The Performance Enhancement Project: Improving Physical Performance in Older Persons

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ABSTRACT. King MB, Whipple RH, Gruman CA, Judge JO, Schmidt JA, Wolfson LI. The Performance Enhancement Project: improving physical performance in older persons. Arch Phys Med Rehabil 2002;83:1060-9.

Objective: To determine the effects of center-based exercise on physical performance in older persons at risk for decline in physical functioning.

Design: Randomized controlled trial.

Setting: Senior centers.

Participants: A total of 155 community-dwelling persons, 78.7% women, ages 70 years and older (mean ± standard deviation, 77.0±4.5y), with mobility impairments.

Intervention: Intervention volunteers (n=80) exercised at a center (endurance, strength, balance, flexibility) 3 times weekly, for months 1 to 6; once weekly, for months 7 to 12 with home exercise 2 sessions a week; and at home only, for months 13 to 18. Home control volunteers (n=75) were instructed in home endurance exercise.

Main Outcome Measures: MacArthur battery, Physical Performance Test (PPT-8), and 6-Minute Walk Test (6MWT) at baseline and 3, 6, 12, and 18 months.

Results: MacArthur battery scores improved in intervention compared with home control at 3, 6, and 12 months (repeated-measures analysis of variance: group × time, $P<.05$) but not 18 months. PPT-8 and 6MWT did not improve. Intervention group assignment, younger age, and better baseline physical function and self-perceived health were independent predictors of long-term MacArthur battery score improvement.

Conclusions: Compared with home control, center-based exercise improved gait, chair rise time, and balance over 1 year. Improvements were not sustained with transition to home exercise for months 13 to 18. Classes may be necessary to maintain improvements in older persons attending center-based exercise.

Key Words: Activities of daily living; Elderly; Exercise; Physical performance; Rehabilitation.

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PREVENTING LOSS OF FUNCTION and disability are important goals for older persons. Overall, approximately 18% of persons at or over the age of 65 years are dependent in 1 or more activities of daily living (ADLs).[1] This percentage increases with age. Although 10% of persons between the ages of 65 and 69 require help, 47% of persons at or over the age of 85 years have ADL dependencies.[1] Mobility impairment and low or slow physical performance predict loss of independence in ADLs.[2-5] This is because older persons may experience difficulty performing an ADL before they lose the ability or willingness to do the ADL.[6,7] Buchner and Wagner[6] have proposed that strategies to maintain independence in ADLs must address losses in functional reserve. Thus, older persons who have poor physical performance and are at high risk for losing independence in ADLs theoretically have the most to gain from interventions that maintain or improve physical performance.

Performance of daily activities is dependent on adequate strength, balance, flexibility, and endurance. Previous research suggests that gains from an exercise intervention are domain specific; resistance training, for example, produces strength gains, balance training results in balance improvement.[8,9] The goal of exercise interventions for older persons who have lost functional reserve is to increase reserve and therefore to preserve performance of daily activities. Short-term home- or center-based exercise has been shown to improve the physical performance of older adults living in the community.[10-13] However, for long-term preservation of physical performance, we believe that an exercise intervention must (1) include all 4 exercise elements (strength, balance, flexibility, endurance) to increase functional reserve, (2) begin with a closely supervised phase to ensure correct practice and to progress in intensity in a timely manner, and (3) provide sufficient support to achieve high rates of long-term adherence. The advantages of group exercise include peer support, modest program costs, close supervision, and encouragement from the exercise leader. The disadvantages of group exercise are loss of flexibility in scheduling exercise times and the effort, time, and expense to travel to the center.

In this article, we report the results of the Performance Enhancement Project, a 3-phase, 18-month, group, then home, exercise intervention for mobility-impaired, community-dwelling older persons with decreased functional reserve. Our goal was to enroll older persons who were identified by a screening test[2] as being at risk for loss of ADL function and mobility. The purposes of the Performance Enhancement Project trial were to test (1) whether a comprehensive center-based program for older persons with declining mobility could improve physical performance and (2) whether the program could be transitioned to a long-term, home-based program. Our comparison group did unsupervised home exercise based on recommendations

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from the US Surgeon General's report.[14] Secondary study outcomes were balance confidence and health-related quality of life.

METHODS

The University of Connecticut Health Center's Institutional Review Board approved this randomized, controlled intervention study.

