

Exercise and Depressive Symptoms: A Comparison of Aerobic and Resistance Exercise Effects on Emotional and Physical Function in Older Persons With High and Low Depressive Symptomatology

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This study examines and compares the effect of aerobic and resistance exercise on emotional and physical function among older persons with initially high or low depressive symptomatology. Data are from the Fitness, Arthritis and Seniors Trial, a trial among 439 persons 60 years or older with knee osteoarthritis randomized to health education (control), resistance exercise, or aerobic exercise groups. Depressive symptoms (assessed by the Center for Epidemiologic Studies–Depression scale) and physical function (disability, walking speed, and pain) were assessed at baseline and after 3, 9, and 18 months. Compared with results for the control group, aerobic exercise significantly lowered depressive symptoms over time. No such effect was observed for resistance exercise. The reduction in depressive symptoms with aerobic exercise was found both among the 98 participants with initially high depressive symptomatology and among the 340 participants with initially low depressive symptomatology and was the strongest for the most compliant persons. Aerobic and resistance exercise significantly reduced disability and pain and increased walking speed both, and to an equal extent, in persons with high depressive symptomatology and persons with low depressive symptomatology.

THE many physical and physiological benefits of exercise for older persons have been well reported (King, Rejeski, & Buchner, 1998). However, benefits are not restricted to physical health alone but extend to the psychological domain of health as well. Longitudinal epidemiological studies have shown that a high level of physical activity reduces the risk of developing high depressive symptomatology over time (Farmer et al., 1988) and that this effect is not limited to individuals who have been active throughout their adult life. In short, physical activity seems to be an effective form of prevention for depressive symptomatology among older adults even when adopted later in life (Camacho, Roberts, Lazarus, Kaplan, & Cohen, 1991). Physiological, biological, and psychological mechanisms have been suggested to explain the antidepressive effects of exercise (North, McCullagh, & Tran, 1990).

Evidence for a beneficial effect of exercise on psychological health has been confirmed in several experimental studies, most of which have been conducted among clinically depressed persons. For example, Greist and colleagues (1979), McCann and Holmes (1984), and Martinsen, Medhus, and Sandvik (1985) have shown that clinically depressed persons randomized to an exercise program were more likely to improve their depression status than those not receiving an exercise program. Other experimental studies have shown that an exercise program appears to be at least as effective in reducing clinical depression as more conventional treatment regimens like antidepressant medication (Babyak et al.,

2000; Blumenthal et al., 1999; McNeil, LeBlanc, & Joyner, 1991) or psychotherapy (Freemont & Craighead, 1987; Klein, Greist, & Gurman, 1985). Also in older clinically depressed persons, evidence for an antidepressive effect of exercise is provided by controlled trials involving a resistance exercise program (Singh, Clements, & Fiatarone, 1997) or an aerobic exercise program (Babyak et al., 2000; Blumenthal et al., 1999).

Whether exercise improves depressive symptomatology in a general older population has been less consistently demonstrated in trials; some have been positive (Blumenthal et al., 1991; Blumenthal, Williams, Needels, & Wallace, 1982; Coyle & Santiago, 1995; King, Taylor, & Haskell, 1993; McMurdo & Rennie, 1993; Williams & Lord, 1997), whereas others have yielded null effects (Dustman et al., 1984; Emery & Gatz, 1990; Jette et al., 1996; King, Taylor, Haskell, & DeBusk, 1989; McMurdo & Burnett, 1992; Pierce, Madden, Siegel, & Blumenthal, 1993). Consequently, it has been suggested that the antidepressive effect of exercise is most likely due to normalizing depressed mood states in older participants who have high initial depression levels rather than to inducing improvements in all older participants (Craft & Landers, 1998; King et al., 1993; Williams & Lord, 1997). Because no earlier studies have directly compared the effect of exercise on mood among a sufficient number of older persons with initial high or low depression scores, it is rather unclear whether the antidepressive effect of exercise is general or specific to depressed persons.

Physical inactivity is very common among depressed persons (Penninx, Guralnik, Leveille, Ferrucci, & van Eijk, 1999; Stephens, 1988), partly because their attitudes toward exercise and exercise self-efficacy may be more negative. There is some evidence that compliance rates with a variety of treatment regimens are lower and dropout rates are higher among depressed older persons than among nondepressed peers (Blumenthal, Williams, Wallace, Williams, & Needels, 1982; Shaw, Cronan, & Christie, 1994). If this is true for exercise interventions as well, it would suggest that exercise programs may be less effective for improving physical function among persons with high depressive symptomatology than among persons with low depressive symptomatology.

