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The Effect of Strength and Endurance Training on Gait, Balance, Fall Risk, and Health Services Use in Community-Living Older Adults

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Background. The study tested the effect of strength and endurance training on gait, balance, physical health status, fall risk, and health services use in older adults.

Methods. The study was a single-blinded, randomized controlled trial with intention-to-treat analysis. Adults (n = 105) age 68–85 with at least mild deficits in strength and balance were selected from a random sample of enrollees in a health maintenance organization. The intervention was supervised exercise (1-h sessions, three per week, for 24–26 weeks), followed by self-supervised exercise. Exercise groups included strength training using weight machines (n = 25), endurance training using bicycles (n = 25), and strength and endurance training (n = 25). Study outcomes included gait tests, balance tests, physical health status measures, self-reported falls (up to 25 months of follow-up), and inpatient and outpatient use and costs.

Results. There were no effects of exercise on gait, balance, or physical health status. Exercise had a protective effect on risk of falling (relative hazard = .53, 95% CI = .30–.91). Between 7 and 18 months after randomization, control subjects had more outpatient clinic visits ($p < .06$) and were more likely to sustain hospital costs over \$5000 ($p < .05$).

Conclusions. Exercise may have beneficial effects on fall rates and health care use in some subgroups of older adults. In community-living adults with mainly mild impairments in gait, balance, and physical health status, short-term exercise may not have a restorative effect on these impairments.

THE importance of regular exercise in the prevention of injurious falls and frail health in older adults is unclear. Exercise has beneficial physiologic effects in older adults, including effects on strength, aerobic capacity, flexibility, and bone strength (1,2) But the effect of exercise on many risk factors for falls is not clear. For example, some studies report that endurance and/or resistance exercise improves gait and balance (3–6) while other studies do not (7–9). Exercise does not modify many factors affecting fall risk and frail health, raising concern that the effect of exercise is small. For example, all environmental risk factors for falls, and many host risk factors such as impaired vision, are not directly modified by exercise.

However, longitudinal cohort studies report that physically active adults have less risk of falls and functional impairment (10–16). Experimental studies have begun to address the potential of exercise to prevent injurious falls and frail health (17). Two recent studies suggest that fall prevention is possible, but both studies tested multicomponent interventions and did not directly address the issue of whether exercise is effective (18,19). While a recent meta-analysis of falls suggested exercise may reduce the incidence of falls, the meta-analysis did not suggest the two most common types of exercise — endurance training and strength training — reduce fall risk, and the frequency, type, duration, and intensity of exercise varied widely across studies (20).

The purpose of this study was to determine if strength and endurance training can modify risk factors for falls. It also tested the hypothesis that exercise has a beneficial effect on falls and health services use.

METHODS

Study design. — The study was part of the National Institute on Aging's FICSIT (Frailty and Injuries: Cooperative Studies of Intervention Techniques) initiative (17), and is called the Seattle FICSIT/MoveIT study. The study was a randomized controlled trial with intention-to-treat analysis comprising three FICSIT exercise groups, three MoveIT exercise groups, and a control group. We have described the study design elsewhere (21). Only the FICSIT and control group results are reported here. The study was approved by both the University of Washington and Group Health Cooperative human subjects review committees.

Study sample. — The study recruited from a random sample of older adults enrolled in Group Health Cooperative of Puget Sound, a large health maintenance organization (HMO) that provides health care to a defined population of enrollees. Eligible subjects were (a) between 68 and 85 years of age, (b) unable to do an eight-step tandem gait without errors, and (c) below the 50th percentile in knee extensor strength for the subject's height and weight. Subjects with active cardiovascular, pulmonary, vestibular, and bone diseases were excluded. Other exclusion criteria were a positive cardiac stress test; body weight >180% of ideal; major psychiatric illness; active metabolic diseases; chronic anemia; amputation; chronic neurological or muscle disease; inability to walk; dependency in eating, dressing, transfer, or bathing; terminal illness; and inability to speak English or fill out written forms.