Participants

Volunteers were recruited from the geographic area surrounding the 3 senior centers in which exercise classes were to be held. The senior centers were selected based on support of the center administration, facilities, and availability of transportation for study volunteers. Two of the 3 centers were in urban areas, and 1 center was in a suburb adjacent to Hartford where volunteers were enrolled from Hartford. Volunteers were recruited and enrolled sequentially at the 3 sites so that only 1 senior center was involved in any aspect of the program at a time (eg, enrollment, phase 1, phase 2 of the intervention). In all, cards were mailed to 16,579 people; there were 969 responses. After an initial telephone screen, 581 volunteers attended orientation sessions in small groups. There were 387 attendees who completed an informed consent; they were given the Short Physical Performance Battery[15] (SPPB; a test of standing balance, chair rise, and usual gait), Mini-Mental State Exam[16] (MMSE), and ADL[17,18] questions. Seven research assistants performed the baseline screening; 4 to 6 tested volunteers at each orientation meeting, depending on the number of volunteers. The assessors were trained in administering the 3 screening tests by practicing testing until timing and scoring were done uniformly. These tests were chosen to select volunteers who had decreased mobility but were not home bound and did not meet criteria for nursing home admission. The initial screening criteria were age 70 years or older, MMSE score of 24 or better, SPPB score of 9 or lower out of 12 (best), and independence in at least 5 of 6 ADLs. The SPPB score criterion was chosen because persons scoring at or below 9 are at least 1.6 times more likely to lose ADL function and 1.8 times more likely to develop mobility-related disability at 4-year follow-up than those scoring 10 to 12.[2] Of 215 who met criteria, 187 completed a targeted history and physical exam at the senior center. Exclusion criteria were recent myocardial infarction or coronary artery bypass surgery, uncontrolled hypertension, chronic pulmonary disease requiring oxygen, terminal illness, symptomatic coronary artery disease, Parkinson's disease requiring medication, lower-extremity amputation, corrected distance vision worse than 20/70 in both eyes, current enrollment in rehabilitation or an aerobic exercise program, inability to complete a 3.1-m walk without an assistive device, inability to speak English, and no access to a telephone. After the physical examination, volunteers completed 4 baseline-testing sessions. A total of 155 volunteers completed baseline testing and, at the last testing session, were randomized to 1 of 2 groups by using an allocation schedule of random assignments in blocks of 10 stratified by gender. The 2 groups were senior center-based exercise (intervention group) or self-paced exercise at home (home control group). Couples or persons living together were randomized together to the same group to prevent cross-group contamination.

Baseline Testing

Volunteers rated their general health and answered questions about depression and mobility. Volunteers were classified as depressed if they scored 17 or higher on the Center for Epidemiologic Studies–Depression (CES-D) Scale.[19] They answered 5 mobility-related questions rating difficulty walking 0.4km, climbing 1 flight of stairs, carrying 4.5kg, pushing large objects such as heavy furniture, and stooping, crouching, or kneeling.[20,21] Volunteers scored 1 point for each activity rated moderate difficulty or unable to do. Study physicians gave each volunteer a baseline chronic disease rating, based on the modified Cumulative Index Rating Scale,[22] for 8 body systems (cardiac; vascular; respiratory; eyes, ears, nose, throat; musculoskeletal-integumentary; neurologic; endocrine and metabolic; psychiatric and behavioral) plus hypertension. Each volunteer's chronic disease burden score was the total number of the 9 systems or diseases rated 3 (moderately severe, symptomatic) or greater in severity.

Outcome Measures

Testing at baseline and during the intervention at each site was performed by 4 research assistants who reviewed detailed written instructions and observed, then practiced, testing procedures under supervision to assure uniform administration and measurement. Testing procedures were reviewed with assessors again before each measurement time. Assessors were blinded to group assignment. The primary outcome measures were the 8-item Physical Performance Test[10,23] (PPT-8), the 6-Minute Walk Test[24] (6MWT), and the MacArthur battery.[3] These tests were given at baseline and 3, 6, 12, and 18 months. The items tested in the PPT-8 were based on common daily activities (write a sentence, simulated eating [pick up 5 beans], pick up an object from the floor, put on a jacket, lift a book from a table to a shelf, 360° turn, walk 7.6m, climb a flight of stairs) and were performed at usual speed.[23] Each item was timed and scored from 0 to 4 points (maximum total score, 32). For the 6MWT, volunteers walked a 32-m circuit and the number of meters walked was recorded. The MacArthur battery consisted of 5 timed tasks: write signature, semitandem plus tandem stance, 5 chair rises, walk 6.1m, and 10 alternating toe taps. Stances were held a maximum of 10 seconds; the other 4 tasks were performed as quickly as possible. Normalized scores[3] ranged from 0 to 5 (best). Interrater and test-retest reliability for the PPT-8 and the 6MWT were determined in a pilot study[10]; the interrater reliability intraclass correlation coefficient for the MacArthur battery was .99 (unpublished data from pilot study).[10] Two other performance measures, usual and fast gait speed, were measured with an electronic timer by using photoelectric detectors over an 8-m course, marked out in a long (25m) hallway. Participants began from a standing start and walked beyond the 8-m mark without slowing down.

Secondary outcome measures included the Activities-Specific Balance Confidence (ABC) Scale[25] and the physical functioning and mental health subscales of the Medical Outcomes Study 36-Item Short-Form Health Survey[26] (SF-36). These questionnaires were given at baseline and 6, 12, and 18 months. On the ABC Scale, volunteers rated their confidence in maintaining balance during each of 16 activities as a percentage (0%–100%) and an average confidence percentage was calculated. The physical functioning subscale consisted of 10 items concerning ability to do common activities and interference because of physical health. The mental health subscale consisted of 5 items concerning mood and mental functioning. Physical functioning and mental health subscale scores were transformed into percentages, ranging from 0 (worst) to 100 (best).[26]

Intervention

The intervention was subdivided into 3 phases, each 6 months long (table 1). All classes were led by a physical

Table 1: Timeline and Overview of Training for the Intervention Group

	Phase 1 (1–6mo)			
	Months 1–3 (strength, endurance)	Months 4–6 (balance, flexibility)	Phase 2 (7–12mo)	Phase 3 (13–18mo)
Training stages/goals	Improvement	Improvement	Maintenance	Maintenance
Training feature emphasis	Strength, endurance	Balance, flexibility*	Strength, endurance, balance, flexibility	Strength, endurance, balance, flexibility
Supervised training (75min/session)	3×/wk	3×/wk	1×/wk	None
Home exercise (75min/session)	None	None	2×/wk	3×/wk

* Includes maintenance of strength and endurance.

therapist (RHW) and 1 of 2 other exercise leaders, one with a bachelor of science degree and the other with a master's degree in exercise science.