Using data from the Fitness, Arthritis and Seniors Trial (FAST), a randomized exercise trial with a long duration (18 months) among older persons with knee osteoarthritis, the present study examined and compared whether exercise has equal benefit on outcomes representing emotional and physical health among older persons with initially high or low depressive symptomatology.

METHODS

Study Sample

The present study is based on secondary analyses using data from FAST, a single blind, randomized controlled trial of therapeutic resistance and aerobic exercise conducted at two sites: Memphis, Tennessee, and Winston-Salem, North Carolina. Details of the design and methods have previously been reported (Ettinger et al., 1997). Participants were community-based adults with knee osteoarthritis who were recruited through local advertisements and mass mailings. Eligibility criteria were (a) 60 years of age or older; (b) pain in the knee(s) on most days of the month; (c) difficulty with at least one of the following due to knee pain: walking a quarter mile; 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 (d) radiographic evidence of knee osteoarthritis. Exclusion criteria were (a) presence of a medical condition that precluded safe exercise participation (e.g., recent myocardial infarction or stroke, severe chronic obstructive pulmonary disease, congestive heart failure); (b) inflammatory arthritis; (c) regular exercise participation (more than one time per week for at least 20 min); or (d) inability to walk on a treadmill or to walk, unassisted, 128 m in 6 min. A total of 439 participants were enrolled and assigned to one of the three intervention arms (144 in the control condition, 146 in the resistance exercise program, and 149 in the aerobic exercise program). Baseline depression data were missing for 1 person, leaving 438 persons for the present study.

Interventions

Control condition (health education).—During the first 3 months, participants received monthly education sessions by a nurse on issues related to arthritis management. Later, participants were called bimonthly (Months 4 to 6) or monthly (Months 7 to 18) to maintain health updates and provide support.

Aerobic exercise program.—This program 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 supervision of an exercise leader and was scheduled three times per week for 1 hr. Each session consisted of a 10-min warm-up and cool-down phase including flexibility stretches, and a 40-min period of walking at an intensity equivalent to 50%–70% of the heart rate reserve as determined from a screening exercise treadmill test. In Months 4 to 6, the exercise leader visited participants four times and called them six 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, phone contacts were made every 3 weeks (Months 7 to 9) or monthly (Months 10 to 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 number of sessions prescribed.

Resistance exercise program.—This program also consisted of a 3-month supervised facility-based program with three 1-hr sessions per week and a 15-month home-based program. Each session consisted of a 10-min warm-up and cool-down phase and a 40-min phase consisting of repetitions of various upper and lower body exercises using dumbbells and cuff weights. Weight was increased in a stepwise fashion as long as the participant could complete two sets of 10 repetitions. During the home-based phase, participants continued their exercises at home with dumbbells and cuff weights that were provided as part of the intervention. 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 contacts with the exercise leader. These latter contacts occurred with the same frequency as in the aerobic exercise program. Like in the aerobic program, compliance was assessed as the percentage of attendance at exercise sessions.

Earlier papers on the FAST study have reported that the exercise interventions resulted in a lower score on a global disability questionnaire, improved physical performance and strength, improved aerobic capacity (for aerobic exercise only), decreased pain, and improved balance (Ettinger et al., 1997; Messier et al., 2000). A higher compliance with the exercise intervention resulted in more favorable outcomes for disability, physical performance, and pain (Ettinger et al., 1997). Depression data were not considered in these earlier articles.

Data Collection

Depression.—The presence of depressive symptoms was assessed using a short version of the Center for Epidemiologic Studies Depression (CES-D) scale (Radloff, 1977) at baseline (before randomization) and in the assessments 3, 9,

and 18 months postrandomization. The brief version of the CES-D asks about depressive feelings and behaviors experienced during the past week, with the original 0 (rarely or none) to 3 (most or all days) response format (Cronbach's $\alpha = .74$). The six items were chosen because of their ability to predict a clinical diagnosis of major depression in a community-based sample (Burnam, Wells, Leaske, & Landsverk, 1988). In addition, the short-item version showed psychometric properties that compare favorably with the original 20-item format (Burnam et al., 1988). Data from two observational studies among older persons, the Longitudinal Aging Study Amsterdam ($n = 3,107$) and the Established Populations for Epidemiologic Studies of the Elderly ($n = 2,812$) yielded high correlations (.91 and .90, respectively) between the short CES-D version and the full CES-D. For assessing the effect of exercise intervention on depressive symptoms, we used the continuous CES-D score as the outcome. For comparing characteristics and intervention effects among persons with high and low depressive symptomatology, we dichotomized participants by using a baseline CES-D cutoff of 5, which is transformed from the commonly used cutoff of 16. Using data from the Longitudinal Aging Study Amsterdam, we found that the short CES-D version cutoff score of 5 had good criterion validity for major depression (sensitivity 86%, specificity 90%), similar to that of the full CES-D version cutoff (Beekman et al., 1997).