Of a random sample of 13,866 HMO enrollees, only 968 (7%) passed the first phase of screening. Reasons for exclusion were: pharmacy records indicated a drug prescribed for an excluded disease [6981 (50%)], subject reported an exclusion criterion [2181 (16%)], subject refused [2445 (18%)], and subject lived out of area [1291 (9%)]. The second phase of screening comprised a clinic visit and an exercise treadmill examination. Of the 968 adults who passed the first phase, 181 (19%) were randomized, with 30 subjects in the control group, 25 in each FICSIT exercise group, and the rest in MoveIT groups. The most common reasons for exclusion at the second phase were the strength test and the tandem gait test.

Exercise interventions. — Exercise consisted of endurance training (ET) and/or strength training (ST) in supervised classes for 24–26 weeks. Exercise occurred 3 days per week for 1 h. Exercise sessions began with a 10- to 15-min warm-up and ended with a 5- to 10-min cool-down. Endurance training used Schwinn Air-Dyne stationary cycles (Schwinn Cycling and Fitness Co., Boulder, CO) that allow both arms and legs to propel the wheel, at 75% of heart rate (HR) reserve. {Target HR = [75% × (maximum HR – resting HR)] + resting HR; maximum HR determined by treadmill test}. Strength training groups did resistance exercise of the upper and lower body using mainly Cybex Eagle weight machines (Lumex, Ronkonkoma, NY). The weight machines included exercise for the lower body (leg press, leg extension, leg curl, hip adduction and abduction), trunk (rotary torso), and upper body (incline press and rowing). Training at the ankle joint involved strapping the foot to a metal plate with (adjustable) weights attached to the anterior, posterior, medial, and lateral plate. The weights provided resistance for training dorsiflexion, plantar flexion, inversion, and eversion.

There were three exercise groups. The 6-month ET group performed 30–35 min of endurance exercise each session. The 6-month ST group did two sets (10 repetitions per set) of exercises on each weight machine, with the first set being at lower intensity [50–60% of the 1 repetition maximum (RM)] than the second set (75% of the 1 RM). The 6-month ST+ET group did 20 min of endurance training and one set of strength training exercises (75% of 1 RM).

To estimate usual activity levels, all subjects wore Caltrac activity monitors (Hemokinetics, Madison, WI) for 4 consecutive days each month (monitors were not worn during exercise classes). The monitors were set to report arbitrary activity units.

The control group was instructed to maintain usual activity levels. It was hoped that allowing control subjects to exercise after 6 months would encourage enrollment, but only seven control subjects chose this option.

Subjects randomized to exercise groups (except the 14 dropouts) received a discharge planning intervention to promote continued exercise. However, subjects could choose any type of exercise in either supervised (in existing community classes) or unsupervised settings.

Outcome measures. — Most study outcomes were measured by blinded examiners in all groups at baseline and at 6 months. The exercise groups, but not the control group, had 9-month measures.

The primary physiologic measures were strength and aerobic capacity. Skeletal muscle strength was measured using a Cybex II+ isokinetic dynamometer.

Maximal aerobic capacity was determined by graduated treadmill exercise and analysis of expired gases. Data from each test were blindly reviewed. Criteria used to judge a maximal test were (a) maximal heart rate ≥220 – age, (b) maximal respiratory exchange ratio ≥1.0, and (c) oxygen consumption increase in the last stage ≤1 ml/kg/min. Tests that failed to meet at least one criterion and tests with technical problems (usually evidence of gas leaks attributed to difficulty using the mouthpiece) were excluded (percent excluded were 16% at baseline, 28% at 6 months, and 18% at 9 months). In this report, subjects were not required to meet two of three criteria for a maximal test because the included tests were reliable over 3 months in the control group (Pearson $r = .92$), because tests were blinded, and because of concern about the appropriateness of more rigid criteria (22).

The primary outcome measures at 6 months were balance, gait, and physical health status. Balance was measured as ability to walk on wide (17 cm) and narrow (8.5 cm) 6-m balance beams, ability to stand (up to 30 sec) on one-directional (antero-posterior) and omni-directional tilt boards that require appropriate shifts in foot pressure to keep the board level with the ground, and ability to balance (up to 10 sec) in parallel, semitandem, and tandem stances. Average usual gait speed (m/min) and step length (m) were calculated based upon three trials over a 40-m course. Stair climbing speed (step/sec) was measured as the average of four trials of climbing 11 steps at a comfortable pace. As part of the FICSIT common database (23), subjects completed the Sickness Impact Profile physical dimension (24); the SF-36 role limitations–physical, bodily pain, and general health scales (25); and the Lawton Instrumental Activities of Daily Living (IADL) scale (26).