Phase 1. Supervised group training took place at a senior center 3 times a week, each session 75 minutes long. Each class had 2 leaders and 8 to 10 volunteers. The first 3 months were devoted to strength and endurance and the second 3 months to balance and flexibility training along with maintenance strength and endurance exercise.

The first 15 minutes of strength and endurance consisted of supervised brisk walking for endurance and warm-up inside the senior center at a self-selected pace of moderate intensity (Borg Ratings of Perceived Exertion,[27] 12–14). A 60-minute progressive resistance exercise period followed the warm-up (appendix 1). The intensity of loading for exercises using flexible Velcro®-closure weights (hip abduction, flexion and extension, elbow flexion, ankle dorsiflexion) was based on a weight that could initially be lifted 8 to 10 times. Once the 15-repetition level was attained, loads were raised in increments of 0.5 to 1.1kg. Loading-intensity criteria for body-weight exercises were similar. Progression in pushups was determined by increasing the angle of the body relative to the pushing surface (20°–75°). Dips were progressed by raising the armrest height by 5.1cm every 2 weeks to a maximum possible height of 30.5cm. Heel-ups (plantarflexion) progressed in stages: bilateral to bilateral on 3.8-cm block to unilateral to unilateral on block. Weight vests were worn as supplementary loading for walking, stair climbing, dips, and plantarflexion, with increments of 0.9 to 1.4kg added every 2 weeks (maximum load, 7.3kg).

Balance and flexibility training exercises (appendix 2) resembled commonly performed physical activities and required only body-weight resistance and home furnishings (eg, chairs, tables). Weighted vests were used for the endurance circuits during group exercise. The balance and flexibility training exercises became the home exercise program in phases 2 and 3 (see below).

Phase 2 (months 7–12). Volunteers attended weekly exercise classes at the senior center and exercised twice a week at home following the program introduced in the phase 1 balance and flexibility training. At a home visit, an exercise leader reviewed the program and its implementation in the volunteer's home, provided written instructions for the exercises, and indicated the individualized targeted intensity level and prop for each exercise. Volunteers were asked to complete and return a weekly home exercise log and to report any untoward events.

Phase 3 (months 13–18). Volunteers exercised 3 times a week at home following the program set up in phase 2. They were asked to mail in completed exercise logs each month, and they received monthly phone calls from an exercise leader. During the monthly telephone call, subjects who forgot to mail in completed logs were asked questions about the amount of time they spent walking in the previous week.

Home Control Home Exercise

The home control group attended an instructional session on the principles of physical activity, exercise, and nutrition. The volunteers were given a booklet that listed different modes of exercise and how gradually to increase moderate exercise to 180 minutes a week. This recommendation was based on the Surgeon General's statement.[14] Recommended activities included walking, shopping, swimming, and gardening. Moderate-endurance exercise was stressed, and written instructions were given for additional simple stretching exercises. Balance or resistance training was not permitted. Volunteers were told to exercise alone or with others but that enrollment in formal exercise classes or use of resistance equipment was not permitted. Home control volunteers were asked to complete and mail in monthly exercise and fall logs and were contacted by telephone monthly. The telephone calls were designed to support the volunteer, answer any questions, and encourage completion of exercise logs. As with the intervention group, during monthly telephone calls home control volunteers answered questions about number of minutes walked in the preceding week if they had not submitted their exercise logs.

Communication With Volunteers

During the first 6 months, volunteers in both groups attended 4 group meetings. Topics were healthy feet, home safety, nutrition, and stress reduction, and exercise. All volunteers received a monthly newsletter designed to sustain enthusiasm for exercise. The newsletter contained exercise and health tips and other topical information.

Compliance and Adverse Events

Compliance during the first 6 months of the intervention was calculated as the percentage of exercise classes attended for the intervention group; for the home control group, the percentage of weeks that the volunteer achieved the prescribed amount of activity was calculated. Compliance during the last 3 months of the study was determined by averaging the number of minutes walked a week in the 3 months. A subject was considered compliant in the last 3 months if he averaged 180 or more minutes of walking in a week. Adverse events were recorded and included all reported illnesses, injuries, and hospitalizations, whether or not they were related to the study testing and exercise. At the end of the study, physicians rated each adverse event's effect on participation. The ratings were as follows: (1) no effect, (2) transient decrease—less than 1 week, (3) stopped

Table 2: Baseline Characteristics of the Performance Enhancement Project Home Control and Intervention Volunteers