Physical function.—Three indicators of physical function were used: self-reported disability, 6-min walking speed, and knee pain. For these indicators, assessments were conducted before randomization and 3, 9, and 18 months postrandomization. These physical indicators are considered to be the main outcomes for the FAST study and have been used in earlier analyses (Ettinger et al., 1997).

A 23-item disability questionnaire assessed experienced difficulties with activities in five domains: mobility, transfer activities, upper extremity tasks, instrumental activities of daily living, and basic activities of daily living (Rejeski, Ettinger, Shumaker, James, et al., 1995). For each activity, participants were asked how much difficulty they had had over the past month doing this activity, with responses ranging from 1 (no difficulty) to 5 (unable to do). A composite disability score was created by averaging the scores on all 23 items. The internal reliability of the composite disability score was good (Cronbach's $\alpha = .79$). Walking speed was assessed during a 6-min test in which participants were asked to walk as far as they possibly could. The distance walked during a 6-min usual pace walk test was used to calculate the mean walking speed during these 6 min. The intensity of knee pain was measured by asking participants to rate the intensity of knee pain during the past week for six different activities of daily living on a Likert scale ranging from 1 (no pain) to 6 (excruciating pain). A summary pain intensity score was calculated by averaging the six scores for both ambulation and transfer activities (Rejeski, Ettinger, Shumaker, Heuser, et al., 1995).

Demographic and clinical variables.—Baseline demographics were age, gender, race, and education. Chronic co-

morbid conditions were considered to be present if participants had ever been told by a health professional that they had the following conditions: coronary heart disease (myocardial infarction, angioplasty, coronary artery bypass surgery, or angina), diabetes, 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 medications or a blood pressure of 160/90mm Hg or more. Body mass index was calculated as measured weight in kilograms divided by the square of measured height in meters.

Statistical Analyses

Baseline characteristics and compliance to exercise were described and compared among participants with high and low depressive symptomatology. Differences in depression scores at 3, 9, and 18 months postrandomization across intervention groups were determined by repeated measures analysis of covariance, or ANCOVA (SAS PROC MIXED; Laird & Ware, 1982). The advantage of this analysis is that it uses all available observations and adjusts results based on correlations between outcomes and predictor variables. If the probability of a follow-up observation being missing is dependent on either covariates included in the model or previously observed outcomes, then maximum-likelihood repeated measures ANCOVA can still provide unbiased parameter estimates. Analyses were adjusted for site, race, age, sex, education, and baseline depression score. This was done to correct for chance imbalances in prognostic factors between the groups and to reduce the variance estimate for between-group differences. Primary analyses were conducted by intention to treat using data of all randomized participants. Secondary analyses were conducted to examine the effect of compliance with exercise on depression score over time. Finally, separately for participants with initially high or low CES-D scores, repeated measures ANCOVAs were conducted to test the effects of exercise on disability score, walking speed, and pain score at 3, 9, and 18 months postrandomization. Because tests of Time of Follow-Up \times Intervention Effect showed that the effect of the intervention was consistent over time for depression and all physical function outcomes, tests for between-group differences were averaged over the 3-, 9-, and 18-month follow-up. Adjusted least squares means obtained in the presence of such interactions are used in all figures to display trends across time.

RESULTS

The mean age of the 438 participants was 68.8 years ($SD = 5.6$), 70% were female, and 56% had more than 12 years of education. A total of 98 (22%) respondents scored above the CES-D cutoff and were considered to have high depressive symptomatology. These persons were significantly more often female and less educated and had arthritis in other joints or diabetes more often than persons with low depressive symptomatology (Table 1). At baseline, persons with high depressive symptomatology also reported more physical disability, slower walking speed, and more pain than those with low symptomatology. The randomization resulted in an assignment of a similar number of persons with high de-

Table 1. Baseline Characteristics in Participants With Low and High Depressive Symptomatology

