The Effect of Group Exercise on Physical Functioning and Falls in Frail Older People Living in Retirement Villages: A Randomized, Controlled Trial

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OBJECTIVES: To determine whether a 12-month program of group exercise can improve physical functioning and reduce the rate of falling in frail older people.

DESIGN: Cluster randomized, controlled trial of 12 months duration.

SETTING: Retirement villages in Sydney and Wollongong, Australia.

PARTICIPANTS: Five hundred fifty-one people aged 62 to 95 (mean ± standard deviation = 79.5 ± 6.4) who were living in self- and intermediate-care retirement villages.

MEASUREMENTS: Accidental falls, choice stepping reaction time, 6-minute walk distance postural sway, leaning balance, simple reaction time, and lower-limb muscle strength.

RESULTS: Two hundred eighty subjects were randomized to the weight-bearing group exercise (GE) intervention that was designed to improve the ability of subjects to undertake activities for daily living. Subjects randomized to the control arm (n = 271) attended flexibility and relaxation (FR) classes (n = 90) or did not participate in a group activity (n = 181). In spite of the reduced precision of cluster randomization, there were few differences in the baseline characteristics of the GE and combined control (CC) subjects, although the mean age of the GE group was higher than that of the CC group, and there were fewer men in the GE group. The mean number of classes attended was 39.4 ± 28.7 for the GE subjects and 31.5 ± 25.2 for the FR subjects. After adjusting for age and sex, there were 22% fewer falls during the trial in the GE group than in the CC group (incident rate ratio = 0.78, 95% confidence interval (CI) = 0.62–0.99), and 31% fewer falls in the 173 subjects who had fallen in the past year (incident rate ratio = 0.69, 95% CI = 0.48–0.99). At 6-month retest, the GE group performed significantly better than the CC group in tests of choice stepping reaction time, 6-minute walking distance, and simple reaction time requiring a hand press. The groups did not differ at retest in tests of strength, sway, or leaning balance.

CONCLUSION: These findings show that group exercise can prevent falls and maintain physical functioning in frail older people. **J Am Geriatr Soc 51:1685–1692, 2003.**

Key words: exercise; aged; accidental falls; mobility; fitness; choice stepping reaction time; muscle strength; postural sway

For several years now, it has been clear that exercise can modify key falls risk factors such as decreased muscle strength, reduced speed, and poor balance in older people,[1,2] and there is now good evidence that exercise can reduce the incidence of falls themselves. Interestingly, the interventions shown to be effective have involved disparate exercise regimes, including tai chi,[3] supervised strength and endurance training,[4] and home exercise prescribed by a physiotherapist[5,6] or specially trained nurse.[7] Further evidence for exercise being an effective intervention comes from the Yale Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) study, which included a home exercise program as one of its multifaceted interventions.[8] These interventions resulted in significantly lower falling rates in the intervention subjects and improvements in intermediate measures such as balance and transfer abilities.

However, not all exercise interventions have been found to be effective in preventing falls.[9–12] For example, the meta-analysis of the seven FICSIT trials that involved exercise found that interventions that contained a balance component reduced falls significantly by about 17%. In

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contrast, programs classified as resistance, endurance, or flexibility training were not effective in reducing fall rates.

It has also been suggested that that some interventions have failed to be effective because the subjects were at too high or too low a risk of falling for the interventions implemented.[7,8] The findings of the recent successful trials that have targeted their interventions carefully to those most likely to benefit (those with mild strength and balance deficits,[4] women aged 80 and over,[5,6] and those aged 70 and older with one or more falls risk factors) have supported this claim.[8]

Previous studies have shown that a 12-month exercise program resulted in improved strength, coordination, standing and leaning balance, and walking speed in older community-dwelling women.[13–15] The exercise program consisted of group activities that were designed to maximize enjoyment and social interaction, with the aim of facilitating long-term compliance. In spite of improvements in physical functioning, falling rates in the exercise group were similar to those observed in the control group. This may have been due to the untargeted nature of the program, in that the subjects who took part in the trial had relatively high physical performance levels and low falling rates.