	Home Control (n=75)		Intervention (n=80)			
Characteristic	n (%)	Mean ± SD	n (%)	Mean ± SD	χ^2 *P**	*t P**
Age		77.9±4.4		77.0±4.6		.222
Gender					.428	
Women	60 (80.0)		62 (77.5)			
Men	15 (20.0)		18 (22.5)			
Education (y)		13.2±3.3		12.6±2.6		.260
MMSE score (0–30)		28.3±1.4		28.0±1.6		.125
Marital status					.267	
Widowed, divorced, single	45 (60.0)		43 (53.8)			
Married	30 (40.0)		37 (46.3)			
ADL assistance					.450	
None	44 (60.3)		55 (69.6)			
Equipment	23 (31.5)		18 (22.8)			
Person	6 (8.2)		6 (7.6)			
Self-reported health					.202	
Excellent	10 (13.7)		6 (7.5)			
Good	48 (65.8)		49 (61.3)			
Fair/poor	15 (20.5)		25 (31.3)			
CES-D					.340	
Not depressed	62 (82.7)		63 (78.8)			
Depressed	13 (17.3)		17 (21.3)			
Chronic disease burden					.446	
0 impaired systems	47 (62.7)		52 (65.0)			
1+ impaired systems	28 (37.3)		28 (35.0)			
Fall in past year					.308	
No	47 (65.3)		48 (60.0)			
Yes	25 (34.7)		32 (40.0)			
Mobility (0–5)		0.8±1.3		0.6±0.9		.123
ABC Scale (0%–100%)		75.6±19.9		69.8±20.8		.079
SPPB at enrollment (0–12)		7.3±1.7		6.9±1.8		
SF-36 physical functioning (0–100)		54.7±24.7		56.6±24.4		.650
SF-36 mental health (0–100)		78.0±15.2		76.9±16.2		.652

Abbreviation: SD, standard deviation.
* Significance of differences between the home control and intervention groups.

for self-limited illness—less than 1 month, (4) stopped because of prolonged illness (eg, hospitalized)—less than 4 months, (5) stopped permanently, and (6) death. Events scored 3 or more were considered to have had a noticeable effect on participation.

Statistical Analysis

SPSS, version 7.5,[a] and SAS[b] statistical software were used for the analysis. The Student *t* test, Fisher exact test, and chi-square statistics were used to test for differences in baseline characteristics by treatment and control group. The effects of the intervention on physical performance measures were measured at baseline, and 3, 6, 12, and 18 months using repeated-measures analysis of variance (ANOVA) to analyze data from volunteers tested at every time point. All tests of hypotheses and reported *P* values are 2 sided.

A linear regression analysis was used to determine independent predictors of improvement in performance measures (change score) from baseline to 6 months (end of the intensive intervention) for volunteers with data at both time points. A second regression analysis, the SAS PROC MIXED procedure, was used to measure the impact of covariates on performance-based measures in an intention-to-treat model over the entire 18 months of the study. Baseline data served as the reference point for measuring performance at subsequent time points; all volunteers with at least 1 follow-up measurement were included in the PROC MIXED analysis. This approach allowed within- and between-volunteer covariance structure modeling and simultaneously accounted for changes in health and functioning over time, as well as for missing data at various time points for several of the volunteers. This technique was chosen over repeated-measures ANOVA because of its flexible use of time-varied covariates and lack of case-wise deletion for missing points. The estimates of exercise intervention effects were obtained at each follow-up observation. Restricted maximum likelihood estimation was used to accommodate both the fixed and changing covariates. Covariates were included in the model if they were judged potentially to confound the analysis or if they were thought to have clinical importance. For highly correlated covariates (eg, self-rated health and disease burden), the variable that contributed the most to the overall model was included. For example, self-rated health was included, rather than chronic disease burden, because it has the greatest clinical relevance and contributed most to the model.

RESULTS

Baseline Characteristics

There were 80 volunteers in the intervention group and 75 in the home control group (table 2). Little subjective mobility

Table 3: Progression in the Intervention, Phase 1

Exercise	SE: Baseline	SE: 6 Weeks	SE: 13 Weeks	BF: Baseline	BF: 13 Weeks
Ankle dorsiflexion (kg)	0	2.5±1.3 (0–6.8)	3.4±1.2 (0–6.8)		
Hip abd, flex, ext (kg)	0	.9±.3 (0–1.8)	3.1±1.1 (0–5.7)		
Elbow flexion (kg)	1.6±.8 (0–4.5)	2.6±1.0 (1.1–6.8)	3.8±1.1 (0–6.8)		
Dips in chair (kg)	0	1.9±1.1 (0–3.4)	4.6±2.7 (0–7.3)		
Vest weight on stairs (kg)	0	1.7±1.2 (0–3.4)	4.6±2.7 (0–7.3)		
No. endurance circuits				1.2±.4 (0–2.5)	1.8±.6 (0–3.0)
Vest weight (kg)				0	3.2±1.1 (0–4.5)
Weight lifted (kg)				1.4±.7 (0–3.4)	3.3±.5 (0–4.5)
No. push-ups				10±2 (0–15)	14±3 (0–20)
No. sit-to-stands				9±2 (0–15)	14±4 (0–20)

NOTE. Values are mean ± SD (range). Participants (n=70) used weights for progressive resistance exercise in the first 13 weeks (SE); endurance circuits maintained strength and endurance during the second 13 weeks (BF).
Abbreviations: SE, strength and endurance; BF, balance and flexibility; abd, abduction; flex, flexion; ext, extension

impairment was noted on answers to the 5 mobility-related questions, yet SPPB scores were moderately low (mean score, 7.1±1.7). No differences in ADL dependence existed between groups; overall, 65% of the volunteers were independent in ADL function. There were 31 volunteers (18 home control, 13 intervention) who dropped out before 3-month testing. We observed baseline differences between volunteers who dropped out in the first 3 months of the study and volunteers who continued: dropouts had greater chronic disease burden and musculoskeletal problems, poorer perceived physical functioning, and lower scores on tests of physical performance.[28] Twenty-five volunteers (13 home control, 12 intervention) dropped out between 3 months and the end of the study; they did not differ from the remaining 99 volunteers on any of the outcome measures at baseline.

