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Psychological and Cognitive Outcomes of a Randomized Trial of Exercise Among Patients With Chronic Obstructive Pulmonary Disease

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Exercise rehabilitation is recommended increasingly for patients with chronic obstructive pulmonary disease (COPD). This study examined the effect of exercise and education on 79 older adults (*M* age = 66.6 ± 6.5 years; 53% female) with COPD, randomly assigned to 10 weeks of (a) exercise, education, and stress management (EXESM; $n = 29$); (b) education and stress management (ESM; $n = 25$); or (c) waiting list (WL; $n = 25$). EXESM included 37 sessions of exercise, 16 educational lectures, and 10 weekly stress management classes. ESM included only the 16 lectures and 10 stress management classes. Before and after the intervention, assessments were conducted of physiological functioning (pulmonary function, exercise endurance), psychological well-being (depression, anxiety, quality of life), and cognitive functioning (attention, motor speed, mental efficiency, verbal processing). Repeated measures multivariate analysis of variance indicated that EXESM participants experienced changes not observed among ESM and WL participants, including improved endurance, reduced anxiety, and improved cognitive performance (verbal fluency).

Key words: chronic obstructive pulmonary disease, exercise, cognitive function, psychological well-being

Patients with chronic obstructive pulmonary disease (COPD) typically experience a prolonged course of illness marked by a gradual decrease in physical endurance, increased shortness of breath, and greater reliance on medications and medical interventions (Cugell, 1988). The COPD patient often, in turn, experiences reduced capability for physical functioning, limitations in activities of daily living, loss of traditional social roles, and emotional distress, especially depression and anxiety (Agle & Baum, 1977; McSweeny, Grant, Heaton, Adams, & Timms, 1982). In addition, past studies have revealed impaired cognitive function among adults with COPD. One past study found that mildly hypoxemic (mean $PaO_2 = 66.3 \pm 7.0$) COPD patients exhibited decrements on tests of abstract reasoning, psychomotor speed, and memory when compared to age- and gender-matched controls (Prigatano, Parsons, Wright, Levin, & Hawryluk, 1983). It has been suggested that blood oxygenation level may play a substantial role in the degree of neuropsychological impairment in this population (Grant, Prigatano, Heaton, McSweeny, Wright, & Adams, 1987).

Because exercise has become more widely accepted as a standard treatment for patients with COPD, it is of interest to evaluate the effects of exercise not only on physical functioning of COPD patients but also on indicators of psychological well-being and cognitive functioning. It has been suggested that exercise may contribute to enhanced psychological functioning via a number of pathways, including (a) enhanced self-efficacy resulting from ability to perform physical activities, (b) release of natural opiates in the brain, and (c) social support inherent in the exercise setting contributing to psychological well-being (de Coverley Veale, 1987). Cognitive functioning is thought to be enhanced following exercise by reductions in sympathetic hyperarousal and greater oxygen-carrying capacity of the blood contributing to enhanced neurotransmitter regulation (Dustman, Emmerson, & Shearer, 1994). COPD patients are an optimal population for further study of exercise-related changes in psychological and cognitive functioning because they are at risk for psychological distress and cognitive difficulties.

The small number of previous studies evaluating exercise outcomes among COPD patients provide equivocal results.

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Several past studies have found that exercise is associated with enhanced psychological functioning, including decreased negative mood states (Dekhuijzen, Beek, Folgering, & Van Herwaarden, 1990; Emery, Leatherman, Burker, & MacIntyre, 1991) and improved self-concept (Kersten, 1990). However, other studies have found few psychological benefits of exercise among COPD patients (Gayle, Spitler, Karper, Jaeger, & Rice, 1988; D. Lewis & Bell, 1995; Toshima, Kaplan, & Ries, 1990). A recent randomized study of 119 COPD patients assigned either to a comprehensive rehabilitation program (including exercise and education) or to an education-only program revealed significant benefits of exercise rehabilitation for physical endurance, shortness of breath, and walking self-efficacy but no changes in pulmonary function, depression, and self-rated quality of life (Ries, Kaplan, Limberg, & Prewitt, 1995). These results provide evidence for the benefits of exercise training for physical endurance among COPD patients, despite the absence of changes in pulmonary function or psychological well-being. Although no changes in pulmonary function were expected following exercise, the lack of positive change in psychological well-being was attributed to outcome measures that may not have been sensitive to change in this population.

