

# Physical Exercise and the Prevention of Disability in Activities of Daily Living in Older Persons With Osteoarthritis

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**Background:** The prevention of disability in activities of daily living (ADL) may prolong older persons' autonomy (older persons are defined in this study as those aged  $\geq 60$  years). However, proved preventive strategies for ADL disability are lacking. A sedentary lifestyle is an important cause of disability. This study examines whether an exercise program can prevent ADL disability.

**Methods:** A 2-center, randomized, single-blind, controlled trial was conducted in which participants were assigned to an aerobic exercise program, a resistance exercise program, or an attention control group. Of the 439 community-dwelling persons aged 60 years or older with knee osteoarthritis originally recruited, the 250 participants initially free of ADL disability were used for this study. Incident ADL disability, defined as developing difficulty in transferring from a bed to a chair, eating, dressing, using the toilet, or bathing, was assessed quarterly during 18 months of follow-up.

**Results:** The cumulative incidence of ADL disability was lower in the exercise groups (37.1%) than in the attention control group (52.5%) ( $P=.02$ ). After adjustment for demographics and baseline physical function, the relative risk of incident ADL disability for assignment to exercise was 0.57 (95% confidence interval, 0.38-0.85;  $P=.006$ ). Both exercise programs prevented ADL disability; the relative risks were 0.60 (95% confidence interval, 0.38-0.97;  $P=.04$ ) for resistance exercise and 0.53 (95% confidence interval, 0.33-0.85;  $P=.009$ ) for aerobic exercise. The lowest ADL disability risks were found for participants with the highest compliance to exercise.

**Conclusions:** Aerobic and resistance exercise may reduce the incidence of ADL disability in older persons with knee osteoarthritis. Exercise may be an effective strategy for preventing ADL disability and, consequently, may prolong older persons' autonomy.

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**I**NCREASES in life expectancy and the subsequent growth of the elderly population have a marked effect on the proportion of persons with a disability. Approximately 20% of the persons aged 70 years or older report difficulty with performing essential activities of daily living (ADL), referred to as ADL disability.<sup>1</sup> This type of disability is the most severe form of disability that limits older persons' autonomy and introduces dependence. It marks a serious decline in functional health and increases the risk of outpatient care, hospitalization, nursing home admission, and death.<sup>2-5</sup> The number of elderly people with ADL disability will continue to increase in the future, which highlights the urgent need to develop effective strategies to prevent ADL disability in old age.

Observational studies<sup>6-9</sup> suggest that regular physical exercise may be one of the most important preventive factors for the onset of late-life disability. Clinical trials

among older persons have shown that exercise programs improve objective indexes of physical performance (aerobic capacity, walking speed, and muscle strength)<sup>10-20</sup> and self-reported functional scores.<sup>10</sup> These previous studies provide strong evidence for the benefits of physical exercise. Nevertheless, it is still unclear whether exercise interventions can be sustained for a sufficient duration and if the beneficial effects are strong enough to actually prevent a clinically significant disability outcome and thereby prolong autonomy. To our knowledge, no randomized trials have shown that physical exercise can prevent the onset of ADL disability. The Fitness Arthritis and Seniors Trial (FAST)<sup>10</sup> was a randomized controlled trial on resistance and aerobic exercise among community-dwelling older adults with knee osteoarthritis, one of the leading causes of disability.<sup>21</sup> We used data from FAST to assess whether a physical exercise intervention can prevent the incidence of ADL disability.

## PARTICIPANTS AND METHODS

### STUDY SAMPLE

FAST was a 2-site, single-blind, randomized controlled trial of resistance or aerobic exercise. Details of the design and methods of FAST have been described before.<sup>10</sup> Briefly, older adults with knee osteoarthritis were recruited from the community through local advertisements and mailings. Eligibility criteria were as follows: (1) age 60 years or older; (2) pain in the knee(s) on most days of the month; (3) difficulty with at least one of the following because of knee pain: walking 0.4 km; climbing stairs; getting in and out of a car, bath, or bed; rising from a chair; or performing shopping, cleaning, or self-care activities; and (4) radiographic evidence of knee osteoarthritis. Exclusion criteria were as follows: (1) the presence of a medical condition that precluded safe participation in an exercise program (eg, recent myocardial infarction or stroke, severe chronic obstructive pulmonary disease, or congestive heart failure); (2) inflammatory arthritis; (3) regular exercise participation (>1 time per week for at least 20 minutes); and (4) inability to walk on a treadmill or walk, unassisted, 128 m in 6 minutes.