Progression Through the Intervention

During the first 13 weeks of phase 1 (strength and endurance), participants increased the intensity of loading for progressive resistance exercise (table 3). During the second 13 weeks of phase 1 (balance and flexibility training), participants learned and performed a series of balance and flexibility exercises while maintaining strength and endurance by completing endurance circuits (table 3, appendix 2).

Primary Outcome Measures

Scores on physical performance tests at 3, 6, 12, and 18 months were compared with those at baseline (table 4). Repeated-measures ANOVA showed statistically significant improvements in the MacArthur battery score at 3 months in the

Table 4: Values of Outcome Variables Measured at Baseline and 3, 6, 12, and 18 Months for the Home Control and Intervention Exercise Groups

	Baseline		3 Months: End of Phase 1-SE		6 Months: End of Phase 1-BF		12 Months: End of Phase 2		18 Months: End of Phase 3	
Variable HC n, IN n	HC Mean ± SD Baseline *P*	IN Mean ± SD	HC Mean ± SD Time *P*	IN Mean ± SD Group × Time *P*	HC Mean ± SD Time *P*	IN Mean ± SD Group × Time *P*	HC Mean ± SD Time *P*	IN Mean ± SD Group × Time *P*	HC Mean ± SD Time *P*	IN Mean ± SD Group × Time *P*
Primary outcomes										
MacArthur (0–5)	3.34±.42	3.21±.46	3.37±.45	3.39±.43	3.36±.48	3.47±.46	3.29±.43	3.40±.49	3.39±.44	3.37±.51
51, 43	.172		.553	.020	.653	<.001	.404	.003	.293	.204
Chair rise (s)	12.0±3.7	12.9±4.6	11.7±5.0	12.2±5.1	12.0±4.1	10.9±3.0	12.1±4.2	11.3±3.8	13.0±3.9	12.4±4.1
50, 42	.193		.684	.894	.553	.007	.337	.065	.046	.076
Standing balance (s)	10.8±5.4	9.8±5.6	11.5±5.3	11.9±5.4	12.2±6.1	13.3±5.4	10.7±5.6	12.5±5.9	12.7±5.7	11.7±5.3
49, 42	.473		.816	.050	.235	.042	.292	.008	.057	.849
PPT-8 (0–32)	24.1±3.4	23.7±3.6	25.1±3.0	24.5±3.6	24.7±3.6	24.6±3.8	24.6±3.6	24.2±4.1	24.1±4.0	24.0±4.7
51, 43	.420		.016	.914	.191	.273	.366	.796	.657	.707
6MWT (m)	356.1±71.3	344.0±86.7	365.7±81.8	354.6±84.5	358.2±88.0	348.5±91.7	348.5±91.7	352.7±84.6	341.0±91.8	331.9±85.6
45, 35	.302		.323	.478	.737	.140	.221	.248	.015	.750
8-m fast gait (m/s)	1.34±.25	1.26±.28	*	*	1.37±.25	1.31±.32	1.34±.26	1.34±.27	1.34±.27	1.30±.27
45, 37	.215				.458	.194	.762	.288	.417	.532
8-m usual gait (m/s)	1.01±.18	0.96±.19	*	*	1.07±.18	1.03±.22	1.04±.17	1.04±.17	1.03±.19	1.03±.18
45, 37	.338				.001	.044	.222	.023	.295	.164
Secondary outcomes										
ABC Scale (0–100)	77.4±19.5	69.5±21.2	*	*	75.9±20.7	78.3±16.8	79.2±18.6	79.0±14.1	78.1±19.6	76.6±15.3
54, 45	.001				.357	<.001	.822	.005	.340	.002
SF-36 PF (0–100)	54.1±24.6	56.6±23.0	*	*	70.9±18.8	67.6±21.0	66.0±23.8	60.7±24.1	58.6±26.6	64.0±25.8
42, 27	.930				<.001	.317	.023	.521	.066	.757
SF-36 MH (0–100)	77.5±16.2	77.7±16.0	*	*	82.7±14.0	76.7±15.9	84.6±12.4	79.2±15.7	79.0±16.3	80.4±13.2
42, 27	.090				.656	.707	.085	.660	.873	.299

NOTE. Repeated-measures ANOVA time and group by time *P* values are given.
Abbreviations: IN, intervention exercise group; HC, home control exercise group; SE, strength and endurance; BF, balance and flexibility training; PF, physical functioning subscale; MH, mental health subscale.
* Not tested at 3 months.

Table 5: PROC MIXED Regression Examining Variables That Predicted MacArthur Battery Score by Using Baseline MacArthur Score for Comparison

Effect	Estimate	SE	P
Intercept	5.30	.52	<.001
3mo	.03	.06	.629
6mo	.02	.05	.763
12mo	−.09	.06	.156
18mo	−.02	.06	.779
Group assignment	−.06	.07	.352
Age	−.03	.01	<.001
Gender	−.01	.07	.955
CES-D category	.15	.07	.041
Self-rated health			
Excellent	.36	.10	.001
Good	.19	.07	.009
SF-36 PF subscale	.01	.00	<.001
Adverse events	−.04	.04	.267
3mo × group	.12	.09	.160
6mo × group	.24	.07	.001
12mo × group	.22	.08	.010
18mo × group	.13	.08	.131

Abbreviation: SE, standard error.

intervention group compared with home control. The 1 battery item that improved was standing balance time. At 6 months, chair rise and standing balance time, as well as total MacArthur battery score, improved further in the intervention group, with statistically significant group by time effects. There was also an increase in 8-m usual gait speed in the intervention group compared with home control. No statistically significant time or group by time effects existed for the PPT-8, 8-m fast gait, or 6MWT at 6 months.