This study was designed to evaluate psychological well-being with a battery of measures sensitive to changes in parameters relevant to patients with COPD. Specifically, the study included measures of depression and anxiety, the most frequently reported psychological conditions among COPD patients, as well as indicators of health-related quality of life (i.e., perceived control of health, self-rated impairment). Cognitive measures were selected to assess areas of functioning in which COPD patients are likely to demonstrate impairment and that may be compromised among older adults (i.e., attention, motor speed, mental efficiency, verbal processing). The study included a control group receiving education and stress management as well as a waiting-list control group.

It was hypothesized that (a) none of the participants would achieve improvements in pulmonary function per se; (b) the exercise group would achieve significant improvements in cardiopulmonary endurance but the control groups would show no improvement in endurance; (c) both the exercise group and the education–stress management control group would achieve improvements in psychological well-being and COPD knowledge, but the waiting-list control group would not; (d) exercise participants would experience enhanced health-related quality of life and improved cognitive performance, but control participants would not experience changes in quality of life or cognitive performance; (e) among exercise participants, enhanced physical endurance would be associated with improved cognitive performance and quality of life; (f) among both the exercise participants and the education–stress management control participants, increased COPD knowledge would be associated with enhanced psychological well-being; and (g) across the total study sample, indicators of pulmonary disease status (i.e., blood oxygen level) would be associated with cognitive performance.

Method

Participants

Participants over age 50 with stable COPD were recruited through announcements at local Better Breathers Clubs, television announcements, word of mouth, advertisements in weekly newspapers for older adults, and physician referral. All potential participants received a preliminary telephone screening to confirm the presence of COPD symptoms and length of diagnosis as well as to rule out significant cardiac disease or other diseases that might affect exercise tolerance or learning skills. Ninety-two participants met eligibility requirements for the study and were scheduled for baseline evaluation. Criteria for study participation included (a) age > 50 years, (b) airflow obstruction demonstrated on spirometry (i.e., the ratio of forced expiratory volume in 1 s divided by forced vital capacity [FEV_1/FVC] < .70), and (c) clinical symptoms of COPD (i.e., chronic cough or dyspnea, or both, limiting some activities) for more than 6 months. Individuals with primarily acute, reversible airway disease (asthma) without fixed airflow obstruction were excluded, as were individuals with other significant and disabling diseases such as tuberculosis, pulmonary fibrosis, or cancer; unstable cardiac disorder (e.g., myocardial infarction, unstable angina, or congestive heart failure) during the previous 3 months; or other medical conditions that would limit participation in a regular exercise program. Baseline spirometry revealed that 9 participants had normal values (and thus were ineligible for this study), and an additional 4 participants decided that they would be unable to make the commitment to participate in the study. Thus, a total of 79 older adults with COPD entered the randomized study. Characteristics of the sample are included in Table 1. Most participants were taking chronic pulmonary medications (e.g., inhaled and oral bronchodilators or corticosteroids) before study entry. The medical appropriateness of these regimens was reviewed and adjusted by members of the Duke Pulmonary Rehabilitation Program staff, after which no significant adjustments were made during the course of the study.

Procedures

Participants were randomized to one of three groups: (a) exercise, education, and stress management (EXESM; $n = 29$); (b) education and stress management but no exercise training (ESM; $n = 25$), or (c) waiting list (WL; $n = 25$). Group assignments were taken from a random number schedule, printed on a piece of paper, and placed in a sealed envelope. Participants were not given the envelope containing their group assignment until after completing the baseline assessment, and technical staff conducting the assessments were not aware of group assignments.

Because of the limited number of participants available at one time, they entered the study in small groups of 1 to 5 participants per month, and the data were collected over a period of more than one year. Participants in the EXESM group participated with other COPD patients in a clinical pulmonary exercise rehabilitation program that included the same components as the EXESM condition. Participants in the ESM group engaged in the educational and stress management components but received no exercise training.