Falls were detected prospectively by asking subjects to inform study staff of any falls immediately by mail. In addition, all subjects returned postcards each month reporting the occurrence of falls in the prior month. Subjects not returning postcards were phoned, resulting in virtually 100% ascertainment of falls (except dropouts). The postcard contained the FICSIT common database definition of a fall: "A fall is unintentionally coming to rest on the ground, floor, or other lower level, whether or not you were injured." Fall surveillance occurred from randomization to the end of study funding (follow-up ranged from 0 to 25 months, median = 18 months). Blinded reviewers excluded only seven reported falls as not meeting the FICSIT definition.

Health care use and cost data were obtained from HMO computerized records. Baseline data covered the year before randomization. Postintervention data covered the year from 7 to 18 months after randomization. Utilization and cost data from the first 6 months after randomization were excluded because exercise subjects (but not controls) were asked to delay elective procedures until after the end of supervised exercise.

Statistical analysis. — All reported results are from intention-to-treat analyses. Outcomes measured at baseline and 6 months were analyzed using repeated measures analysis of variance (ANOVA). Each exercise group was separately compared to the control group. Only the exercise groups had 9-month outcome measures. The paired *t*-test was used to assess whether the 9-month measure differed from baseline. Using a one-way ANOVA analysis, no statistically significant differences were found among groups on any baseline variables in Tables 1, 2, or 3.

Due to modest statistical power for analyses of fall rates and health care use, the a priori strategy was to compare the control group to any exercise (combined exercise groups). Falls were analyzed using a proportional hazards regression model. The assumption that hazards are constant over time was supported by inspection of log-minus-log survival plots and survival functions. A person-time analysis was also done. Inpatient costs were analyzed using contingency tables. Outpatient ancillary cost and outpatient visits were analyzed with repeated measures ANOVA.

Results

Study sample, dropouts, and exercise process measures. — The characteristics of the study sample and process measures of the study are shown in Table 1. Fourteen (19%) of 75 subjects randomized to the FICSIT exercise groups dropped out, while only 1 (3%) of 30 subjects randomized to the control group dropped out (Table 1). Exercise-related injuries were infrequent and not an important cause of dropouts (27). Since six dropouts agreed to 6-month measures, 6-month follow-up was obtained on 92% of subjects randomized. Exercise subjects who did not drop out had excellent exercise adherence, attending 95% of scheduled exercise sessions.

Increases in average training loads provided evidence that intervention subjects experienced a training effect (Table 1). Both ST and ST+ET groups showed substantial increases in the 1 RM for all strength training exercises. For ET and ST+ET groups, the bicycle load increased over 24 weeks by 31% and 27%, respectively. The average training heart rate, 78% of heart rate reserve in the ET group and 76% in the ST+ET group, was close to the target of 75%.

At discharge from supervised exercise all subjects agreed to try to continue exercising. Subjects reported adherence to unsupervised exercise at the 9-month follow-up, at which time 58% exercised three or more times per week, 24% twice per week, and 5% not at all.

There was no evidence of contamination of the control group. Analysis of activity monitor data showed no significant differences in activity counts/hour over the 6 months (Table 1). The aerobic capacity and strength of the controls were stable over time (Table 2).

Strength and aerobic capacity. — The ST group showed significant increases in isokinetic strength at 6 months in all muscle groups except the ankle (Table 2). The ST+ET group also increased in strength, though the increases in strength were less than the ST group and only statistically significant at the knee. The ET group generally did not increase strength, except at the knee. The lack of improvement in ankle strength cannot be explained by poor reliability, as measurement reliability was excellent (28). However, the 1 RM data (Table 1) did suggest that strength increased at the ankle, consistent with other reports that isokinetic and isotonic measures of strength give different impressions of strength changes (29). Gains in isokinetic strength at 6 months were partly maintained at 9-month follow-up.