This study builds on this work by assessing whether group exercises designed to improve the ability of subjects to undertake activities for daily living (ADLs) can prevent falls in a large sample of older people who are living in retirement villages—a population group with high levels of functional impairments and risk of falling. It was hypothesized that a weight-bearing group exercise program would be more effective in reducing falls than a control program primarily of seated flexibility and relaxation activity or no exercise at all.

METHODS

Subjects

Five hundred fifty-one subjects aged 62 to 95 (mean age ± standard deviation = 79.5 ± 6.4) constituted the study sample. The subjects were recruited from all the self- and intermediate-care Anglican Retirement Villages in Sydney and Wollongong, Australia. At self-care apartment villages, common room facilities are available, and residents can seek the assistance of managers for help with arranging home maintenance services. At intermediate-care hostels, personal care, provision of meals, physiotherapy, and organized group activities are available. Four hundred thirty subjects (78.0%) were living in self-care apartments, and 121 (22.0%) were living in intermediate-care hostels.

Because the exercise intervention was conducted within the village sites, the subjects were randomized by cluster (i.e., village) to avoid contamination and enhance feasibility.[16] Randomization was stratified by accommodation status (self-care or intermediate-care) and cluster size (<75 or ≥75 residents). In all, there were 20 clusters:, seven self-care and three intermediate-care exercise group clusters and seven self-care and three intermediate-care control group clusters. Table 1 shows the number of study group participants in each cluster.

Information sessions were held at each site, and residents were informed about the objectives of the study, the nature of the exercise program (if applicable), and the schedule of interviews and assessments. Subjects were then approached individually and asked to participate. Subjects were excluded from taking part if they had a standardized Mini-Mental State Examination score less than 20;[17] had a medical condition involving the neuromuscular, skeletal, or cardiovascular system that prevented them from taking part in an exercise program (as determined by nursing staff or a physician at pretest); were in the hospital or away from the village at the time of recruitment; or were already attending exercise classes of equivalent intensity to the study intervention. The number of subjects in each exclusion category and the number who declined to take part for the group exercise (GE) and combined control (CC) groups are shown in Figure 1. The participation rates in self-care sites ranged from 34.3% to 57.1% (mean = 50.1 ± 7.1). The participation rates in intermediate-care sites ranged from 24.1% to 40.6% (mean = 28.6 ± 6.0). The overall participation rates with respect to total and eligible subjects were 44% and 53%, respectively.

Table 1. Self- and Intermediate-Care Village Sites (Clusters) Ranked by Size

Cluster	Cluster Size (n) Group Exercise	Cluster Size (n) Combined Controls
Self-care apartments		
Rank 1	18	11*
2	23	14*
3	27	27
4	33	31
5	36	32*
6	39	40
7	40	52
Total	216	207
Mean ± SD	30.9 ± 8.4	29.6 ± 14.2
Intermediate-care hostels		
Rank 1	10	12
2	22	19†
3	32	33*
Total	64	64
Mean ± SD	21.3 ± 11.0	21.3 ± 10.7

* Undertook seated flexibility and relaxation exercises.
† This site contained seven self-care residents.
SD = standard deviation.

To assess for a possible response bias, age and sex data were collected for 157 eligible nonparticipants who resided at village sites where the exercise intervention and flexibility and relaxation control group activities were established. These subjects had a similar mean age to the study participants at these sites (80.9 ± 7.6 and 80.3 ± 6.4 years, respectively; $t_{525} = 0.92$, $P = .36$). The proportions of nonparticipants and participants at these sites who were women were also similar (83.4% and 87.6%, respectively; $\chi^2 = 1.59$, $df = 2$, $P = .21$).

The Exercise Intervention Program

Two hundred eighty subjects were randomized to the GE intervention. The exercises included an intervention pro-