EXESM participants met daily for 4 hr per day during a 5-week period. Daily sessions included a total of 45 min of aerobic exercise as well as strength training on Nautilus equipment. Each exercise session began with a 10-min warm-up period followed by aerobic exercise activities (i.e., stationary bicycle, arm ergometry, and walking) and ended with a cool-down period of stretching. The EXESM sessions also included approximately four hour-long

Table 1
Baseline Characteristics of the Sample

Variable	EXESM	ESM	WL	Total
Gender				
Male	15	10	12	37
Female	15	14	13	42
Age (years)				
M	65.4	67.4	67.4	66.6
SD	6.4	5.9	7.1	6.5
FEV_1 (L)				
M	1.24	1.13	1.02	1.14
SD	0.6	0.5	0.4	0.5
% predicted FEV_1				
M	43	43	39	42
SD	18	18	16	17
PaO_2 (mmHg)				
M	75.4	76.0	72.5	74.7
SD	12.7	9.5	8.3	10.5
$\dot{V}O_2max$ (ml/kg/min)				
M	12.0	11.8	10.9	11.6
SD	4.0	3.3	3.4	3.6
% using O_2	20	8	8	13
% medications				
Taking at least 1 pulmonary medication	86	95	81	87
Prednisone	33	14	33	27
Theophylline	33	52	48	44
Aerosolized steroids	52	48	62	54
Other bronchodilators	81	90	76	83
Education				
<High school	20	29	28	25
<College graduation	57	38	40	46
≥College graduation	23	33	32	29
SCL-GSI				
M	57.9	55.8	58.8	57.5
SD	8.7	5.4	7.6	7.5

Note. EXESM = exercise, education, and stress management; ESM = education and stress management; WL = waiting list; % predicted FEV_1 = forced expiratory volume in 1 s (FEV_1) divided by predicted FEV_1 according to age, gender, and height norms; L = liters; PaO_2 = partial pressure of oxygen in the arterial blood; $\dot{V}O_2max$ = maximum oxygen consumption; O_2 = oxygen; SCL-GSI = summary score of psychological distress from the Hopkins Symptom Checklist–90—Revised.

educational lectures per week on topics relevant for COPD patients (e.g., anatomy and physiology of the lungs, medications for chronic lung disease, interpreting pulmonary function tests, pathophysiology of COPD, and understanding arterial blood gases). EXESM participants also were provided a weekly 1-hr group meeting for stress management and psychosocial support. Stress management groups were conducted by a clinical psychologist using a cognitive–behavioral format. Participants were taught progressive muscle relaxation, strategies to increase awareness of cognitive distortions associated with physical limitations, and the negative emotional consequences of cognitive distortions.

Following the initial intensive 5-week period, EXESM participants then participated in 5 more weeks of a less intense regimen consisting of exercise sessions three times per week for 60–90 min and one hour-long weekly stress management class. Thus, over the course of the 10-week intervention period, EXESM participants were expected to attend 37 exercise sessions, 16 educational sessions, and 10 stress management classes. All exercise and educational classes were conducted at the Duke Center for Living, an easily accessed rehabilitation facility affiliated with Duke University Medical Center. ESM participants attended the same schedule of lectures ($n = 16$) and stress management sessions ($n = 10$) as the EXESM participants but were not provided with any exercise training. WL participants were asked not to alter their activities significantly during the 10-week study period.

Assessments

Participants underwent assessments of physiological functioning, psychological well-being, and cognitive functioning at baseline (T1) and after the 10-week intervention period (T2).