Aerobic capacity increased in the endurance training groups over time. At 9 months the ET group showed a 9% increase and the ST+ET group showed a 12% increase, which were significant. In the controlled analyses at 6 months, the 8% improvement in the ST+ET group was not significant, and the ET group showed little improvement in aerobic capacity — a finding that remained after excluding dropouts. Unfortunately, the 6-month treadmill exam in the ET group had several dropouts and excluded tests, with adequate data on only 14 subjects. The 95% confidence interval for the change in aerobic capacity did not exclude the possibility of a true change as large as +12%.

Gait, balance, and physical health status. — There were no significant effects of exercise on any measures of gait and balance (Table 2). Excluding subjects who dropped out of exercise from the analysis does not affect the results. Ceiling effects can explain the lack of improvement on some measures (e.g., AP tilt board), though there was no improvement on tests where ceiling effects were not a problem (e.g, narrow balance beam). Statistical power was adequate to rule out clinically important changes. For example, post-hoc power calculations showed the analysis had 90% power to detect as small as a 4% improvement in gait speed and a 3% improvement in stair climbing speed.

Measures of physical health status did not change with exercise. Again, there were ceiling effects with some measures (IADL and SIP scales). The SF-36 scales did not have problems with ceiling effects, and SF-36 scores also did not change (except for an isolated improvement at 9 months in the ST group).

Falls, utilization, and costs. — Cox regression analysis showed a significant beneficial effect of exercise on time to the first fall (relative hazard = .53, 95% CI = .30–.91) (Figure 1). In the year after randomization, 42% of exercise subjects reported a fall compared to 60% of control sub-

Table 1. Subject Characteristics at Randomization and Exercise Process Measures

	Control (n = 30)	ET (n = 25)	ST (n = 25)	ET+ST (n = 25)	All (N = 105)
Subject Characteristics					
Age	75	75	74	75	75
Female (%)	50	52	52	52	51
Caucasian (%)	97	88	100	88	93
Years of formal education	13	15	14	14	14
Health is fair or poor (%)	10	4	0	8	6
≥ 1 IADL dependency (%)	26	16	12	20	19
Fall in past year (%)	23	20	16	28	22
Outpatient visits/year	7.8	5.6	6.3	9.6	7.3
Ancillary outpatient costs/year ($)	168	92	145	371	193
Inpatient days/year	0.13	0.12	0	0.32	0.14
Inpatient costs/year ($)	79	116	0	429	153
Attendance and Dropout Status					
Sessions attended (including dropouts) (%)		74	81	88	81
Sessions attended (excluding dropouts) (%)		95	95	95	95
Dropout from exercise (%)		24	20	12	19
Outcomes measured at 6 months (%)	97	84	88	96	92
Outcomes measured at 9 months (%)		76	80	88	80
Activity counts/hour	3.2	3.2	3.3	3.4	3.3
Endurance Training Process Measures					
Average percent of HRR attained during exercise (%)		78		76	
Increase in bicycle exercise load over 6 months (%)		31		27	
Strength Training Process Measure: Percent Increase in 1 RM at 6 months					
Leg press			71	91	
Leg extension			57	75	
Leg curl			87	87	
Hip abduction			41	40	
Hip adduction			39	45	
Rotary torso			113	81	
Incline press			54	54	
Rowing			63	87	
Ankle plantar flexion			96	112	
Ankle dorsiflexion			57	53	
Ankle inversion			118	114	
Ankle eversion			91	96	

Notes: Mean values (or percent) are shown for each group. ET = endurance training; ST = strength training; IADL Instrumental Activities of Daily Living; HRR = heart rate reserve; 1 RM = one repetition maximum. One-way ANOVA showed no significant baseline differences between groups in any subjects characteristics. Utilization and cost data are for the year prior to randomization. Activity counts are from body-motion monitors set to report arbitrary units of activity. Average percent of HRR attained during exercise was based upon the last 18 weeks of exercise, as intensity was gradually increased over the first 6 weeks.

jects. Since nonrandom dropouts may bias these results, we did a "worst case scenario" check for bias: all intervention dropouts who did not report a fall were assumed to have fallen immediately after dropping out. There was still a significant beneficial effect of exercise (relative hazard = .58; 95% CI = .34–.98).

A person-time analysis addressed whether exercise subjects had fewer total falls during follow-up. The fall rate in controls (.81 falls/year) was significantly higher than the rate in exercise subjects (.49 falls/year) (relative risk = .61; 95% CI = .39–.93).