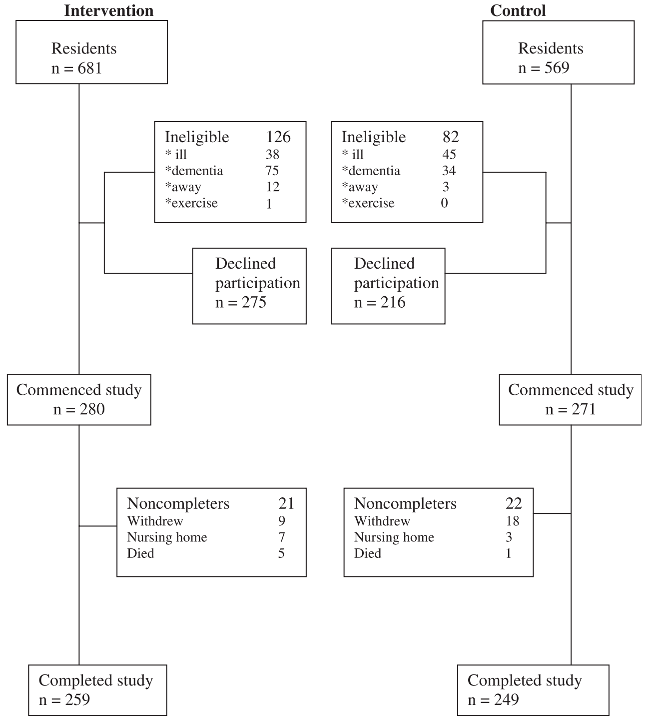

Figure 1. Study design: flow of participants through the study. Twenty retirement villages were randomized to intervention group (seven self-care and three intermediate care) or control group (seven self-care and three intermediate care), with 681 intervention enrollees and 569 control enrollees. The total number of participants completing the study is shown.

gram designed and selected to meet two criteria: (1) to address known major risk factors for falls (impaired strength, speed, coordination, balance, and gait) and (2) to improve the subject's ability to undertake ADLs (performing everyday tasks such as balancing while turning and reaching, rising from a chair, negotiating stairs, maintaining balance in standing and walking conditions that challenge balance, and making fast and appropriate balance corrections).

The exercise classes were conducted twice weekly for a 12-month period in a common room within each village site. Six instructors trained to provide the same program led the classes (with one instructor assigned to a village site and exercise session). Each class was conducted for 1 hour and consisted of three sections: a 5- to 15-minute warm-up period, a 35- to 40-minute conditioning period, and a 10-minute cool-down period. Most exercises were weight bearing and undertaken as group activities, with a major emphasis on social interaction and enjoyment. Although following a core theme, the exercise classes were individualized to the functional capabilities of the subjects. For example, to enable subjects with moderate balance impairments to take part in the program, these subjects undertook certain weight-bearing balance exercises holding on to or in reach of a support. All participants were also encouraged to go at their own pace.

For the first 5 weeks of the program, the warm-up period consisted of chair activities and stretching of large muscle groups. For the remainder of the program, the warm-up included slow- to moderate-paced walking. The pace and duration of the walking increased from 5 to 15 minutes in the first 10 weeks of the program and was maintained at 15 minutes for the remainder of the program.

The conditioning period consisted of aerobic exercises, specific strengthening exercises, and activities for balance, hand-eye and foot-eye coordination, and flexibility. The aerobic exercises involved movement of the legs, trunk, and arms to involve all joints and major muscle groups. The leg movements were designed to use the full range of movement of the hip, knee, and ankle joints and to condition and strengthen all major muscle groups. The trunk movements were designed to maintain flexibility of the spine and to condition and strengthen the back, chest, and abdominal muscle groups. The arm movements were designed to use the full range of movement of the shoulder, elbow, and wrist joints and to strengthen all major muscle groups. Whole-body exercises included pacing, dance patterns, directional changes and speeds, and complicated routines of whole-body movement. Walking pattern exercises consisted of large strides, heel-toe walking, narrow- and wide-based walking, and sidestepping.

Specific graded muscle group strengthening exercises were undertaken with an increased number of repetitions per session. Muscle groups targeted included ankle dorsiflexors, knee extensors, hip abductors, and hip side-flexors. Repetitions were increased from four at Week 2 to 30 at Week 10. Thirty repetitions were then maintained for the remainder of the program.

The activities for balance included tandem foot standing, heel-toe walking, line walking, standing on one leg, altering the base of support, weight transfers (from one leg to the other), rocking back and forth onto toes and heels, rotating on the spot, lateral movement challenges, and reaching and stretching movements away from the center of gravity (forward, laterally, and upward). The flexibility exercises were undertaken in the seated and standing positions. They included toe pointing forward and laterally and heel strike exercises moving the heel forward and to the sides.