Of the 4575 persons screened by telephone for the first 3 eligibility criteria, 1402 came in so that a knee x-ray film could be obtained; 1164 of these persons had radiographically evident osteoarthritis. Of these 1164 persons, 323 (27.7%) scored on one or more of the exclusion criteria and 402 (34.5%) declined to participate. The remaining 439 persons were enrolled at baseline and were, based on the randomization assignment generated by computer at the biostatistics core, assigned to 1 of the 3 intervention arms: 144 to the attention control group, 146 to the resistance exercise program, and 149 to the aerobic exercise program. To examine the incidence of ADL disability, 178 participants (40.5%) with baseline ADL disability were excluded for the present study. The presence of baseline ADL disability was not significantly associated with group assignment ( $\chi^2=3.4$ ,  $P=.12$ ). In addition, 11 participants (1 in the attention control group, 2 in the resistance exercise group, and 8 in the aerobic exercise group) were excluded because they had no follow-up data. The remaining 250 persons (80 in the attention control group, 82 in the resistance exercise program, and 88 in the aerobic exercise program) formed the present study sample.

### INTERVENTIONS

#### Attention Control Group

To give subjects in the control group adequate study attention, they attended, during the first 3 months, monthly group sessions on education related to arthritis management, including time for discussions and social gathering. Later, participants were called bimonthly (months 4-6) or monthly (months 7-18) to maintain health updates and provide support.

#### Aerobic Exercise Program

This intervention consisted of a 3-month facility-based walking program and a 15-month home-based walking program. The facility-based program took place at an indoor track under the supervision of exercise leaders, master's-degree exercise scientists with training in exercise therapy, and was scheduled 3 times per week for 1 hour (leader-participant ratio, 2:20). Each session consisted of a 10-minute warm-up and cool-down phase, including slow walking and flexibility stretches, and a 40-minute period of walking at an intensity equivalent to 50% to 70% of the participants' heart rate reserve, as determined from their screening exercise treadmill test. Subjects progressed at different rates, with the emphasis placed on continued participation. For example, during disease flare-ups, some subjects could not walk continuously for 40 minutes; hence, short rest periods were interspersed within the 40-minute exercise phase. During months 4 to 6, the exercise leader visited participants 4 times and called them 6 times to offer assistance and support in the development of a walking exercise program in their home environment. Most participants chose to walk on sidewalks along streets or in nearby parks, but some walked in a nearby facility such as a gymnasium or shopping mall. For the remainder of the exercise program, telephone contacts were made every 3 weeks (months 7-9) or monthly (months 10-18). Attendance at the facility-based exercise sessions was registered by exercise leaders. In the home-based phase, participants maintained exercise logs in which they mentioned how many exercise sessions were conducted. To assess compliance, the percentage attendance was calculated by dividing the number of sessions completed by the total number of sessions prescribed multiplied by 100.

#### Resistance Exercise Program

This program also consisted of a 3-month supervised facility-based program, with 3 one-hour sessions per week, and a 15-month home-based program. Each session consisted of a 10-minute warm-up and cool-down phase and a 40-minute phase consisting of 2 sets of 12 repetitions of 9 exercises: leg extension, leg curl, step up, heel raise, chest fly, upright row, military press, biceps curl, and pelvic tilt. Upper body exercises were performed with dumbbells and lower body exercises with cuff weights. Beginning with a low resistance (1.3 kg for the upper body and 1.1 kg for the lower body), weight was increased in a stepwise fashion as long as participants could complete 2 sets of 12 repetitions. Once a self-imposed plateau was reached, weight was increased after the participant performed 2 sets of 12 repetitions for 3 consecutive workouts. However, because the emphasis was placed on continued participation, during periods of disease flare-ups, subjects were allowed to reduce their weight for exercises that exacerbated the pain. During the home-based phase, participants continued their