Outpatient visit rates for exercise subjects were stable over time at 7.2 visits per year. Control subjects had an increase from a mean of 7.8–10.8 ($p < .06$) (Figure 2). There were no significant differences between groups in ancillary outpatient costs.

Hospital use 7–18 months after randomization was similar in both groups, with 84% of exercise subjects and 80% of control subjects having no hospital use (Table 3). However, hospitalized controls were significantly more likely to spend more than 3 days in the hospital ($p < .05$). Reflecting the high correlation between number of hospital days and total hospital costs, hospitalized control subjects were also more likely to have over $5000 in hospital costs ($p < .05$). The results were still significant using log-linear models to adjust for baseline hospital use.

Discussion

This study found a beneficial effect of exercise on fall risk and health care use. Two studies have reported that a multiple risk factor intervention can reduce fall risk (18,19). Because these studies tested several interventions

Table 2. Effect of Exercise on Strength, Aerobic Capacity, Gait, Balance, and Physical Health Status

	Control		Endurance Training (ET)			Strength Training (ST)			Combination Training (ST+ET)		
	Baseline (*n* = 29)	Change at Month 6 (*n* = 29)	Baseline (*n* = 21)	Change at Month 6 (*n* = 21)	Change at Month 9 (*n* = 19)	Baseline (*n* = 22)	Change at Month 6 (*n* = 22)	Change at Month 9 (n = 20)	Baseline (*n* = 24)	Change at Month 6 (*n* = 24)	Change at Month 9 (*n* = 22)
Skeletal Muscle Strength											
Hip extension (Nm)	78 (42)	−2 (34)	90 (37)	12 (39)	2 (36)	87 (49)	28 (42)**	4 (45)	80 (44)	17 (36)	9 (32)
Hip flexion (Nm)	68 (26)	−2 (18)	78 (39)	−6 (23)	−5 (26)	68 (29)	18 (16)**	14 (38)	75 (34)	6 (15)	2 (20)
Hip abduction (Nm)	63 (24)	−2 (17)	73 (25)	−2 (17)	−4 (18)	60 (26)	12 (23)*	7 (20)	64 (26)	8 (19)	5 (26)
Hip adduction (Nm)	36 (33)	−2 (25)	47 (23)	6 (19)	0 (32)	35 (26)	23 (35)**	11 (26)	36 (36)	5 (27)	6 (34)
Knee extension (Nm)	88 (32)	−4 (17)	88 (30)	9 (13)**	9 (13)*	86 (31)	13 (15)**	8 (16)*	80 (17)	11 (11)**	7 (16)*
Knee flexion (Nm)	48 (20)	1 (7)	52 (22)	6 (12)	2 (13)	44 (21)	17 (17)**	11 (18)**	52 (23)	9 (12)**	6 (12)*
Ankle plantar flexion (Nm)	38 (18)	3 (15)	38 (18)	5 (13)	4 (14)	38 (19)	6 (13)	8 (12)**	40 (17)	5 (10)	2 (17)
Ankle dorsiflexion (Nm)	16 (7)	0 (4)	17 (9)	−1 (5)	0 (6)	18 (6)	1 (4)	0 (4)	15 (6)	0 (4)	2 (6)
Ankle eversion (Nm)	10 (5)	1 (4)	11 (4)	1 (3)	1 (4)	10 (4)	2 (4)	1 (4)	11 (5)	1 (4)	1 (3)