Baseline characteristic	Participants with low depressive symptomatology (n = 340)	Participants with high depressive symptomatology (n = 98)	p
Age (M ± SD)	68.8 ± 5.6	68.5 ± 5.6	.63
Sex (% female)	66.8	81.6	.005
Race (% non-Whites)	24.4	32.7	.10
Education (% > 12 years)	59.7	44.9	.009
Comorbid illnesses (%)			
Arthritis in other joints	70.6	82.7	.02
Hypertension	44.7	48.0	.57
Heart disease	7.6	10.2	.42
Diabetes	7.1	15.3	.01
Obesity (body mass index >30)	52.4	53.1	.90
Physical disability (mean score ± SD)	1.81 ± 0.52	2.09 ± 0.63	< .001
Walking speed (mean score ± SD)	1.15 ± 0.27	1.09 ± 0.27	.04
Pain score (mean score ± SD)	2.32 ± 0.70	2.56 ± 0.72	.004
Intervention group (%)			.61
Health education	33.2	36.7	
Resistance exercise	32.9	34.7	
Aerobic exercise	33.8	28.6	

pressive symptomatology to all interventions. Among persons with low depressive symptomatology, 113 were randomized to health education, 112 to resistance exercise, and 115 to aerobic exercise. Among persons with high depressive symptomatology, these numbers were 36, 34, and 28, respectively.

Of the 146 persons randomized to the resistance exercise, 120 (82%) completed the intervention and 26 (17%) dropped out of the intervention. These numbers were 115 (80%) and 28 (20%), respectively, for the aerobic exercise intervention. Although the intervention dropout rate for both the resistance exercise and the aerobic exercise is slightly higher among persons with high depressive symptomatology (24% and 25%, respectively) than among those with low depressive symptomatology (16% and 18%, respectively), differences were not statistically significant (Table 2). Of the persons with high depressive symptomatology who dropped out, 40% reported that medical reasons were responsible for their discontinuation, whereas 31% of the dropouts with low depressive symptomatology reported this reason. Also for average compliance among the adherers, measured as percentage of attendance at exercise visits, no significant differences were found between persons with initially high and those with initially low depressive symptomatology.

Follow-up depression data were available on 407 (93%) of the 438 enrolled participants. Missing depression data were not associated with group assignment, χ^2 (2, N = 438) = .37, $p = .83$, or with baseline depressive symptomatology, χ^2 (1, N = 438) = .22, $p = .63$. Using the total study sample, Figure 1A reports the results of repeated measures ANCOVAs, with depression as the outcome vari-

Table 2. Descriptive Data on Intervention Drop Out and Compliance in Participants With Low and High Depressive Symptomatology at Baseline

Descriptive data	Participants with low depressive symptomatology	Participants with high depressive symptomatology	p
Resistance exercise	n = 112	n = 34	
Intervention drop out (%)	16.1	23.5	.32
Mean % compliance among adherers (SD)			
0–3 months	83.1 (17.5)	82.4 (22.8)	.87
4–9 months	64.2 (32.5)	54.2 (36.4)	.21
10–18 months	61.2 (43.1)	71.9 (58.3)	.34
Overall (0–18 months)	62.1 (28.4)	57.5 (30.4)	.51
Aerobic exercise	n = 115	n = 28	
Intervention drop-out (%)	18.3	25.0	.42
Mean % compliance among adherers (SD)			
0–3 months	87.7 (14.0)	89.2 (11.8)	.61
4–9 months	72.6 (26.1)	68.2 (28.1)	.45
10–18 months	57.2 (40.9)	47.6 (47.2)	.31
Overall (0–18 months)	66.0 (24.5)	59.8 (27.9)	.27

Note: Compliance is measured as percentage attendance to exercise sessions prescribed.

able, time as the repeated measure, treatment group as the between-subjects factor, and adjustment for site, race, age, sex, education, and baseline depression score. This analysis examines whether follow-up depression scores differed significantly across the three assignment groups. Participants randomized to the aerobic exercise intervention group reported significantly lower depression scores over time ($p < .001$) than those in the control group. On average, the control group increased their depression score by 2% (from 2.74 to 2.80), whereas the aerobic exercise group reduced their score by 23% (from 2.74 to 2.12). Those in the resistance exercise group experienced a reduction of 6% (from 2.74 to 2.59), but their depression scores over time were not significantly different from those in the control group ($p = .27$).