## RESULTS

The mean age of the 250 participants who were free of ADL disability at baseline was 69.1 years (SD, 5.5 years); 68.0% were women, 41.2% had 12 or less years of edu-

cation, and 50.0% had an annual household income below \$20,000. Eighty persons were assigned to the attention control group, 82 to the resistance exercise group, and 88 to the aerobic exercise group. Demographics, comorbidity, intensity of knee pain, walking speed, and dis-

exercises at home. Weights were exchanged at the participant's request or after a determination was made to increase the weight during the face-to-face or telephone contact. As with the aerobic program, compliance was assessed as the percentage attendance to exercise sessions based on registrations by exercise leaders (months 0-3) and on exercise logs (months 4-18).

Earlier articles<sup>10,22</sup> reported on the findings of FAST, and showed that both exercise interventions resulted in a lower score on a global disability questionnaire, improved physical performance, decreased knee pain, and improved balance.

## DATA COLLECTION

### Incidence of ADL Disability

Self-reported disability was assessed every 3 months during the 18-month follow-up period. At 3, 9, and 18 months postrandomization, participants were invited for data collection visits, for which transportation was provided, if necessary. At 6, 12, and 15 months postrandomization, telephone interviews were conducted. For this study, a 30-item physical disability questionnaire was developed that assessed self-reported difficulty with tasks in the following domains: mobility, transferring from a bed to a chair, upper extremity, instrumental, and basic ADL items.<sup>23</sup> Each item was scored from 1 (no difficulty) to 5 (inability). The basic ADL items included in the questionnaire are the ADL items used and validated for the first time by Katz et al<sup>24</sup> in 1963, and since then used by many others. ADL disability was defined as experiencing (yes or no) some or a lot of difficulty or an inability in doing at least one of the following without help: bathing, eating, dressing, transferring from a bed to a chair, or using the toilet. All available data were used to determine whether persons developed a new ADL disability during the 18 months of the trial. The primary analysis was based on the first report of ADL disability at follow-up, which was considered as the event of incident ADL disability.

### Demographic and Clinical Variables

Demographics assessed at baseline were age, race, educational level, and household income. Chronic comorbid conditions were considered to be present if participants had ever been told by a health professional that they had the following: coronary heart disease (diagnosed as having a myocardial infarction or angina or having undergone angioplasty or coronary artery bypass surgery), artery disease, diabetes mellitus, lung disease, cancer, or osteoarthritis in joints other than the knee (hands, spine, hips, or feet). Hypertension was defined as self-reported hypertension and concomitant use of antihypertensive drugs or a blood pressure of 160/90 mm Hg or higher. The body mass index was calculated as measured weight in kilograms divided by the square of measured height in meters. To assess the base-

line intensity of knee pain, participants rated the intensity of knee pain during the past week for 6 different ADL items on a Likert scale from 1 (no pain) to 6 (excruciating pain).<sup>25</sup> A summary pain intensity score was calculated by averaging the 6 scores for ambulation and transfer activities. Baseline aerobic capacity was assessed by a graded exercise treadmill test during which ventilatory and gas exchange responses were measured using a computerized system (CPX system; Medical Graphics Corp, Vadnais Heights, Minn). Oxygen uptake is reported as the volume of oxygen taken up in 1 minute per kilogram of body weight at peak exercise. Two indicators for baseline physical function were used: the average walking speed during a 6-minute test in which subjects were asked to walk as far as they possibly could and the average score on the disability questionnaire measuring perceived difficulty with mobility, transferring from a bed to a chair, upper extremity function, and instrumental ADL items (basic ADL items did not contribute to the score because those with baseline ADL disability were excluded from the study).

