights	25 lbs
Dorsiflexion	Supine†	Elastic band	Extra heavy	Super heavy
Plantar flexion	Standing	Waist weights	No weights	25 lbs
Endurance Training‡				
Bicycle			5 min @ 30 watts	15 min @ 80 watts
Treadmill			6-min walk speed for 5 min	>6-min walk speed for 5 min
Indoor walking			5 min	15 min
Balance Training§			5 min	15 min

*For strengthening exercise, subjects progressed from 1 to 3 sets of 12 repetitions over the first 4 weeks. Rate of progression was modified for subjects with physical limitations (e.g., joint pain, orthopedic deformities).

†Elastic band was attached to wall and secured over dorsum of foot.

‡Endurance training alternated between the bicycle ergometer (once a week), treadmill (twice weekly), and indoor walking (twice weekly). The indoor walking course consisted of a 430-foot loop along indoor corridors and included 2 flights of stairs. Heart rate was monitored to insure that participants did not exceed 70% of their heart rate reserve.

§Balance training was performed twice a week, increasing in difficulty over the 12-weeks. Exercises incorporated a rocking balance board, balance beam, obstacle course, and group activities (e.g., balloon volleyball, horseshoes).

Table 2. Characteristics of Subjects at Randomization

Baseline Characteristics	Control (n = 28)	Exercise (n = 31)	p value*
Mean age (mean ± SD)	74.4 ± 43.4	76.4 ± 4.9	0.08
Caucasian (%)	92.9 (26)†	96.8 (30)	0.60
Married (%)	71.4 (20)	74.2 (23)	1.0
>12 yrs education (%)	67.9 (19)	58.1 (18)	0.59
Arthritis (%)	60.7 (17)	64.5 (20)	0.79
Diabetes mellitus (%)	14.3 (4)	22.6 (7)	0.51
Heart disease (%)	42.9 (12)	45.2 (14)	1.0
Hypertension (%)	67.9 (19)	61.3 (19)	0.79
Pulmonary disorder (%)	7.1 (2)	12.9 (4)	0.67
Stroke (%)	10.7 (3)	25.8 (8)	0.19
No. prescription medications (mean ± SD)	2.0 ± 1.4	2.7 ± 2.1	0.18
No. of prescription doses/day (mean ± SD)	3.0 ± 2.3	4.2 ± 3.9	0.14
Health is fair or poor (%)	35.7 (10)	32.3 (10)	0.79
Uses cane (%)	32.1 (9)	22.6 (7)	0.56
Instrumental Activities of Daily Living Scale (ref. 18) (range 0–8; mean ± SD)	7.7 ± 0.54	7.4 ± 1.2	0.15
Mental status scale (ref. 17) (range 0–28; mean ± SD)	3.6 ± 2.4	3.1 ± 2.8	0.42
Abnormal mental status score (>6) (%)	7.1 (2)	6.4 (2)	1.0
Fall in past 6 months (%)	64.3 (18)	48.4 (15)	0.29
Obese (>120% IBW) (%)	28.6 (8)	32.3 (10)	0.79
Underweight (<90% IBW) (%)	7.1 (2)	6.5 (2)	1.0
Hip flexors (≤4‡) (%)	71.4 (20)	61.3 (19)	0.58
Hip extensors (≤4‡) (%)	82.1 (23)	74.2 (23)	0.54
Knee flexors (≤4‡) (%)	57.1 (16)	51.6 (16)	0.79
Knee extensors (≤4‡) (%)	50.0 (14)	54.8 (17)	0.80
Dorsi flexors (≤4‡) (%)	46.4 (13)	41.9 (13)	0.79
Plantar flexors (≤4‡) (%)	71.4 (20)	71.0 (22)	1.0
POMI balance score (ref. 15) (range 0–16; % ≤13)	35.7 (10)	35.5 (11)	1.0
POMI gait score (ref. 15) (0–12; % ≤9)	67.9 (19)	64.5 (20)	1.0

*Student's t test for continuous variables; Fisher's Exact Test (two-tailed) for categorical variables.

†Number of subjects.

‡≤4/5 on manual muscle testing (i.e., complete range of motion against gravity with moderate resistance).

there were no serious exacerbations of health problems associated with exercise.

Exercisers showed significant pre–post strength increases in 8 of the 12 joint movements measured, whereas controls improved in 4 of the 12 measurements (Table 3). There was a significant group by time interaction only for right knee flexion (p = .009), which increased significantly more for exercisers. Borderline interactions were observed for right knee extension and right hip flexion.

Exercisers showed large and significant increases in muscle endurance at the knee joint as compared to controls. Exercisers showed a significantly greater increase than controls in total work for three of the four joint movements tested.

Exercisers showed greater improvement than controls in the gait and endurance measures (Table 4). For the 6-minute walk, exercisers increased the distance they walked an average of 48 meters compared to 12 meters for controls (F = 6.6, p = .01). Likewise, the POMI gait score improved significantly more for exercisers than for controls (F = 6.0, p = .02). For the sit-to-stand test, exercise subjects increased their average number of repetitions by 23% compared to 4% for controls (p = .07). There were no significant group differences for the obstacle course score, the POMI balance scale, or the one-leg balance test.