When similar analyses were conducted separately among the 340 persons with low depressive symptomatology at baseline (Figure 1B), on average depression scores increased over time. However, when compared with the control group, the increase in depression score over time was significantly lower in the aerobic exercise group ($p = .01$), but not significantly different in the resistance exercise group ($p = .66$). The average adjusted change in depression score was 31% in the control group (1.56 to 2.05), 0% in the aerobic group, and 26% in the resistance exercise group (1.56 to 1.96). When analyses were conducted separately among the 98 persons with high baseline depressive symptomatology (Figure 1C), depression scores appeared to decrease over time. Again, the aerobic exercise group ($p = .03$), but not the resistance exercise group ($p = .31$), showed significantly lower depression scores during follow-up than did the control group. The average adjusted reduction in depression score was –20% in the control group (from 6.90 to 5.49), –30% in the resistance exercise group (from 6.90 to 4.81), and –40% in the aerobic exercise group (from 6.90 to 4.11). Thus, depression scores showed

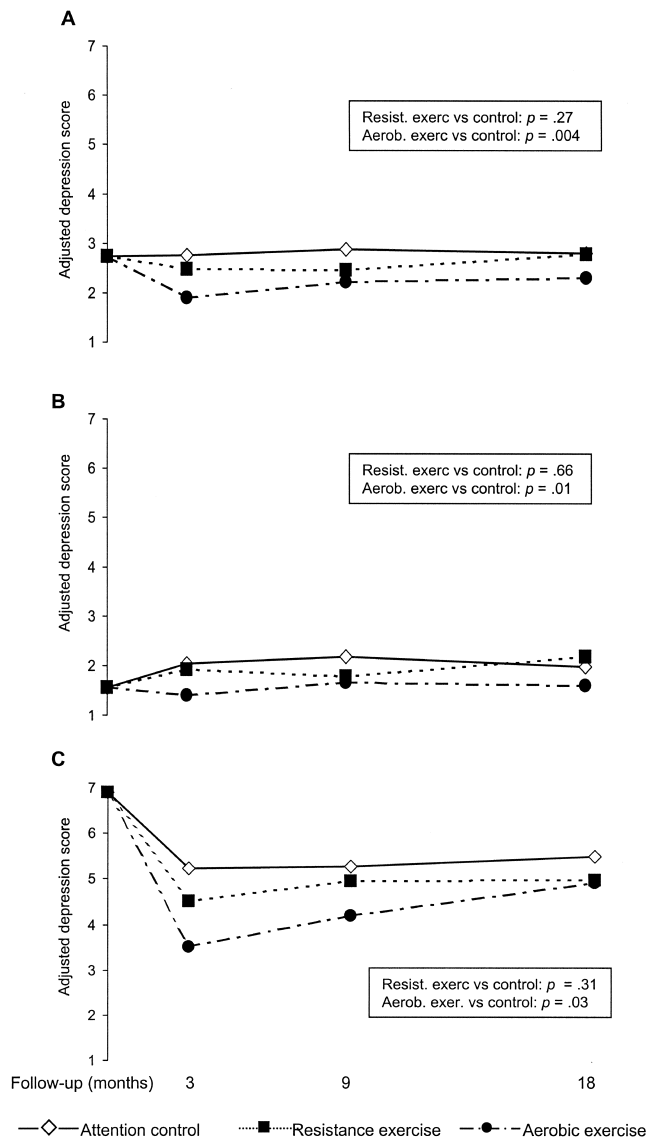


Figure 1. Adjusted depression scores for the three intervention groups during follow-up in the total sample (A), in subjects with low baseline depressive symptomatology (B), and in subjects with high baseline depressive symptomatology (C). The p values are based on repeated measures analysis of covariance, adjusted for site, race, age, sex, education, baseline disability, and baseline depression score. Resist. exerc. = resistance exercise; Aerob. exerc. = aerobic exercise.

a different trend over time according to baseline depressive symptomatology status: They, on average, increase in those with low depressive symptomatology at baseline (Figure 1B) and decrease in those with high initial depressive symptomatology (Figure 1C). Nevertheless, the magnitude of the antidepressant effect of exercise appears to be rather similar among persons with high and low depressive symptomatology; that is, the difference between the aerobic exercise group and the control group was 26% among those with a high initial CES-D score and 20% among those with a low initial CES-D score. We tested the interaction between baseline depression status and exercise intervention by including an interaction term for High/Low CES-D Score \times

Intervention Group in the adjusted repeated measures ANCOVA of the total sample (described above and shown in Figure 1A). The interaction term was not significant ($p = .31$), illustrating that the beneficial effect of aerobic exercise on depressive symptoms over time was not significantly different for those with high and low depressive symptomatology.