## STATISTICAL ANALYSES

$\chi^2$  Statistics (for categorical variables) and 1-way analyses of variance (for continuous variables) were used to compare baseline characteristics across the 3 assignment groups. Cox proportional hazards analyses were used to evaluate the effect of assignment on time to incident ADL disability. Persons who survived with no evidence of disability were censored at 18 months, and those unavailable for follow-up were censored after their last interview. Multivariate analyses were adjusted for race, site, sex, age, body mass index, walking speed, volume of oxygen taken up in 1 minute per kilogram of body weight at peak exercise, baseline disability, and pain. Primary analyses were conducted by intention to treat using the data of all participants. Secondary analyses were conducted to examine the effect of compliance with exercise on ADL incidence. The assumption of proportionality of hazard was checked with log minus log plots and by tests of the interaction of time with the group assignment variable. In complementary analyses conducted to confirm the findings from the Cox proportional hazards analyses, Markov logistic regression models<sup>26</sup> were used to examine all 3-month transitions during the 18-month follow-up. For this purpose, the data of subjects without ADL disability at the beginning of each 3-month interval were pooled across subjects and across intervals. Using these pooled data, 3-month transition probabilities for changing from the non-ADL-disabled to the ADL-disabled state were calculated across all intervals. The Markov model adjusts for the fact that not all observations are independent, but can still achieve more statistical power than survival analyses because the number of transitions studied is much higher. Finally, we conducted Cox proportional hazards analyses with the onset of disability in each of the specific ADLs to assess which of the 5 ADL items were affected by exercise assignment.

ability scores did not differ across the randomized groups (**Table 1**). The intervention dropout rate was 9.8% for the resistance exercise group (2 dropouts between 0-3 months, 4 between 4-9 months, and 2 between 10-18 months) and 13.6% for the aerobic exercise group (2 drop-

outs between 0-3 months, 6 between 4-9 months, and 4 between 10-19 months). Reasons for dropping out were moving from the area (n=1), increased severity of knee osteoarthritis (n=3), major illness (n=5), and lost interest (n=11). When dropouts were scored as

**Table 1. Baseline Characteristics of Randomized Participants\***

Baseline Characteristics	Attention Control Group (n = 80)	Resistance Exercise Group (n = 82)	Aerobic Exercise Group (n = 88)	P Value†
Age, y‡	68.5 (5.4)	68.8 (5.2)	69.9 (5.8)	.28
Female sex	53 (66)	59 (72)	58 (66)	.65
African American race	22 (28)	17 (21)	22 (25)	.60
Education >12 y	49 (61)	47 (57)	51 (58)	.86
Income >\$20 000	43 (54)	39 (48)	43 (49)	.71
Body mass index, kg/m <sup>2</sup>				
Mean (SD)	31.2 (5.4)	29.5 (5.6)	30.6 (5.7)	.15
>30	43 (54)	34 (41)	40 (45)	.28
Comorbid illnesses				
Arthritis in other joints	56 (70)	62 (76)	61 (69)	.61
Hypertension	37 (46)	31 (38)	39 (44)	.52
CHD	15 (19)	17 (21)	15 (17)	.83
Artery disease	11 (14)	6 (7)	9 (10)	.41
Diabetes mellitus	6 (8)	7 (9)	8 (9)	.93
Lung disease	5 (6)	6 (7)	8 (9)	.78
Cancer	4 (5)	7 (9)	2 (2)	.18
Pain intensity score‡	2.12 (0.6)	2.08 (0.5)	2.18 (0.6)	.50
6-min walking speed, m/s‡	1.20 (0.3)	1.18 (0.3)	1.14 (0.3)	.32
̇V <sub>O</sub> <sub>2</sub> peak, mL/(kg · min)‡	18.6 (4.8)	17.6 (4.6)	18.2 (5.2)	.42
Disability score‡	1.64 (0.4)	1.67 (0.5)	1.74 (0.5)	.39

\*Data are given as number (percentage) of participants unless otherwise indicated. CHD indicates coronary heart disease; ̇V<sub>O</sub><sub>2</sub> peak, volume of oxygen taken up in 1 minute per kilogram of body weight at peak exercise.

†Based on  $\chi^2$  tests for categorical variables and on 1-way analysis of variance tests for continuous variables.

‡Data are given as mean (SD).