The cool-down period consisted of muscle relaxation, controlled breathing, and guided imagery.

The Control Group Activities

Subjects allocated to four village sites (n = 90) took part in a flexibility and relaxation (FR) program to assess the effects of a group activity involving a minimal-intensity exercise program but one that did not appear to be a sham activity to the participants. Two yoga instructors trained to provide the same program led the classes. All of the activities were undertaken in the seated position. In each 1-hour session, toe bending, ankle bending and rotation, knee bending and rotation, hand clenching, wrist bending and rotation, elbow bending, shoulder rotation, exercises that involved rotation or movement of the trunk and neck, and controlled rhythmical breathing were performed. All bending and rotation exercises were repeated 10 times. The final component of each session required the subjects to assume the breath balance pose. Subjects crossed their arms in front of the chest and placed their hands under the arms with the thumbs pointing upwards in front of the armpits. The final

10 to 15 minutes of each session consisted of slow, rhythmic breathing. As with the GE program, the FR program was conducted twice weekly for 12 months.

The remainder of the control group (n = 181) did not take part in any group activity. A no-exercise control (NEC) group was included because, at the time of implementation of this study, the role of exercise (and in particular group exercise) in preventing falls was unclear. Furthermore, the study sought to determine the effectiveness of exercise on other important outcome measures such as cognitive functioning and mood, for which a NEC group was essential.

Ascertainment of Falls

All residents were followed up for 1 year. For the purposes of this study, a fall was defined as an event that resulted in a person coming to rest unintentionally on the ground or other lower level not as the result of a syncopal event, other major intrinsic event, or an overwhelming hazard.[2]

Questionnaires were given to residents every month. The questionnaire provided information on the number of falls in the past month, the location, the cause, and any injuries suffered. Subjects who did not complete questionnaires were followed up with additional home visits or telephone calls in the week after the questionnaires were due. In addition, to minimize underreporting of falls by subjects with memory impairments, a falls record book was established by the nursing staff at the commencement of the study at the intermediate-care sites. Nurses recorded falls they witnessed and cases where residents came to the nursing station for treatment of an injury because of a fall.

Physical Performance Outcome Measures

Two functional measures related to stepping and mobility requirements for ADL were treated as the primary physical performance outcome measures. Choice stepping reaction time was determined by assessing subjects' ability to step as quickly as possible onto one of four 32 cm by 13 cm rectangular panels (one in front of each foot and one to the side of each foot) that were illuminated in a random order.[18] Subjects used the left foot only for the two left panels (front and side) and the right foot only for the two right panels. The average time of 20 experimental trials was used in the analysis. The 6-minute walk test was used as a measure of fitness[19] and mobility.[20] At each site, subjects walked as quickly as they could on a level course for 6 minutes, and the distance walked was taken as the test measure.

The secondary physical performance outcome measures assessed strength, speed, and balance and were included to provide information about how the intervention influenced important and complementary physiological domains. Isometric knee extension strength in both legs was assessed in the seated position with the angles of the hip and knee at 90°.[13,21] The best of three trials was recorded, and the average of these scores for both legs was recorded. Simple reaction time was measured with subjects seated using a light as the stimulus and a hand press as the response.[13,18] Postural sway was measured using a sway meter that measured displacements of the body at the level of the waist. Testing was performed with subjects standing on the floor with eyes open and eyes closed.[13,21] Leaning balance was measured using the maximal balance range and coordinated stability tests.[14]

The reliability of these tests has been established in previous studies.[14,18–21]

Statistical Analysis

Chi-square tests for cross-tabulation tables and grouped *t* tests were used to compare the prevalence of health and lifestyle factors and the means of the test measures of the GE and CC groups at initial assessment. The number of falls in the two groups was compared by calculating incidence ratio rates (IRRs) using negative binomial regression models (Stata Corp., College Station, TX),[7,22] adjusting for baseline differences (age and sex) that resulted from the cluster randomization. Negative binomial regression models take into account not only all falls during the trial, but also the distribution of falls, which is like Poisson (exponential) but with overdispersion (i.e., contain a wider, higher tail in the distribution).[22] Robust confidence intervals (CIs) were calculated to allow for the clustering (i.e., the fact that the unit of randomization was the village and not the individual and the likelihood that residents within a village (cluster) would be more similar than residents between villages). The physical performance measures at the 6-month retest were compared using forced-entry multiple linear regression analysis with robust standard errors to adjust for the clusters. In these models, baseline scores, age, sex, and experimental group were included as independent variables. For variables with right-skewed distributions (i.e., the reaction time and sway measures), logarithms of these variables were calculated and examined in the analyses.