After phase 2 (group exercise once weekly plus home practice), at 12 months, the intervention group change from baseline score on the MacArthur battery and 8-m usual gait speed remained statistically significant, compared with the home control group. The only battery item that showed a significant group by time effect was standing balance. There was no difference in test results on the other measures.

At 18 months, after 6 months of home exercise, no differences existed between groups on any measures. Chair-rise time increased in the home control group, and 6MWT distance decreased in both groups, compared with baseline.

A multivariate linear regression analysis was done to determine independent predictors of improvement in MacArthur score and usual gait speed at 6 months, the end of the intensive group intervention. Intervention group assignment (P=.001) and excellent self-rated health (P=.024) were independent predictors of improvement in MacArthur score after controlling for age, gender, depression, chronic disease, and physical functioning. There were no independent predictors of improvement in normal gait speed using the same model. A second multivariate analysis, using data from all test points over the 18-month study, was done using the PROC MIXED procedure to examine contribution to MacArthur score and usual gait speed, measured as continuous variables. MacArthur score results indicated that intervention group assignment, younger age, excellent or good self-rated health, not being depressed, and better physical functioning were independent predictors of improvement in MacArthur score; however, intervention group assignment was not a predictor at the 3- or 18-month testing periods (table 5). Gender and occurrence of adverse events did not contribute to the model. Independent predictors of 8-m usual gait speed were younger age (P<.001), better physical functioning (P<.001), and excellent (P=.002) or good (P=.018) self-perceived health; intervention group assignment was not an independent predictor in the model.

Secondary Outcomes

Secondary outcomes were balance confidence (ABC Scale), and the physical functioning and mental health subscales of the SF-36 health status questionnaire. At baseline, intervention volunteers had lower scores on the ABC Scale than home control (table 4). At 6-month testing, the average intervention group score increased, resulting in a significant group by time effect. Although the 2 groups did not differ at 6, 12, and 18 months, differences seen between baseline and 6-month ABC scores in the intervention group persisted. The physical functioning subscale score improved in both groups from baseline to 6 months and remained higher than baseline at 12 months. There was no group by time effect. The mental health subscale score did not change over time or with the intervention.

Compliance and Adverse Events

During the first 6 months, the mean level of compliance was 61% for the intervention group and 51% for the home control group. Compliance percentages were higher in the first 6 months (71% for intervention, 66% for home control) when the 31 volunteers who dropped out in the first 3 months were not included. Compliance for the 108 volunteers who completed months 16 to 18 of the study was 22% for the intervention group and 19% for the home control group; 30% of the volunteers had missing data.

Although volunteers in both groups had a considerable number of moderate to severe adverse events during the 18 months of the study, most events did not occur because of exercise or testing. By 6 months, 16% of the home control group and 35% of the intervention group had experienced 1 or more illnesses or accidents that necessitated stopping exercise for more than 1 week. At 12 months, the numbers increased to 31% of home control and 54% of intervention group volunteers. By the end of the study, the number of intervention group volunteers reporting adverse events was greater than home control (χ^2, P=.015); 50 intervention group volunteers (63%) had experienced 78 adverse events rated 3, 4, or 5 in severity, whereas 28 home control volunteers (47%) had 43. Of these adverse events, only 9 were related to intervention or testing; 1 event led to dropout and 3 to cessation of exercise for more than 1 month. Three home control volunteers died from adverse events unrelated to the study.

We examined the relations between compliance, adverse events, and outcomes in the first 6 months. Intervention group volunteers who had adverse events attended fewer sessions than those having none (P<.001). There was no relationship between adverse events and compliance for the home control group (P=.065). By using PROC MIXED multivariate analysis, we observed that having had an adverse event did not affect MacArthur battery score at any time point.

DISCUSSION

This center-based exercise program that trained strength, endurance, balance, and flexibility in older persons at risk for loss of ADL function and mobility improved MacArthur battery scores, compared with the home control group, over the first year of the program. The MacArthur battery improvements were driven by small but clinically significant improvements in balance (tandem plus single stance) time and, to a lesser extent,

by faster chair-rise time. At 6 months, the end of the intensive center-based intervention, balance stance time increased by 3.5 seconds, or 36% over baseline, and chair-rise time decreased by 2 seconds, or 16% less than baseline, in the intervention group. The change in chair-rise time was equivalent to an improvement of 1 point on the SPPB.[2] The improvement in the MacArthur battery scores in the intervention group suggests that this group improved physiologic reserve because the items in this battery test maximal performance. Usual gait speed improved in both groups at 6 months, with greater improvement in intervention than home control (7% vs 6% over baseline).