**Table 2. Incidence of Disability in Activities of Daily Living (ADL) During 18 Months According to Intervention Assignment**

Group	No. of Participants	Cumulative Incidence in 18 mo, %	Rate per 1000 Person-Months	Risk of Incident ADL Disability*	
				Unadjusted	Adjusted†
Attention control	80	52.5	44.6	1.00‡	1.00‡
Exercise					
Both	170	37.1	27.1	0.62 (0.42-0.92)	0.57 (0.38-0.85)
Resistance exercise	82	37.8	26.6	0.61 (0.38-0.98)	0.60 (0.38-0.97)
Aerobic exercise	88	36.4	27.5	0.62 (0.39-0.98)	0.53 (0.33-0.85)

\*Data are given as relative risk (95% confidence interval).

†For site, race, age, sex, body mass index, baseline walking speed, disability, volume of oxygen taken up in 1 minute per kilogram of body weight at peak exercise, and pain score.

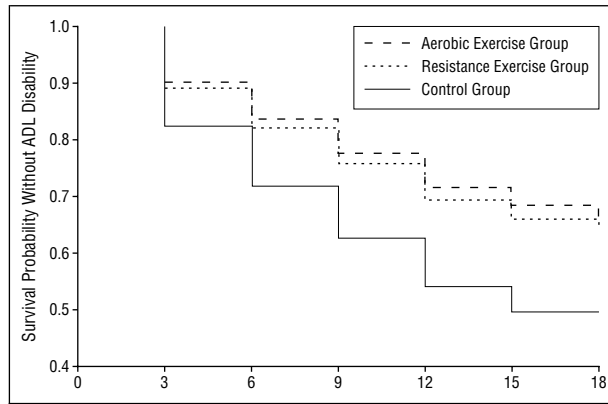
‡Referent.

having 0% compliance for their remaining time in the study, the overall compliance with the exercise sessions was 61% for resistance exercise and 56% for aerobic exercise. Compliance with exercise declined over time, with an average of 85% compliance during the first 3 months, 61% for months 4 through 9, and 54% for months 10 through 18. There was no statistically significant difference in compliance between the exercise groups ( $t=1.38$ ;  $P=.17$ ).

Of the 250 persons, 105 (42.0%) developed ADL disability during an average follow-up of 13.1 months (SD, 6.1 months). The cumulative incidence of ADL disability over 18 months was significantly higher ( $\chi^2_1=5.3$ ,  $P=.02$ ) among the 80 persons in the attention control group than among the 170 persons in the exercise groups (**Table 2**). Cumulative incidences were similar for the resistance exercise program and the aerobic exercise program. In the Cox proportional hazards model, the unadjusted relative risk (RR) of inci-

dent ADL disability associated with exercise was 0.62 ( $P=.01$ ). After adjustment for age, sex, site, race, body mass index, walking speed, and disability and knee pain scores, the RR was 0.57 ( $P=.006$ ). The adjusted risk was 0.60 ( $P=.04$ ) for those in the resistance exercise program and 0.53 ( $P=.009$ ) for those in the aerobic exercise program. Thus, persons participating in either a resistance or an aerobic exercise program had a significantly higher probability of remaining free of ADL disability for 18 months (**Figure**).

We assessed whether differential study loss (due to unavailability) could have biased our results. Overall, 129 (8.6%) of the total 1500 ADL disability assessments were missing. Of the 250 participants, 36 (14.4%) had 1 missing ADL disability assessment during 18 months and 26 (10.4%) had 2 or more missing assessments. Those who missed 1 or more ADL disability assessments did not differ from those with complete information for baseline sex, race, educational level, income, comorbidity, and dis-



Survival probability without activities of daily living (ADL) disability according to assignment group: results from adjusted Cox proportional hazards analysis. For the resistance exercise group vs the control group,  $P=.03$ ; for the aerobic exercise group vs the control group,  $P=.01$ ; and for both exercise groups vs the control group,  $P=.006$ .

ability and knee pain scores. Also, unavailability for follow-up was not associated with assignment group ( $\chi^2=0.96$ ,  $P=.62$ ), which illustrates that study loss to follow-up was nondifferential. When analyses were repeated among only those with complete data ( $n=188$ ), results were similar: the adjusted RR was 0.55 (95% confidence interval, 0.34-0.90;  $P=.02$ ) for resistance exercise and 0.58 (95% confidence interval, 0.36-0.94;  $P=.03$ ) for aerobic exercise.