Because of the differing allocation of self- and intermediate-care subjects to the FR and NEC groups that occurred as part of the cluster randomized design, comparisons between the GE and CC groups constituted the primary analyses for this study. Secondary analyses were also performed to examine the intervention effects on the outcome measures among the GE, FR, and NEC groups.

The data were analyzed on an intention-to-treat basis to minimize retest bias and to provide a more realistic indication of the generalizability and effectiveness of the intervention[23] and were analyzed using STATA 7 (Stata Corp., College Station, TX) and SPSS for Windows (SPSS Inc., Chicago, IL) statistical software.

RESULTS

Demographic, Health, and Lifestyle Characteristics at Baseline

Despite the reduced precision of cluster randomization, there were few differences in the baseline characteristics between the GE and CC subjects. The mean age ± standard deviation of the GE group was 80.1 ± 6.4, which was significantly older than the mean age of the CC group of 78.9 ± 6.4 ($t_{549} = 2.13$, $P = .03$). There were also fewer men in the GE group than in the CC group, although not significantly so (11.4% vs 16.6%, respectively; $\chi^2 = 3.07$, $df = 1$, $P = .08$). Table 2 shows the numbers and proportions in the GE, FR, NEC, and CC groups who reported medical conditions, falls, instability, drug use,

Table 2. Prevalence of Major Medical Conditions, Medication Use, Participation in Physical Activity, and Mobility and Activity of Daily Living (ADL) Limitations in the Exercise and Control Groups at Baseline

Condition	Group Exercise (n = 280)	Flexibility and Relaxation (n = 90)	No-Exercise Controls (n = 181)	Combined Controls (n = 271)
	n (%)			
Demographic factors				
Male	32 (11.4)	14 (15.6)	31 (17.1)	45 (16.6)
Intermediate (hostel) care	65 (23.2)	33 (36.7)	24 (13.3)	57 (21.0)
Medical conditions				
Poor vision	79 (28.2)*	19 (21.1)	34 (18.8)	53 (19.6)
Poor hearing	103 (36.8)	46 (51.1)	68 (37.8)	114 (42.1)
Stroke	33 (11.8)	9 (10.0)	17 (9.4)	26 (9.6)
Parkinson's disease	6 (2.1)	2 (2.2)	2 (1.1)	4 (1.5)
Heart attack	30 (10.7)	10 (11.1)	14 (7.7)	24 (8.9)
Heart disease	87 (31.1)	26 (28.9)	50 (27.6)	76 (28.0)
Poor circulation	119 (42.5)	32 (35.6)	72 (39.8)	104 (38.4)
Vascular disease/leg ulcers	36 (12.9)	16 (17.8)	32 (17.7)	48 (17.7)
High blood pressure	137 (48.9)	41 (45.6)	99 (54.7)	140 (51.7)
Low blood pressure	47 (16.8)	12 (13.3)	21 (11.6)	33 (12.2)
Respiratory conditions	62 (22.1)	6 (6.7)	37 (20.4)	43 (15.9)
Arthritis	198 (70.7)	60 (66.7)	111 (61.1)	171 (63.1)
Diabetes mellitus	21 (7.5)	2 (2.2)	23 (12.7)	25 (9.2)
Foot problems	76 (27.1)	32 (35.6)	44 (24.3)	76 (28.0)
Medication use				
≥4 medications	147 (53.1)	40 (44.9)	92 (50.8)	132 (48.9)
Cardiovascular medications	178 (64.3)	57 (64.4)	128 (70.7)	185 (68.5)
Psychoactive medications	91 (32.9)	28 (31.5)	53 (29.3)	81 (30.0)
Musculoskeletal medications	69 (24.9)*	15 (16.9)	33 (18.2)	48 (17.8)
Physical activity				
≥3 hours planned exercise/wk	120 (43.5)	39 (43.5)	78 (43.1)	117 (43.2)
≥7 hours physical activity/wk	189 (68.5)	49 (54.4)	117 (64.4)	166 (61.3)
Undertook planned walks ≥1 times/week	179 (63.9)	62 (68.9)	126 (69.6)	188 (69.4)
Mobility and ADL limitations				
One or more fall in past year	97 (34.6)	30 (33.3)	61 (33.7)	91 (33.6)
Uses a walking aid only when outside the home†	76 (27.3)	32 (35.6)	29 (16.0)	61 (22.5)
Uses a walking aid when inside or outside the home†	26 (9.3)	6 (6.7)	12 (6.6)	18 (6.6)
Requires a walking frame	6 (2.2)	4 (4.4)	5 (2.9)	9 (3.3)
Difficulty shopping	70 (25.2)	30 (33.3)	34 (18.4)	64 (23.6)
Difficulty with clothes washing/room cleaning	25 (9.0)	12 (13.3)	13 (7.2)	25 (9.2)
Difficulty cooking	54 (19.4)	14 (15.6)	30 (16.6)	44 (16.2)
Difficulty dressing	9 (3.2)	2 (2.2)	3 (1.7)	5 (1.8)
Difficulty bathing or toileting	9 (3.2)	1 (1.1)	4 (2.2)	5 (1.8)