To examine whether a high compliance with the exercise program was associated with lower depressive feelings over time, we determined the average adjusted depression score by tertiles of exercise compliance using repeated measures ANCOVA adjusted for baseline depression score, disability, age, sex, race, education, and site. These analyses showed that, for both exercise programs, the highest compliance tertile had a lower average depression score than the lowest compliance tertile (Table 3). Persons who completed 79% or more of the resistance exercise sessions prescribed had a significantly lower adjusted depression score ($M = 2.01$, $p = .004$) than the controls ($M = 2.80$). For aerobic exercise, both the middle and the highest compliance tertiles had significantly lower depression scores during follow-up than the control group ($ps = .009$ and $.01$, respectively).

The efficacy of resistance and aerobic exercise on physical function outcomes was analyzed separately for persons with high and low depressive symptomatology using repeated measures ANCOVAs with time as the repeated measure and the intervention group as the between-subjects factor (Figure 2). Analyses were adjusted for site, race, age, sex, education, body mass index, and baseline score of outcome. Among the persons with low depressive symptomatology, when compared with the control group, aerobic exercise resulted in significantly lower disability and pain scores and higher walking speed over time (all $ps < .001$), with average differences in follow-up scores between exercisers and controls of -9% , -12% , and 9% , respectively. For resistance exercise, similar results were found for disability ($p = .01$) and pain (marginally significant $p = .07$), with average differences of -7% and -5% , but not for walking speed (0%).

Also, when similar analyses were conducted among the 98 persons with high depressive symptomatology, the aerobic exercise group had lower disability ($p = .005$) and pain scores ($p = .05$) and a higher walking speed ($p = .02$) over time than the control group, with average differences between exercisers and controls of -13% , -19% , and 8% , respectively. For the resistance exercise group, favorable effects were found for disability ($p = .01$) and pain ($p = .10$), with average differences of -11% and -10% . These results show that, even in the small subgroup of persons with high depressive symptomatology, the exercise interventions resulted in significantly improved physical function and that the effects had a comparable magnitude when compared with persons with low depressive symptomatology. The latter was confirmed by the nonsignificant interaction term ($p > .15$) between high/low CES-D score and intervention group for all physical outcomes.

Finally, the question arises as to whether the antidepressant effect found for aerobic exercise in our study can be partly explained by the fact that aerobic exercisers, when compared with controls, had lower disability, less pain, and

Table 3. Effect of Compliance With Exercise Prescription on Depression Score

Exercise prescription	No. of observations	Adjusted mean depression score (SE) during follow-up	Change from baseline (%)	Physical exercise vs control
Health education	374	2.80 (0.14)	+2.3	
Resistance exercise				
Lowest compliance tertile ($\leq 50\%$)	110	3.39 (0.26)	+23.8	.03
Middle compliance tertile (51%–78%)	121	2.52 (0.25)	–10.0	.47
Highest compliance tertile ($\geq 79\%$)	139	2.01 (0.24)	–28.2	.003
Aerobic exercise				
Lowest compliance tertile ($\leq 40\%$)	98	2.23 (0.27)	–18.5	.17
Middle compliance tertile (41%–77%)	124	2.06 (0.25)	–24.7	.003
Highest compliance tertile ($\geq 78\%$)	136	2.09 (0.24)	–23.6	.006

Notes: Compliance is defined as percentage attendance to the exercise sessions prescribed. The results are adjusted least squares mean scores with SEs in parentheses, statistical comparisons made using repeated measures analyses of covariance. Analyses are adjusted for site, race, age, sex, education, baseline disability, and baseline depression score.

an improved walking speed over time. To address this issue, we conducted additional, exploratory repeated measures ANCOVAs with time-dependent covariates for disability, pain, and walking speed. Analyses without time-dependent covariates revealed that the model-based estimate of the average follow-up depression score was 2.80 in the control group and 2.12 in the aerobic exercise group, $t(864) = -3.40, p < .001$. The time-dependent covariates for pain ($p = .002$) and disability ($p = .003$), but not the time-dependent covariate of walking speed ($p = .91$), were significant predictors of follow-up depression scores. When all time-dependent covariates were included in the analyses, the model-based estimate of the average follow-up depression score was 2.65 in the control group and 2.13 in the aerobic exercise group, $t(861) = -2.48, p = .01$. These analyses show that the difference in follow-up depression scores between the control group and the aerobic exercise group are somewhat smaller after considering change in pain and disability over time, but the difference between the groups remains statistically significant.