Survival analyses examine the first onset of disability and ignore eventual recovery and subsequent disability patterns after recovery, if present. In complementary analyses, all 3-month transitions during 18 months (from no disability to disability, and vice versa) were pooled and examined using first-order Markov regression models. Pooling of the data across subjects and across intervals resulted in 1048 three-month intervals starting from the non-ADL-disabled state. During these intervals, 138 (13.2%) made a transition from the non-ADL-disabled state to the ADL-disabled state, and 910 (86.8%) showed continuation of the non-ADL-disabled state. When compared with the attention control group, the adjusted RR for making a transition from a non-ADL-disabled state to an ADL-disabled state was 0.53 for resistance exercise (95% confidence interval, 0.31-0.91;  $P=.02$ ) and 0.45 for aerobic exercise (95% confidence interval, 0.26-0.78;  $P=.004$ ). Thus, the RRs associated with exercise assignment were even somewhat lower than those derived from survival analyses, which strengthened our finding of a significantly protective effect for exercise on onset of ADL disability over time.

We examined the risk of incident ADL disability by tertiles of exercise compliance, defined as the percentage attendance to exercise sessions (**Table 3**). These analyses showed that those in the highest exercise compliance tertile had the lowest risk of incident ADL disability. When compared with the attention control group, persons who completed 81% or more of the resistance exercise sessions prescribed were 0.43 times as likely to develop ADL disability ( $P=.04$ ). This risk was 0.38 ( $P=.01$ ) among those in the most compliant tertile in the aerobic exercise program.

**Table 3. Effect of Compliance With an Exercise Intervention on the Risk of Developing an Incident Activities of Daily Living (ADL) Disability During 18 Months of Follow-up**

Group	No. of Participants	Adjusted Risk of an Incident ADL Disability*
Attention control	80	1.00†
Resistance exercise‡		
Lowest compliance tertile (<43%)	28	0.57 (0.29-1.12)
Middle compliance tertile (43%-80%)	28	0.79 (0.42-1.49)
Highest compliance tertile ( $\geq 81\%$ )	26	0.43 (0.19-0.97)
Aerobic exercise‡		
Lowest compliance tertile (<30%)	30	0.77 (0.41-1.46)
Middle compliance tertile (30%-77%)	30	0.47 (0.23-0.95)
Highest compliance tertile ( $\geq 78\%$ )	28	0.38 (0.17-0.82)

\*Data are given as relative risk (95% confidence interval). The relative risk was adjusted for site, race, age, sex, body mass index, baseline walking speed, disability, volume of oxygen taken up in 1 minute per kilogram of body weight at peak exercise, and pain score.

†Referent.

‡Compliance is defined as the percentage attendance to exercise sessions [(number of sessions completed/number sessions prescribed)  $\times$  100%].

We examined which of the 5 ADL items were affected by exercise assignment by conducting Cox proportional hazards analyses for each specific activity (**Table 4**). Persons in the exercise intervention groups had a significantly lower risk of developing a disability in transferring from a bed to a chair ( $P=.007$ ), a disability in bathing ( $P=.002$ ), and a disability in dressing ( $P=.005$ ). For a disability in eating, the number of incident cases was too small to conduct Cox proportional hazards analyses, but the cumulative incidence was significantly higher in the attention control group than in the exercise groups ( $P=.02$ ). Overall, the specific ADL disability risks for aerobic exercise tended to be somewhat smaller than those for resistance exercise. Although the findings were in the expected direction, exercise assignment was not significantly ( $P=.13$ ) associated with incident disability in “using the toilet.”

Finally, to examine whether the preventive effect of exercise was consistent across demographic and clinical subgroups, we entered an interaction term between demographic or clinical variable and assignment to (resistance or aerobic) exercise in the analyses and checked its significance. The effect of exercise on ADL disability appeared not to be significantly modified by age, sex, race, body mass index, or baseline disability or knee pain score.