* $P < .05$, comparison between exercise and combined control groups.
† Home refers to the apartment for self-care residents and the hostel building for intermediate-care residents.

and inactivity (Table 2). Statistically significant differences between the GE and CC groups were evident for three measures: poor vision, musculoskeletal drug use, and use of a walking aid. For these measures, exercisers had a higher prevalence than controls.

Subject Retention and Intervention Adherence

Five hundred eight subjects (92.2%) were available for analysis: 259 in the GE group (92.5%), 80 in the FR group (88.9%), and 169 in the NEC group (93.4%). Figure 1 shows the number of subjects in the GE and CC groups who were unavailable as a result of withdrawing from the study soon after recruitment, being transferred to a nursing home, or death (Figure 1). The range of exercise classes attended for the GE group was zero to 100 (0–100%). The mean number attended was 39.4 ± 28.7, or 42.3% of those available. The interquartile range was 10 to 62 classes (10.4–67.5%). The range of exercise classes attended for the FR group was zero to 93 (0–100%). The mean number attended was 31.5 ± 25.2, or 45.4% of those available. The interquartile range was six to 50 classes (9.8–73.1%). Planned exercise outside the program was similar for the GE and CC subjects at the midpoint (GE = 3.2 ± 3.3 h/wk,

Table 3. Falls in the Group Exercise and Combined Control Groups

	Falls, n (rate)		
Subjects	Group exercise (n = 259)	Combined controls (n = 249)	IRR (95% CI)*
All subjects (n = 508)	174 (0.67)	211 (0.85)	0.78 (0.62–0.99)
Previous fallers (n = 173)	79 (0.90)	111 (1.31)	0.69 (0.48–0.99)
Previous nonfallers (n = 335)	95 (0.56)	100 (0.61)	0.88 (0.65–1.20)

* Incidence rate ratios (IRR) calculated for comparing the rate of falls adjusting for age and sex, and using robust confidence intervals to allow for the cluster-randomized design.
CI = confidence interval.

CC = 2.9 ± .8 h/wk; t_{457} = 0.98 P = .33) and end (GE = 2.9 ± 3.0 h/wk, CC = 2.7 ± 2.9 h/wk; t_{454} = 0.50, P = .62) of the 12-month trial.

Effect of the Exercise Program on Falls

The overall compliance for completing the falls surveillance questionnaires was 75%. When these data were augmented from the telephone and room-visit follow-ups, 370 falls were self-reported in the study group as a whole. Two hundred fifteen falls were recorded in the falls record books at the intermediate-care hostels, and when the record book data were combined with the self-reports, the total number of falls increased to 385, and six subjects were reclassified as fallers rather than nonfallers. Two hundred eighty-two subjects (55.5%) suffered no falls, 132 (26.0%) suffered one fall, and 94 (18.5%) suffered two or more falls.