The volunteers were able to sustain their performance gains in the MacArthur battery and usual gait speed by combined center-based and home training during months 6 to 12. However, performance declined to baseline during the period when the volunteers exercised only at home. There are several potential explanations for the deterioration in performance in the intervention group between 12 and 18 months. One explanation is that weekly group classes were required to sustain the exercise effect in this group of at-risk older persons. The study investigators recognized and addressed many challenges that volunteers faced in transitioning from center-based to home-based training. The strategies used in the study may have not been effective to sustain the intensity or the frequency of the center-based training at home. By months 15 to 18, exercise compliance was poor in both groups. It is also possible that self-selection of volunteers who were interested in center-based exercise may have influenced adherence to the exercise program when the program became completely home-based. Many volunteers expressed disappointment at study entry when they were informed of their randomized assignment to the home control group.

Implementing an effective intervention that leads to long-term maintenance of exercise gains in older persons with declining physical performance and mobility has been problematic, both in our study and in previous reports.[12] Several factors may have contributed to the low magnitude of the intervention effect in the present study. First, we recruited volunteers who had mild to moderate mobility limitations. These comprised a heterogeneous group; some had stable chronic disease and were otherwise fairly healthy but inactive. The more frail volunteers were more likely to suffer a loss of function because of acute illness and were more likely to drop out within the first 3 months of the study.[28] The drop-out rate was 36% at 18 months, which is comparable to that found in long-term studies of healthy older volunteers, in which 50% or more drop out.[29,30] Although adverse events did not appear to influence outcomes at 6 months, more than half of our volunteers had at least 1 event during the course of the study—the vast majority being unrelated to the intervention—that caused them to decrease or stop exercise for a week or more. Intervention group volunteers reported almost twice as many adverse events as home control volunteers; however, this difference may have been because of underreporting in the home control group. With so many adverse health events affecting participation by volunteers in both groups, the effect of the intervention may have been diminished. Frequent adverse events also made it difficult to effect a lasting change in exercise behavior in these older persons.

Second, obtaining compliance data was problematic. By necessity, we used a different method of calculating compliance for each group. With the methods used, compliance in the first 6 months was comparable for the 2 groups. Beyond 6 months, exercise logs were not returned consistently and were often uninterpretable, and follow-up telephone call information could not be directly compared with other compliance data.

Third, as in long-term studies of younger old persons not selected for chronic disease[30,31] or selected for knee osteoarthritis,[32] the training effect diminished with time and with decreased exercise oversight.

Finally, our study did not have a true control group; home control volunteers may have improved or maintained scores on some performance measures, such as gait speed, because self-paced home exercise was itself an effective intervention. The small improvements and lack of decrements in the home control group are central to the study's results. Had we used a true control group as a reference measure of outcome, the modest improvements seen in the intervention group may have been more compelling. We did not feel that it was ethical to have a no-activity control group, considering the current recommendations by the office of the Surgeon General that older persons have 30 minutes of exercise on most days.[14] Indeed, the present study shows that with the minimal home control intervention, ie, goals for weekly exercise activity, monthly contact with an exercise leader, and required exercise logs, some positive effects occurred. The home control volunteers maintained their baseline performance for 18 months, suggesting potential value for this approach in a frail population.

The improvements seen in balance confidence (ABC Scale) in the intervention group and in self-perceived physical functioning in both groups suggest beneficial effects of exercise for both groups beyond those detected by the physical performance outcome measures. Greater self-efficacy in performance of daily activities resulting from the center-based intervention and greater perceived physical functioning in both groups may have helped maintain physical activity and mobility over a longer time.

The post hoc analysis revealed that, although only intervention group assignment and excellent self-rated health predicted improvement in physical performance at 6 months, the younger volunteers and the volunteers with better baseline performance and self-rated health were more likely to have long-term improvements in performance in response to training. This finding has potentially important implications for center-based training. The frailer volunteers were more likely to drop out and to achieve less apparent long-term benefit from the training program. It is possible that these individuals would have gained more from home-based training. There have been several home-based training interventions that have achieved improvements in performance and reductions in falls.[12,33] One study[33] showed sustained adherence to home-based training and a sustained reduction in injurious falls.

Neither the present study nor others have determined the best setting for training older community-dwelling persons with declining physical performance and mobility. The present study attempted to enroll older persons at greatest risk for declines in ADL and mobility function who were willing and able to attend center-based training. Many older persons with declining mobility are not homebound, but getting to a center for exercise requires great effort and a strong social support network. The challenge facing older persons with declining mobility who are reluctant to travel to a center for exercise is that they are at high risk for loss of independence, yet they do not qualify for home-based programs until they are homebound. Home-based programs are not commonly available nor does Medicare reimburse them.

CONCLUSION

A comprehensive center-based program for older persons with mobility problems initially resulted in modest improve-

ments in physical performance. Gains were maintained with classes once a week and home practice in the second 6 months of the study. After 1 year, however, with no class supervision, there were no differences between groups. The lack of robust differences was probably due to several factors, including numerous adverse health events unrelated to the exercise program and declining adherence with time. The home control intervention, although minimal, may have been sufficient to maintain function in the home control volunteers.

Possibilities for future studies include cost-effectiveness trials that compare home-based and center-based training for older persons at risk for loss of ADL and mobility function. Trials that permit self-selection of training site may finally address the issue that some people prefer to be active in a group, whereas others prefer to be active at home. In addition, more attention must be paid to the individual's readiness for and commitment to exercise, personal goals, and ongoing demonstration of self-efficacy in daily activities to retain volunteers and to show that exercise trials can be effective in improving physical performance and function.