#### COMMENT

Our data suggest that an exercise program may significantly reduce the 18-month incidence of ADL disability in older persons with knee osteoarthritis. When compared with the attention control group, persons assigned to an exercise group had a 0.57 times decreased risk of developing ADL disability. The preventive effect of the resistance exercise program was similar to that of the aerobic exercise program. For both exercise pro-

**Table 4. Incidence of Disability in the Individual Activities of Daily Living (ADL) During 18 Months According to Intervention Assignment**

Group	Cumulative Incidence in 18 mo, %	Adjusted Risk of an Incident ADL Disability*
<b>Disability in Transferring From a Bed to a Chair</b>		
Attention control	50.0	1.00†
Exercise		
Both	32.9	0.56 (0.37-0.84)
Resistance exercise	36.6	0.68 (0.42-1.09)
Aerobic exercise	29.5	0.46 (0.28-0.76)
<b>Disability in Bathing</b>		
Attention control	27.5	1.00†
Exercise		
Both	12.9	0.37 (0.20-0.69)
Resistance exercise	13.4	0.44 (0.21-0.93)
Aerobic exercise	12.5	0.31 (0.15-0.68)
<b>Disability in Toileting</b>		
Attention control	25.0	1.00†
Exercise		
Both	16.5	0.59 (0.33-1.07)
Resistance exercise	13.4	0.61 (0.28-1.31)
Aerobic exercise	19.4	0.58 (0.29-1.15)
<b>Disability in Dressing</b>		
Attention control	17.5	1.00†
Exercise		
Both	6.5	0.31 (0.13-0.71)
Resistance exercise	7.3	0.46 (0.17-1.22)
Aerobic exercise	5.7	0.20 (0.07-0.64)
<b>Disability in Eating</b>		
Attention control	5.0	1.00†
Exercise		
Both	0.6	‡
Resistance exercise	1.2	‡
Aerobic exercise	0.0	‡

\*Data are given as relative risk (95% confidence interval). The relative risk was adjusted for site, race, age, sex, body mass index, baseline walking speed, disability, volume of oxygen taken up in 1 minute per kilogram of body weight at peak exercise, and pain score.

†Referent.

‡The incidence was too small to calculate risks. The cumulative incidence was significantly higher in the attention control group than in the exercise groups ( $\chi^2_1 = 5.40, P = .02$ ).

grams, the most compliant persons with the exercise program showed the largest reduction in their risk of incident ADL disability. In addition, a consistently protective effect of exercise was found in separate analyses examining the disability incidence in each specific activity (transferring from a bed to a chair, bathing, using the toilet, dressing, and eating), with significant results for 4 of the 5 specific ADL items. Previous clinical trials<sup>10-20</sup> have shown that exercise has beneficial effects on intermediate end points, such as continuous disability scales, physical performance, or muscle strength. Despite this evidence, there were still concerns as to whether physical exercise interventions in older persons can be sufficiently sustained in duration and intensity to actually improve clinically significant outcomes in the long-term. To our knowledge, our study is the first to show that an exercise program may be able to prevent major ADL disability in late life.