Ankle inversion (Nm)	16 (9)	1 (5)	16 (8)	1 (5)	0 (6)	16 (8)	3 (7)	3 (6)*	15 (6)	1 (6)	1 (6)
Elbow extension (Nm)	24 (8)	0 (7)	27 (12)	0 (5)	0 (6)	25 (9)	4 (3)**	3 (6)	25 (10)	3 (5)	2 (5)
Elbow flexion (Nm)	24 (9)	0 (5)	28 (13)	0 (5)	−1 (4)	27 (11)	4 (5)**	3 (5)*	26 (10)	3 (5)	1 (5)
Aerobic Capacity											
VO_2max (ml/kg/min)	16.4 (4.6)	0.3 (2.6)	16.6 (4.9)	0.2 (3.3)	1.5 (2.5)*	16.7 (3.1)	0.3 (3.3)	0.5 (4.6)	15.8 (4.1)	1.2 (2.5)	2.0 (2.7)**
Exercise time (min)	10.7 (5.5)	1.3 (4.1)	10.8 (5.6)	1.1 (3.8)	1.3 (3.2)	10.9 (4.8)	1.3 (2.3)	1.8 (3.4)	11.5 (4.1)	1.6 (2.6)	1.7 (2.4)**
Balance											
AP tilt board (sec)	26 (7)	2 (6)	25 (7)	3 (7)	3 (8)	28 (6)	1 (6)	1 (4)	26 (7)	0 (4)	2 (3)*
Omnidirectional tilt board (sec)	22 (10)	4 (9)	23 (9)	1 (10)	0 (12)	26 (5)	0 (5)	1 (4)	24 (9)	1 (5)	−1 (6)
Wide balance beam (m)	5.5 (1.0)	0.3 (0.9)	5.7 (0.6)	0.0 (0.9)	−0.3 (1.4)	5.7 (0.8)	0.2 (0.6)	−0.1 (0.1)	5.6 (0.8)	0.0 (0.6)	−0.2 (0.8)
Narrow balance beam (m)	3.2 (1.8)	0 (1.1)	3.3 (2.2)	0.2 (2.2)	0.6 (1.7)	3.8 (1.8)	0.5 (1.2)	0.3 (1.0)	3.4 (1.8)	0.1 (0.9)	0.1 (1.5)
Tandem stance (sec)	8.4 (3.1)	0 (3.2)	8.5 (3.2)	−.9 (2.7)	0.3 (2.5)	9.5 (2.2)	0 (2.8)	−.3 (3.8)	8.4 (3.1)	−.6 (2.2)	−.9 (2.2)
One-leg stance (sec)	15 (10)	−1 (8)	8 (5)	0 (6)	−1 (7)	12 (9)	−2 (7)	−3 (12)	14 (13)	−2 (3)	−2 (7)
Gait											
Usual gait speed (m/min)	75 (13)	0.2 (9)	79 (12)	1 (7)	−1 (9)	82 (10)	−2 (9)	3 (14)	81 (11)	0 (10)	4 (13)
Step length (m)	.68 (.11)	−.01 (.04)	.69 (.08)	.00 (.05)	−.01 (.05)	.71 (.08)	−.01 (.06)	.00 (.07)	.68 (.08)	.00 (.07)	.00 (.08)
Stair climbing speed (steps/sec)	1.8 (0.3)	0.0 (0.1)	1.7 (0.4)	0.1 (0.2)	0.0 (0.2)	1.9 (0.2)	0.0 (0.2)	0.0 (0.2)	1.7 (0.3)	0.0 (0.2)	−0.1 (0.1)
SIP ambulation	6 (6)	0 (7)	6 (8)	−2 (9)	−2 (7)	6 (8)	−3 (8)	−2 (8)	6 (7)	−1 (10)	−3 (10)
Physical Health Status											
SF-36 general health	77 (14)	−2 (14)	78 (18)	1 (10)	0 (7)	78 (10)	1 (9)	5 (9)*	71 (15)	1 (11)	4 (11)
SF-36 bodily pain	76 (21)	1 (20)	78 (24)	−2 (19)	−4 (19)	74 (21)	2 (22)	−3 (23)	73 (22)	−1 (19)	5 (18)
SF-36 role physical	71 (28)	3 (38)	73 (31)	10 (38)	−8 (38)	65 (39)	4 (47)	24 (49)*	72 (32)	−1 (29)	1 (32)
No. of independent IADLs (total =5)	4.6 (.7)	.2 (.7)	4.7 (.6)	.2 (.5)	.1 (.7)	4.8 (.7)	.1 (.7)	.1 (.7)	4.6 (1.0)	.1 (.4)	−.1 (.4)
SIP body care and movement	3 (4)	−1 (4)	4 (6)	−1 (5)	−2 (5)	2 (3)	−1 (3)	−1 (3)	2 (8)	1 (5)	1 (5)
SIP mobility	3 (5)	−2 (6)	3 (8)	−2 (4)	0 (5)	1 (3)	0 (4)	−1 (4)	2 (5)	0 (6)	0 (8)
SIP physical dimension	3 (4)	−1 (4)	4 (6)	−1 (4)	−2 (4)	3 (3)	−1 (3)	−1 (3)	3 (6)	0 (5)	0 (6)