DISCUSSION

This study involving 438 older participants with knee osteoarthritis showed that aerobic exercise, but not resistance exercise, significantly lowered depression scores during an 18-month follow-up. The antidepressive effect of aerobic exercise was found for both persons with initially high symptomatology and persons with low depressive symptomatology, and was strongest for those who were the most compliant. In addition, we found that both the aerobic and the resistance exercise programs significantly reduced disability and pain and increased walking speed (only for aerobic exercise) over 18 months in participants who had either high or low depressive symptomatology at baseline. These results show that exercise has beneficial effects on emotional and physical function, irrespective of initial depressed mood status.

Overall, depression scores of persons with low initial depressive symptomatology appeared to increase over time. Part of this effect may be due to regression to the mean, because, in general, persons with low depression scores are likely to obtain higher scores over time. However, increasing depression over time may also be partly explained by

an increasing progression of knee osteoarthritis in our sample. For example, this is illustrated by the fact that, although exercise participants were better off, physical disability scores over time tended to go up as well. Of particular interest is the finding that the depression scores in the aerobic exercise group did not show an increase over time (average 18-month change = 0%). Depression patterns among

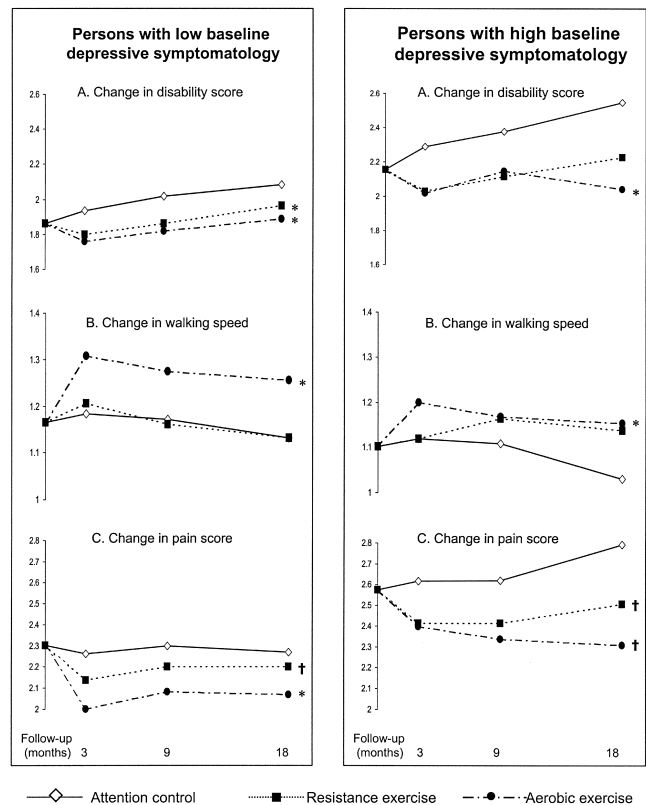


Figure 2. Adjusted disability score (A), walking speed (B), and pain score (C) according to assignment condition during 18 months of follow-up among persons with low and high depressive symptomatology at baseline. The p values are based on repeated measures analysis of covariance, adjusted for site, race, age, sex, education, body mass index, and baseline score of outcome. ps for exercise vs. control group: * $p < .05$; † $p < .10$.

the persons with high initial depressive symptomatology were very different. Overall, persons in all three groups showed declining depression scores over time, with the most pronounced decline in the first 3 months. Again, this may be partly due to regression to the mean. A declining trend in depressive symptoms is in line with observational findings that about half of the older persons with high CES-D scores significantly improve depressive symptomatology over a short follow-up period (Beekman, Deeg, Smit, & van Tilburg, 1995; Kennedy, Kelman, & Thomas, 1991). After 3 months, depression scores went slightly up again but remained lower than the baseline depression scores. Depression patterns over time were similar in all three assignment groups, but participants in the aerobic exercise group had a significantly greater reduction in their depression scores (-40%) than participants in the control (-20%) and resistance exercise (-30%) groups.

It has been suggested that the antidepressive effect of exercise is due to normalizing depressed mood in persons who have high initial depression levels rather than inducing improvements in all persons (Craft & Landers, 1998; King et al., 1993; Williams & Lord, 1997). However, we found that in both persons with high and persons with low depressive symptomatology, the aerobic exercise group had significantly lower depression scores during follow-up than the control group. Thus, in line with the suggestion of North and colleagues (1990), the antidepressive effect of the aerobic exercise intervention is not limited to participants who have depressive symptomatology at baseline.