Various pathways may explain the preventive effect of exercise on ADL disability in patients with knee osteoarthritis. First, as shown in previous trials,<sup>11-14,16,17,20,27</sup> exercise has various beneficial physiological effects, such as improved muscle strength and bone mass and increased aerobic capacity, flexibility, and balance. In line with these findings, the exercise programs in our study resulted in increased physical performance, aerobic capacity (for the aerobic exercise program only), and muscle strength and in improved postural sway,<sup>10,22</sup> which may explain the reduced risk for subsequent major disability. A second pathway for the preventive effect of exercise may be through reduced knee pain, which was another result of our study.<sup>10</sup> Severity of knee pain has been shown to be an independent risk factor for disability.<sup>28</sup> Third, exercise may have favorable psychological consequences, such as a decreased depressed mood and a reduced fear of falling,<sup>29</sup> which influence the risk of ADL disability.<sup>30,31</sup> Rejeski and colleagues<sup>32</sup> reported that increased self-efficacy beliefs mediate the effects of both exercise treatments in this trial on performance-related function. Also, it is likely that the exercise programs increase peer support and counseling and emphasize self-responsibility for maintaining health, which, in turn, may have resulted in favorable health effects. Fourth, greater weight loss in the exercise groups may be another possible mechanism. A greater mean 18-month weight loss was found for the aerobic exercise group (1.89 kg lost) compared with the attention control group (0.40 kg lost) ( $P = .05$ ), but not for the resistance exercise group. This greater weight loss in the aerobic exercise group may have been because of the exercise program, increased physical activity outside of the prescribed exercise intervention, or other improved health behaviors (nutrition). Finally, it is possible that part of the protective effect of exercise is through preventing or favorably influencing the course of frequently disabling other conditions, such as cardiovascular disease,<sup>33</sup> respiratory diseases,<sup>34</sup> diabetes mellitus,<sup>35</sup> and osteoporosis.<sup>27</sup> Because our trial was designed as an outcome study and in-depth exploration of mediating mechanisms between exercise and ADL disability was beyond its scope, future studies should be designed to address this important topic.

Our sample consisted of a selected group of older persons with knee osteoarthritis. Because this population is at a high risk for ADL disability,<sup>21</sup> it forms an appropriate and efficient group to examine preventive strategies for ADL disability. The cumulative incidence of ADL disability in our sample may seem high (52.5% in the attention control group and 37.1% in the exercise groups). However, this number is similar to previously reported rates: among the initially moderately disabled (but not ADL-disabled) older women in the Women's Health and Aging Study,<sup>36</sup> the cumulative incidence of ADL disability was 48% in 1½ years, and in a study<sup>37</sup> among hospitalized older persons without ADL disability at discharge, the ADL disability incidence was 41% in 1 year. Also, the hierarchical structure of the ADL disability incidence is similar to that found in a previous longitudinal study by Dunlop and colleagues,<sup>38</sup> with the highest cumulative incidences for transferring from a bed to a chair and bathing and the lowest for eating.

In the past, there have been some concerns raised that exercise accelerates the underlying osteoarthritis process or results in injury. However, as reported in several studies,<sup>10,18,19</sup> moderate exercise improves knee pain and performance outcomes in patients with knee osteoarthritis. In addition, our study shows that, although 2% of the respondents had an injury related to the exercise program,<sup>10</sup> the aerobic and the resistance exercise programs appear to be effective nonpharmacological therapies for preventing major subsequent disability in older people with knee osteoarthritis.

Our sample consisted of a selected group of patients with knee osteoarthritis and, consequently, the results may not be completely generalizable to the older population at large. However, in addition to knee osteoarthritis, favorable effects of exercise on physiological or performance outcomes have consistently been found for healthy older persons<sup>11,12,16</sup> and for older persons with other conditions, such as cardiovascular disease,<sup>17,39</sup> pulmonary disease,<sup>40</sup> osteoporosis,<sup>41</sup> or frailty.<sup>13-15</sup> Thus, the beneficial effect of exercise on the prevention of disability may well be more broadly applicable across the spectrum of diseases typically prevalent in older persons. Although this may suggest that exercise prevents ADL disability in initially nondisabled older persons irrespective of disease status, future studies are necessary to confirm the effect of exercise in the general older population at large. Many of the older participants with knee osteoarthritis in our study (41%) had other disabling comorbid conditions, such as cardiovascular disease, diabetes mellitus, lung disease, or cancer. Thus, our sample is not solely a sample of persons with knee osteoarthritis.

As the population ages, ADL disability in older persons will increasingly affect quality of life and will considerably increase requirements for informal and formal care. Consequently, there is an urgent need to develop effective interventions that may increase the years of life spent without disability and dependency. Besides minimizing the severity and functional impact of certain diseases and preventing comorbidity, using appropriate exercise regimens may be another valuable target in the prevention of disability. Several studies have shown that it is possible and feasible to enroll older persons with and without various chronic conditions in various exercise programs. Our study suggests that a physical exercise program may be an effective strategy for increasing the active life expectancy of older adults.

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