Notes: Group means are tabulated, with *SD* in parentheses. Positive change scores indicate improvement, except for SIP scores. Though all subjects had baseline data, the baseline data in the table include only subjects who also had 6-month data. Change at 6 months = 6-month score − baseline score. Change at 9 months = 9-month score − baseline score. SIP = Sickness Impact Profile; SF-36 = Short Form 36; IADL = Instrumental Activities of Daily Living; Nm = Newton-meters of torque; control subjects did not have 9-month measurements made; the significance of change scores at 6 months is based upon repeated measures ANOVA using a control group; the significance of change scores at 9 months is based upon a paired *t*-test with the baseline score; only physical health items were included in the IADL total (transportation, cooking, shopping, housework, and laundry); numbers in the analysis vary slightly due to some missing data; the VO_2max variable had more missing data (see text); the joint rotation speeds in degrees per second for the isokinetic strength measures were as follows: elbow, 60; ankle, 30; knee, 60; hip, 30; and ankle, 30.

$^*p < .05$; $^{**}p < .01$.

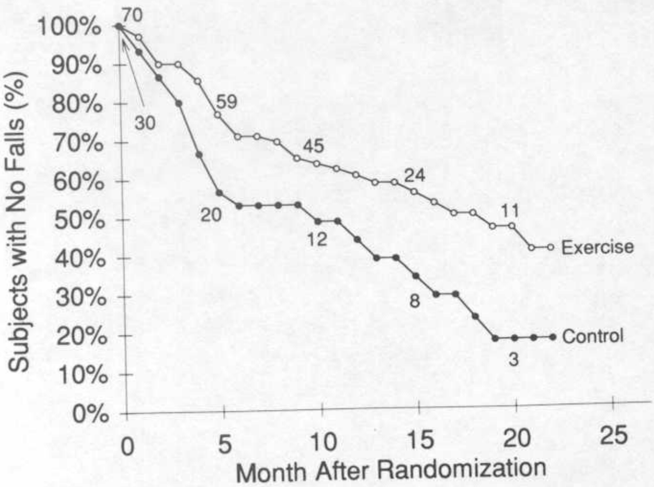

Figure 1. Effect of exercise on time to first fall after randomization. The three FICSIT exercise groups were combined into a single group for the analysis. Exercise had a protective effect on fall risk (relative hazard = .53, 95% CI = .30–.91). Median follow-up was 18 months (range 0–25 months). Survival curves are truncated at 22 months as no subject reported a (first) fall occurring after 21 months. Numbers by the curves indicate the number of subjects remaining in the analysis (under surveillance for falls but who had not reported a fall). Five dropouts from the exercise groups provided no fall data, so the analysis started with 70 exercise subjects and 30 controls.

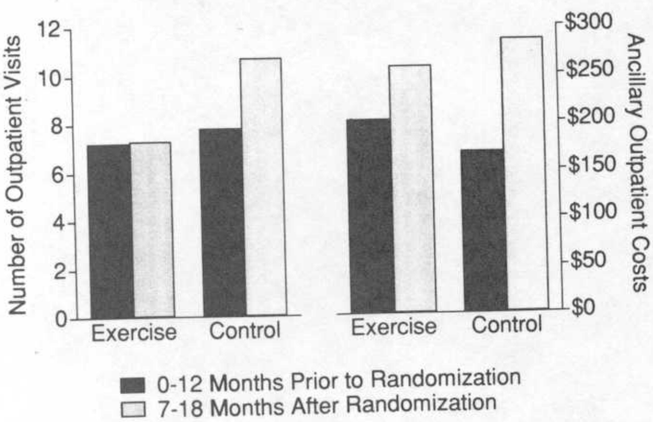

Figure 2. Effect of exercise on outpatient visits and ancillary outpatient costs. The control group had more visits 7–18 months after randomization ($p < .06$), but ancillary costs did not differ significantly. Ancillary costs included costs of pharmacy, laboratory, and radiology services, but not costs of a clinic visit per se.