Table 3 shows details of falls frequency for the GE and CC groups. There were 22% fewer falls during the trial in the GE group than in the CC group (IRR = 0.78, 95% CI = 0.62–0.99). There were also significantly fewer falls in those who had fallen in the past year (IRR = 0.69, 95% CI = 0.48–0.99), but there was no significant difference for those who had not fallen in the year before the commencement of the study (IRR = 0.88, 95% CI = 0.65–1.20).

The secondary analyses indicated a lower rate of falls in the GE group than in the FR group (IRR = 0.76, 95% CI = 0.60–0.96) or the NEC group (IRR = 0.79, 95% CI = 0.60–1.05). There was a nonsignificant difference in the rate of falls between the FR group and the NEC group (IRR = 1.01, 95% CI = 0.79–1.28).

Effects of the Exercise Program on the Physical Performance Measures

Baseline strength, speed, balance, and fitness scores were similar between the GE and CC groups with the exception of two measures: choice stepping reaction time and 6-minute walking distance (t_{483} = 2.99, $P \leq .01$ and t_{522} = 2.05, $P < .05$, respectively). In these tests, the CC subjects performed better than the GE subjects, which may have been due in large part due to the younger age and larger proportion of men in this group.[18,20]

Table 4 shows the baseline and retest scores for physical performance measures for the GE and CC groups. At retest,

Table 4. Baseline and Retest Scores for the Exercise and Control Groups

	Exercise		Combined Controls	
	Baseline	Retest	Baseline	Retest
Physical Performance Measure	Mean ± Standard Deviation			
Choice stepping reaction time, ms	1,217 ± 219	1,182 ± 326†	1,151 ± 255	1,163 ± 199
6-minute walk distance, m	400 ± 134	404 ± 137*	422 ± 115	407 ± 115
Knee extension strength, kg	22.4 ± 9.2	21.9 ± 10.1	23.4 ± 9.9	23.5 ± 10.0
Simple reaction time, ms	291 ± 54	284 ± 53*	282 ± 58	286 ± 56
Sway, eyes open, floor, mm	107 ± 66	126 ± 73	106 ± 50	113 ± 76
Sway, eyes closed, floor, mm	140 ± 86	156 ± 97	138 ± 72	169 ± 127
Sway, eyes open, foam, mm	158 ± 96	187 ± 123	166 ± 104	168 ± 127
Sway, eyes closed, foam, mm	243 ± 127	266 ± 169	247 ± 136	261 ± 181
Maximal balance range, cm	15.2 ± 4.0	16.1 ± 4.4	15.6 ± 4.5	16.3 ± 4.1
Coordinated stability, errors	14.4 ± 8.7	13.6 ± 9.4	15.9 ± 9.6	13.3 ± 9.1

Note: Increases in the tests of strength, maximal balance range, and 6-minute walking distance, and decreases in the tests of reaction time, sway, and coordinated stability indicate improvements.
Differences in 6-month retest scores between exercise and control groups assessed using forced-entry multiple linear regression analysis (with baseline scores, age, sex, and experimental group included as independent variables) and using robust standard errors to adjust for the clusters;
* $P < .05$,
† $P < .01$.

the GE group performed significantly better than the CC group after adjusting for age, sex, and cluster in the two primary physical outcome measures: choice stepping reaction time and 6-minute walking distance. In relation to the secondary outcome measures, the GE group performed significantly better in the simple reaction time test, but the groups did not differ in the tests of quadriceps strength, sway, or leaning balance.

The secondary analyses revealed that, after adjusting for age, sex, and cluster, the GE group performed better at retest than the NEC group in the tests of choice stepping reaction time ($t = 2.89$, $P < .05$) and 6-minute walking distance ($t = 3.42$, $P < .01$) and better than the FR group in the simple reaction time test ($t = 2.86$, $P < .05$). The FR group subjects performed better at retest than the GE group subjects in the quadriceps strength test ($t = 3.01$, $P < .05$) and better than the NEC subjects at retest in the quadriceps and maximal balance range tests ($t = 2.60$, $P < .05$ and $t = 2.47$, $P < .05$, respectively).