For persons not clinically depressed, exercise trials have not always confirmed an antidepressant effect (Dustman et al., 1984; Emery & Gatz, 1990; Jette et al., 1996; King et al., 1989; McMurdo & Burnett, 1992; Pierce et al., 1993). However, some of these latter studies may have found null effects for nondepressed participants because their participants were relatively young and healthy and, consequently, not yet faced with the reality of declining function. Thus, our result of an antidepressive effect of aerobic exercise among nondepressed older persons with knee osteoarthritis may be unique to older adults who are prone to depressive symptoms that frequently accompany chronic diseases such as arthritis. Our results suggest that it is likely that exercise reduces depression in participants who are depressed and that exercise buffers nondepressed participants for events in life that may trigger depressive symptomatology.

Our findings add to the already existing debate in the literature about whether an aerobic exercise intervention is more effective than a resistance exercise intervention in improving mood. Only a few exercise studies have directly compared the psychological effects of aerobic and resistance exercise. Mutrie (1988) studied 24 participants with elevated depression scores and found that after 4 weeks the aerobic exercise group had a superior antidepressive effect compared with the resistance exercise group. Three other studies, however, were not able to find a difference between an aerobic and a nonaerobic exercise program (Doyne et al., 1987; Martinsen, Hoffart, & Solberg, 1989; Sexton, Maero, & Dahl, 1989). However, these previous studies are not comparable to our study as they all included young and healthy participants, the interventions were short and, there-

fore, probably had a high compliance, and the follow-up period was much shorter than the 18 months in our study. In our study, the absence of a favorable psychological effect in the resistance exercise group was consistent for both initially nondepressed and initially depressed persons. It is important to point out that we did find a favorable effect on mood among the persons most compliant with the resistance exercise program (upper tertile). This may suggest that, when performed regularly, resistance exercise may also have antidepressant effects among older persons. Future trials among the general older population should further explore whether aerobic exercise is really more effective for mood improvement than other modes of exercise.

Our time-dependent covariate analyses showed that the greater reduction in disability and pain over time among the aerobic exercisers may partly explain the antidepressant effect of aerobic exercise. However, after adjustment for changes in disability and pain over time, the aerobic group continued to have significantly lower depression scores than the control group. There have been several mechanisms offered as possible explanations for the effect that physical activity has on depression (North et al., 1990). These include but are not limited to increased aerobic capacity (Blumenthal et al., 1999), increases in circulating concentrations of brain amines and beta-endorphine (Ransford, 1982), reduced activity of the hypothalamo-pituitary-adrenocortical axis (Pompe, Bernards, Meijman, & Heijnen, 1999), increased feelings of mastery or self-efficacy (McAuley, Blissmer, Katula, Duncan, & Mihalko, 2000), distraction, and a reduction in negative thought patterns (Hughes, 1984). Because exercise was performed in a group setting, it is also possible that depression was affected in a positive manner by the social interaction between study participants. Because FAST was designed as an outcome trial and in-depth exploration of mediating mechanisms is not feasible, future studies should be designed to address this important topic.

We compared the physical benefits of exercise across initially depressed and initially nondepressed participants. Among both subgroups, aerobic and resistance exercise decreased disability scores, decreased pain scores, and improved walking speed (for aerobic exercise only). Even among the rather small subgroup of 98 depressed persons, various physical improvements associated with exercise were found to be statistically significant. This shows that depression does not moderate the efficacy on physical function. This equal efficacy may be explained by the fact that the 98 depressed persons in our study did not exhibit a lower compliance with or dropout rate from the exercise program.

Our study sample consisted of a selective group of older persons with knee osteoarthritis, and consequently, results may not be completely generalizable to the older population at large. In addition, our study did not include a psychiatric assessment of clinical depression, which makes it impossible to generalize our findings to clinically depressed older persons. Nevertheless, our findings illustrate that an exercise program, especially an aerobic one, may have significant beneficial emotional and physical effects among the general older population at large. Blumenthal and col-

leagues (1991) found that in older clinically depressed persons aerobic exercise is as effective in reducing depressive symptomatology as antidepressant medication. It is likely that other treatment options for depression, for example, medication or psychotherapy, do not have equal beneficial effects on physical function. Consequently, exercise may be a more complete treatment option for depression, as this not only improves emotional function but also has a positive influence on physical function. There exist strong reciprocal associations between depression and health decline in older persons (Penninx et al., 1998, 1999). An exercise intervention could play an important role in preventing the process whereby physical and emotional dysfunction interact to cause a progressive downward spiral in the health of older persons.

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