At post-test, exercisers rated their global health better (p = .005) than controls, but there were no differences between groups on the three subscales of the SF-36. Within the exercise group, total activity time per week, as measured by the Yale survey, increased (p = .03), largely reflecting the time spent in the exercise classes (4.5 hours/week). No change in weekly activity time was observed for controls.

During the 3-month intervention period, 38.7% of exercisers and 32.1% of controls reported falling, with a total of 13 and 14 falls, respectively. There were no serious fall-related injuries in either group. To determine whether greater activity levels were associated with an increased risk of falling, we calculated number of falls per 1000 hours of activity. For this calculation we used only the time reported for exercise and recreation activities, because these categories accounted for most nonsedentary activities. Using the combined totals for these two categories, total hours of activity during the 12-week intervention was 2141.23 hours for the exercise group and 861.60 hours for controls. The fall rate per 1000 hours of activity was 6.0 falls for the exercise group compared to 16.2 falls for the control group (z = 2.18, p = .027; 95% CI for fall rate difference = 10.2 ± 9.1 falls/1000 hours activity).

Discussion

This study demonstrated that a simple program of progressive resistance exercises, walking, and balance training can improve muscle endurance, and functional mobility in elderly men with chronic impairments and risk factors for falls. In addition, this study provides new evidence on the complex relationship between physical activity and falls: exercise participants significantly increased their physical activity, yet experienced fewer falls per unit of activity.

The most notable physical benefit associated with this short-term exercise program appears to be an overall improvement in physical endurance, as evidenced by significant increases in both isokinetic and functional measures. The increase in muscle endurance, as measured by isokinetic total work, has not been reported previously. The fact that exercisers were able to increase their walking distance an average of 48 meters in just 12 weeks further substantiates the improvements we saw in muscle endurance and gait characteristics.

These are clinically important findings for an impaired population such as ours, because even modest improvements in endurance, strength, and mobility can have major impacts on an individual's ability to remain independent in the community. Previous research has shown that exercise has a positive impact on physical performance in both independent (5) and functionally impaired (4) community-dwelling older persons.

Exercise did not reduce *unadjusted* 3-month fall rates in this sample of fall-prone elderly men, which is not surpris-

Table 3. Effect of Exercise on Lower Extremity Isokinetic Strength and Endurance

	Control Group		Exercise Group			
Joint Action	Baseline (n = 26)	Post-Test (n = 26)	Baseline (n = 26)	Post-Test (n = 26)	ANOVA Group × Time	p value
Strength (Peak Torque*) (Nm)						
Knee Extension						
Right knee	87.8 ± 24.1	89.4 ± 24.1	80.1 ± 31.6	87.2 ± 30.1‡	F(1,50) = 3.2	.08
Left knee	83.4 ± 19.8	84.8 ± 17.9	80.3 ± 25.4	86.1 ± 25.0‡	F(1,51) = 2.4	.13
Knee Flexion						
Right knee	64.2 ± 14.0	63.8 ± 12.9	57.9 ± 18.7	67.5 ± 20.9§	F(1,50) = 7.3	.009
Left knee	56.0 ± 14.0	60.6 ± 14.0	56.9 ± 16.9	65.2 ± 18.3‡	F(1.51) = 1.3	.26
Hip Extension						
Right hip	98.4 ± 28.7	108.3 ± 29.6‡	105.2 ± 37.2	115.1 ± 39.5‡	F(1,49) = .00	.98
Left hip	91.2 ± 30.3	101.4 ± 30.5‡	99.1 ± 28.9	106.5 ± 33.4	F(1,51) = .18	.67
Hip Flexion						
Right hip	48.3 ± 10.5	50.5 ± 11.8	47.8 ± 13.8	55.3 ± 17.6‡	F(1,49) = 3.9	.055
Left hip	44.5 ± 12.0	47.3 ± 7.2	47.6 ± 14.9	51.3 ± 16.8	F(1,51) = .07	.79
Ankle Plantar Flexion						
Right ankle	30.8 ± 9.3	34.7 ± 9.8‡	30.3 ± 8.4	34.4 ± 7.5 ‡	F(1,50) = .01	.90
Left ankle	29.7 ± 9.4	33.9 ± 10.2‡	30.2 ± 12.4	35.9 ± 9.1‡	F(1,50) = .33	.57
Ankle Dorsi Flexion						
Right ankle	9.8 ± 5.5	10.7 ± 5.7	9.8 ± 4.0	10.9 ± 3.9	F(1,50) = .07	.79
Left ankle	11.1 ± 4.8	12.1 ± 5.3	11.1 ± 4.9	12.4 ± 5.7	F(1,50) = .07	.80
Endurance (Total Work†) (Nm)						
Knee Extension						
Right knee	898.1 ± 338.3	904.2 ± 309.4	759.4 ± 349.7	958.8 ± 428.2§	F(1,49) = 12.4	.001
Left knee	880.1 ± 325.3	936.2 ± 358.1	790.2 ± 309.9	925.4 ± 325.9‡	F(1,49) = 2.3	.14
Knee Flexion						
Right knee	914.8 ± 319.5	929.3 ± 280.5	730.0 ± 398.7	886.1 ± 355.7§	F(1,49) = 8.4	.006
Left knee	835.6 ± 353.1	848.1 ± 315.4	628.2 ± 359.5	832.9 ± 288.9§	F(1,49) = 9.2	.004

Note: Nm = Newton meters.