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APPENDIX 1: TRAINING COMPONENTS IN STRENGTH AND ENDURANCE PHASE 1 (FIRST 3MO)

Exercise	Type	Equipment and Props	Targeted Functional Effects
Walking (15min, Borg RPE 12–14)*	E, warmup	Weight-vest	↑ Cardiovascular/walking endurance
Ankle plantarflexion (standing)*	S, E	Weight-vest, 3.8-cm block	↑ Step length/speed, forward LOS
Ankle dorsiflexion (standing)	S, E	Weights	↓ Tripping, ↑ backward LOS
Push-ups*	S, E	Edge of table, chair	↓ Fall injury, ↑ transfers and ground mobility
Stair-climbing*	S, E	Staircase, weight-vest	↑ Elevation of body-weight capability
Elbow flexion (bilateral curls)	S, E	Weights	↑ Object lifting/carrying
Raise body from armchair (dips)	S, E	Armchair, weight-vest	↓ Fall injury, ↑ transfers and ground mobility
Standing straight-leg raises (hip extension)	S, E	Body propped over table, weights	↑ Gait, posture, stair-climbing, transfers
Supine-lying, straight-leg raises (hip flexion)	S, E	Carpet (mat), weights	↑ Gait, transfers, ↓ tripping
Side-lying, straight-leg raises (hip abduction)	S, E	Carpet (mat), weights	↑ Gait, pelvic stability, posture, 1-leg stand

Abbreviations: RPE, Ratings of Perceived Exertion; E, endurance; S, strength; ↑, increase; ↓, decrease; LOS, limits of stability.
* Indicates exercise retained in balance and flexibility training phase (months 4–6).

APPENDIX 2: FUNCTIONAL TRAINING COMPONENTS OF BALANCE AND FLEXIBILITY TRAINING PHASE 1 (SECOND 3MO)

Exercise*	Type	Description	Targeted Effects
Strength & endurance (15-min circuit)			
Brisk walk*	S, E	152–183m	†
Stair-climb*	S, E	2–6 flights at a time	†
Lift heavy objects from floor	S, E	1.1–3.4kg sandbags, lift to waist, shoulder, overhead heights, 2 cycles	↑ Hip strength, flexibility, stooping balance
Push-ups*	S, E	Body inclined 30°–60° from vertical (eg, against chair seats or table-top)	†
Sit-to-stands	S, E	10–15 rapid chair rises and returns in a row	↑ Hip & thigh strength, dynamic balance
Calf stretch	F	Stand touching wall, front of soles on 1.5-in block, heels on ground	↑ Forward leaning range, ↓ tripping
Hip flexor stretch	F	Stand touching wall, feet separated as in lunge, hold for 1 min/side	↓ Flexion contractures, improve posture
Ankle plantarflexion (10–20×)*	S, E	Standing on 3.8-cm block, holding wall, 1 set w/ both and w/ each single leg	†
5 balance walks	B	Walk 22.9-m each on toes, heels, backward, tandem, weight overhead	↑ Variety of dynamic balance
Overhead arm reach/hip hike (10–15×)	B, S, E, F	Seated, alternating weight shift to 1 buttock, while lifting opposite	↑ Lateral trunk strength and flexibility
Seated static trunk/hip flexion (10–15×)	S, E	Gripping seat, simultaneous lift-and-hold of both thighs with exhalation	↑ Flexor synergy strength and backward balance
Raise body from armchair (10–15×)*	S, E	Seated, lifting buttocks 5.1–20.3-cm off seat by pushing down on armrests	↓ Fall injury, ↑ transfers and ground mobility
Leaning balance	B, S, E	Maintain balance at extremes of lean (5–10s), 4–5×, all directions	↑ LOS, ↓ falls
One-leg stand	B, S, E	2min each of continued attempts, hand support as needed	↓ Falls to side, ↑ asymmetric balance activity
Lunge-kneel (10–15×)	B, S, E, F	Lower/raise body to/from kneel, AP foot separation of 0.5–0.9m	↑ Ground transfer strength and stability
Vertical weight transfer (on ground)	B, S, E, F	From quadrupedal to side-sit and return (alternating, 10–15x)	↑ Transfers and mobility on ground
Hamstring stretch on ground or bed (1min)	F	Propped long sitting, bilaterally simultaneous knee extension/dorsiflexion	↑ Posture and ease of transfers and mobility
Bridging on ground or bed (10–15x)	S, E, F	Supine, raise body upward, 1 set w/ both legs and w/ each leg alone	↑ Posture, mass extensor strength, transfers
Trunk extension on ground or bed	S, E	Prone, lifting of head and upper trunk, without assistance of arms (10–15x)	↑ Posture, trunk stability and strength
Adductor stretch on ground, or bed	F	Arm-propped sitting, knees pushed apart, soles touching (hold 1min)	↑ Ease of ground, bed and transfer mobility
Pelvic control on ground or bed	F, B	Arm-propped sitting, knees apart, multidirectional buttock weight shifting	↑ Pelvic-trunk coordination and flexibility
Turning	B, F	Turning, vestibulo-ocular and spatial frame-of-reference exercises	↑ Balance, and spatial orienting/processing skills

Abbreviations: F, flexibility; B, balance; AP, anteroposterior.
* Exercises retained from strength and endurance phase 1.
† See appendix 1 for targeted effects of this exercise.

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Suppliers

a. SPSS Inc, 233 S Wacker Dr, 11th F1, Chicago, IL 60606.
b. SAS Institute Inc, SAS Campus Dr, Cary, NC 27513.