DISCUSSION

The study findings indicate that a specifically designed program of group exercise can prevent falls and maintain physical functioning in frail older people. Overall, there were 22% fewer falls during the trial in the GE group than in the CC group. The program was particularly effective for previous fallers, who had 31% fewer falls. Thus, it appears that the intervention, which included exercises to improve the ability of frail older people to perform ADLs, was an appropriate one for this at-risk group.

The finding that the intervention was particularly effective for previous fallers is consistent with other studies that have found largest effects of interventions in the most-at-risk groups.[4–8,24,25] This may indicate that the program was targeted more accurately to this group, although the larger effect in the past fallers may be partially explained by the health belief model.[26] That is, previous fallers may appreciate to a greater extent that they are at risk of further falls and possible injuries and thus be more motivated to participate fully in the program.

The overall reduction in falls of 22% is similar to that found in the FICSIT interventions that contained a balance training component.[10] This is a lower rate than reported in some multifaceted falls prevention interventions,[8,25] but multifaceted studies have a limitation in that it is not possible to determine the independent effects of component parts of their intervention packages.[9,27] Therefore, this study is helpful in that it provides information on the effectiveness of a single low-cost and replicable intervention in an at-risk population.

The study examined mediating factors that could elucidate the mechanisms by which the program prevented falls. When compared with community-dwelling women aged 65 to 84 from a previous study,[13,14] the effects of this program on the physical function measures in this population were less marked. Most notably, there was no improvement in the secondary outcome measures (knee extension strength and standing balance) in the GE group, which indicates that the exercises were of insufficient intensity to produce gains in these domains. The consistent worsening of sway in subjects over time may also reflect age-related changes in this population. However, compared with the CC subjects the GE subjects performed better in the tests of simple and choice reaction time and 6-minute walking distance. The improved ability of the GE group in the choice stepping reaction time test may be particularly important, because this test is not unlike the step response required to avoid a fall and provides a useful composite measure of falls risk.[18] The maintained performances by the GE subjects in the 6-minute walk test is also encouraging, because this measure in this population is dependent on reduced strength, speed, and balance in addition to reduced fitness.[20] Thus, the intervention maintained or produced small gains in important physical function measures in this frail older group, which appears to have provided protection against falls.

It is acknowledged that other factors may have influenced the outcome measures. Because most control subjects did not take part in an equivalent activity, it is possible that the educational component of the program contributed to behavioral changes and a subsequent lower rate of falls reported in the GE group,[28] but it is unlikely that changes in exercise levels outside the program was an important factor because the exercise and control groups reported similar levels of habitual planned exercise at the midpoint and end of the 12-month trial.

Many measures were implemented to maximize participation in the exercise program. The exercise classes were provided at no cost to the participants at sites within their villages. The classes were scheduled so as to not compete with other village activities, and only instructors who had experience conducting classes for older people led the classes. All assessments were also performed on site. Even so, almost half the eligible subjects declined participation, and the adherence rate for those who did commence the program was only moderate. Nonetheless, the findings indicate that group-based exercise programs are feasible for a significant percentage of the frail older populations in retirement village self-care and intermediate-care settings. Participation may have been further enhanced if a range of exercise alternatives were offered, including individual exercise programs, water exercise, and walking programs.

The cluster randomization was essential because of the high likelihood of intervention contamination due to the exercise program being conducted within each village site, but this method of randomization led to some baseline differences between the exercise and control groups. The cluster randomization also made blinding of research staff impractical. Therefore, notwithstanding the quantitative test measures and standardized subject instructions, it is possible that some of the improvements evident at retest may have resulted from observer bias. Second, although there was no significant difference between the FR and NEC subjects for falls, the FR group did show significant improvements in the quadriceps strength and maximal balance range tests. Although the flexibility exercises were designed to provide a low-intensity intervention, reaching and weight-bearing aspects of this program may have led to improved strength and balance. Therefore, the inclusion of the FR group probably decreased the difference in the treatment effect between groups, but it aided in reducing the potential for information bias for the subjects and strengthens the validity of the findings.

In conclusion, this study provides complementary findings to the growing literature on the effectiveness of exercise as a falls-prevention strategy by showing that group-based exercise can produce benefits with regard to maintaining physical functioning and reducing falls frequency in frail older persons.

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