*Peak value obtained from 4 maximal repetitions at an angular velocity of 60°/sec.

†Total amount of work performed over 30 continuous repetitions at an angular velocity of 180°/sec.

‡Paired t test of pre–post within-group difference, $p < .05$.

§Tukey's post hoc analysis; exercise group improved > control group.

Table 4. Effect of Exercise on Functional Measures

	Control		Exercise			
Measures	Baseline (n = 27)	Post-Test (n = 27)	Baseline (n = 28)	Post-Test (n = 28)	ANOVA Group × Time	p value
Performance Measures						
Sit-to-stand (repetitions)*	9.7 ± 4.1	10.1 ± 4.9	8.4 ± 4.2	10.3 ± 3.5‖	F(1,53) = 3.5	.07
Six-minute walk (meters)†	451.7 ± 82.9	464.4 ± 79.4	461.7 ± 81.7	509.8 ± 106.7¶	F(1,53) = 6.6	.01
POMI gait score	8.9 ± 1.5	9.3 ± 1.5	8.8 ± 1.7	10.1 ± 1.6¶	F(1,53) = 6.0	.02
POMI balance score	13.9 ± 1.8	14.5 ± 1.8‖	13.9 ± 1.6	14.9 ± 1.1‖	F(1,53) = .96	.33
Obstacle course score	19.8 ± 4.2	20.5 ± 2.9	19.8 ± 4.5	21.2 ± 2.6‖	F(1,43) = 2.8	.45
One-leg balance—dominant leg (seconds)‡	5.2 ± 4.3	6.5 ± 5.4	3.7 ± 3.5	6.1 ± 4.4‖	F(1,52) = 1.1	.29
One-leg balance—nondominant leg (seconds)‡	4.9 ± 3.8	4.8 ± 3.6	4.2 ± 3.4	5.3 ± 3.9‖	F(1,52) = 2.5	.12
Questionnaires						
SF-36 physical functioning	62.2 ± 21.0	60.6 ± 20.3	59.6 ± 24.8	65.0 ± 17.4	F(1,53) = 3.2	.08
SF-36 role limits-physical	53.7 ± 38.4	57.4 ± 35.2	66.9 ± 36.7	75.0 ± 34.0	F(1,53) = .36	.55
SF-36 health perceptions	58.9 ± 19.5	61.1 ± 19.9	60.0 ± 19.1	64.3 ± 18.2	F(1,53) = .26	.61
SF-36 health question	50.9 ± 20.2	46.3 ± 22.7	51.8 ± 26.3	67.9 ± 21.4¶	F(1,53) = 8.5	.005
Yale survey (hours)§	19.6 ± 12.4	19.4 ± 11.2	15.2 ± 8.2	18.6 ± 10.6‖	F(1,52) = 2.8	.10

*Sit-to-stand: The number of sit-stand cycles in 30 seconds from an armless chair.

†Six-minute walk: Distance (meters) covered during continuous walking on a quarter mile outdoor track.

‡One-leg balance: Number of seconds participant could stand on one leg for a maximum of 15 seconds. Participants were barefoot.

§Yale physical activity survey: Participants estimated the amount of time spent in various work, exercise, and recreational activities during a typical week in the previous month. Total time for each activity was summed over all activities to create a total time summary index (hours/week) for each subject.

‖Paired t test of pre–post within-group difference, $p < .05$.

¶Tukey's post hoc analysis; exercise group improved > control group.

ing given our short follow-up period. Other intervention studies have demonstrated significantly reduced fall rates only after one year of follow-up (9,13). In addition, our participants had multiple risk factors for falling, which makes it more difficult to demonstrate a positive impact from a single intervention alone (24). Two recent studies (12,13) used a multifactorial approach to address multiple fall risk factors and successfully reduced one-year fall rates in community-living older adults.

The fact that the rate of falls per unit of activity was significantly lower in the exercise group is a new and interesting finding. Exercise clearly benefits many aspects of health and quality of life, as is well documented in the rapidly growing exercise research literature. However, for individuals who are already fall-prone, increased activity may result in a greater risk of falling due to increased exposure to environmental hazards (25,26). It is possible that a potential reduction in falls from reduced risk factors would be offset by increased physical activity and exposure to risk, with no net change in overall fall frequency. Our attempt to adjust for exposure is one strategy for dealing with this offsetting phenomenon. Our findings suggest that simply looking at unadjusted fall rates may underestimate positive effects of exercise for fall-prone individuals.

A relatively small sample size and short follow-up period limited our study power, and our results should be generalized primarily to similar fall-prone, male populations. Nonetheless, these findings provide new evidence that older individuals with chronic impairments and risk factors for falls can safely participate in structured group exercise, and achieve improvements in endurance, strength, gait, and function.

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