Table 3. Effect of Exercise on Hospital Use and Costs for the Period 7–18 Months after Randomization

	Combined Exercise Groups *n* (%)	Control Group *n* (%)	Relative Risk	95% CI
Hospital Days				
0 days	63 (84)	24 (80)	1.0	
1–3 days	11 (15)	2 (7)	1.9	(.46–8.2)
Over 3 days	1 (1)	4 (13)	0.11	(.01–.94)
Hospital Costs				
No costs	66 (88)	24 (80)	1.0	
$1–$5000	8 (11)	2 (7)	1.4	(.32–6.2)
Over $5000	1 (1)	4 (13)	0.10	(.01–.89)

Notes: Three subjects had hospital costs reflecting procedures and/or supplies provided at an HMO hospital, but no hospital days, as the subjects were not admitted to the hospital. The χ^2 for the 2×3 contingency table comparing group with hospital days had $p < .02$; for the 2×3 table comparing group with hospital costs, $p < .03$.

(including exercise) simultaneously, they provide limited evidence as to the efficacy of any single intervention. This study suggests that exercise by itself affects risk of falling. A previous meta-analysis suggested that strength and endurance training may not affect fall risk, while balance training may (20). These findings are not consistent with the meta-analysis, even though this study was included in the meta-analysis. However, the meta-analysis aggregated results across different training protocols and different subject populations. Possibly, only some endurance and strength training protocols are effective, and possibly only effective in certain subgroups. Additional studies are needed to clarify the effect of exercise. Other aspects of our findings also deserve comment.

First, exercise did not reduce fall rates, as the 42% 1-year incidence of falls in the exercise group is typical for community-living older adults (11,13,18). Although the 42% rate is higher than the sample's 22% rate in the year before the study, the difference is explainable by measurement methods. The 22% rate was taken from the retrospective question "Have you fallen in the past year?," while the 42% rate was derived from monthly, prospective surveillance.

Instead, the significant effect of exercise on falls occurred because of a high fall rate in the control group. Why might this happen? One explanation was that the eligibility criteria selected a sample on the verge of substantial decline, and exercise prevented this decline. That is, though existing problems with gait and balance were usually mild, subjects were at high risk for worsening problems. For example, the mean aerobic capacity was 16 ml/kg/min, while walking on level ground at normal pace (83 m/min) requires about 11 ml/kg/min of aerobic capacity (30). With loss of only a few ml/kg/min of aerobic capacity, simply walking at a normal pace becomes vigorous exercise and consequently gait speed during usual daily activities slows substantially.

Another possible explanation is that exercise can affect fall risk by mechanisms other than affecting gait and balance. Possibly, physiologic reserve capacity in strength and aerobic capacity have independent effects on fall risk, and exercise reduces risk by increasing reserve. This argument regards a fall as a "stress," and adopts the viewpoint that response to stress depends upon physiologic reserve not used during daily activities. Alternatively, exercise could improve risk factors for falls not ascertained by this study, such as behavioral risk factors like frequency of walking on ice.

Second, 6 months of exercise did not improve mild to moderate impairments in gait, balance, or health status. Again, one explanation is that subjects were just above the threshold where age-related decline in aerobic capacity and strength begin to cause substantial gait and balance problems. Supporting this explanation is that in frail nursing home subjects who are well below the threshold, resistance training is reported to improve gait and balance (31). Another explanation relates to the specificity of exercise training: only balance training would be expected to improve balance, while endurance and strength training would not.

Third, exercise did not affect hospital admission rates, but control subjects were at higher risk of staying in the hospital for more than 3 days. It is plausible that more physically fit subjects could have shorter hospitalizations. However, we believe additional research with larger samples and longer follow-up is needed to confirm this finding.

Finally, the findings should be interpreted in light of the study's limitations. Subjects in exercise studies cannot be blinded to group assignment, and fall data came from self-report. The study had limited information about exercise adherence from 10 to 25 months follow-up. Information was not available about long-term changes in functional status. The generalizability of the results is limited because of the highly selected study sample.

In summary, exercise may have beneficial effects on falls and health care use in older adults at increased risk for decline. In particular, exercise did not increase fall risk, which has been a concern about exercise programs in older adults. In community-living adults with mainly mild impairments in gait, balance, and physical health status, short-term exercise may not improve these impairments. It may be possible to identify subgroups of older adults at risk for decline, for whom exercise programs may be cost-effective.

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