Physiological assessment. The physiological assessment included evaluation of pulmonary function, which serves as a marker of disease severity, and of cardiopulmonary function, which indicates physical endurance during a standard exercise protocol. (a) Pulmonary function was evaluated, using standard pulmonary function equipment (Sensormedics 2450, Yorba Linda, CA) to perform spirometry in accordance with American Thoracic Society standards. Measurements derived from the spirometry assessment included FEV_1, percentage of predicted FEV_1 (based on norms adjusted for age, gender, and height), FVC, and maximal voluntary ventilation (MVV). FEV_1 and FVC provide a marker of progression of lung disease and are used in the diagnosis of COPD. MVV provides an indicator of the maximum rate at which the participant is able to inhale and expel air from the lungs and is a common test of respiratory musculature and airway resistance. (b) Cardiopulmonary endurance was assessed with bicycle ergometry testing, performed in the postabsorptive state, with the participant sitting upright on an isokinetic, magnetically braked bicycle ergometer (Quinton Corival 400). Exercise began at 0 W, and the load was increased 12.5 W every minute, with exercise rates remaining constant at 40–60 rpm. Exercise continued until limited by excessive fatigue or shortness of breath or both. The concentration of expired oxygen and carbon dioxide was analyzed over 20-s intervals (Sensormedics 2900, Yorba Linda, CA) to calculate oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$). In the 9 participants requiring supplemental oxygen with exercise, $\dot{V}O_2$ could not be measured and only $\dot{V}CO_2$ was recorded. Other measurements included heart rate (HR) and work (the maximal workload that the participant achieved during exercise testing). At baseline only, participants had resting and maximal exercise arterial blood gas analysis (PaO_2), providing an additional indicator of pulmonary disease status and blood oxygenation during exercise testing.

Assessment of psychological well-being and health-related quality of life. Psychological well-being was assessed with four self-report scales measuring the domains of depression and anxiety. (a) The Center for Epidemiological Studies—Depression Inventory (CES-D) is a 20-item measure of depressive symptoms developed for community use and validated in an older adult sample (Radloff, 1977). Scores range from 0 to 60, with higher scores indicating greater symptoms of depression and a cut-off score of 16 reflecting significant depression. (b) The Bradburn Affect-Balance Scale is a 10-item scale tapping both positive and negative emotions (Bradburn, 1969), with scores ranging from 0 (*most negative*) to 10 (*most positive*). (c) The State–Trait Anxiety Inventory (STAI) is a 40-item assessment of both immediate and longer-standing symptoms of anxiety (Spielberger, Gorsuch, & Lushene, 1970). Only the State Anxiety scale score (20 items) was used in this study because it is more likely to be responsive to intervention (range of scores: 20–80, with higher scores indicating greater symptoms of anxiety). (d) The Hopkins Symptom Checklist (SCL-90-R) is a 90-item scale of psychiatric and somatic symptoms providing nine clinical subscales and a summary score (Derogatis, 1983). *T* scores are derived for each subscale of the SCL-90-R on the basis of adult outpatient norms. For purposes of this study, only the Depression and Anxiety subscale scores were analyzed.

Health-related quality of life was assessed with two self-report measures: (a) The Multidimensional Health Locus of Control (MHLC) inventory is an 18-item scale assessing attributions of control regarding health outcomes (Wallston, Wallston, & DeVellis, 1978). Three subscale scores are derived from the MHLC (6 items per subscale) tapping internal attributions of control as well as control attributed to powerful others (e.g., medical doctors) and to chance or fate. Participants respond to each item on a 6-point Likert scale, with scores for each of the three subscales ranging from 6 (*low*) to 36 (*high*). (b) The Sickness Impact Profile (SIP) is a 136-item checklist of symptoms and physical limitations in activities of daily living (e.g., sleep, mobility, household management, social interaction, and recreation; Bergner, Bobbitt, Carter, & Gilson, 1981). The SIP has been validated in multiple studies of medical patients, and past research has demonstrated greater impairment on the SIP among COPD patients than among healthy adults (McSweeny et al., 1982). This study evaluated the summary score from the SIP (number of symptoms checked divided by total symptoms listed).

Cognitive assessment. The cognitive test battery evaluated several domains, including attention, motor speed, mental efficiency, and verbal processing. (a) Attention was evaluated with the Digit Vigilance test, which requires that participants search for and cross off all instances of a given digit on a page of random digits (R. F. Lewis & Rennick, 1979). (b) The Finger Tapping test from the Halstead-Reitan battery was used as a reliable indicator of motor speed (Halstead, 1947). Scores reflected a mean of five 10-s trials for each hand. Tests of mental efficiency included (c) the Trail Making Test (Parts A and B), which incorporates components of perceptual motor speed and sequencing (Reitan, 1958), and (d) the Digit Symbol subtest of the Wechsler Adult Intelligence Scale—Revised, which is a common test of psychomotor performance sensitive to brain dysfunction (Wechsler, 1981). (e) The Verbal Fluency test of the Halstead-Reitan battery is an indicator of the participants' capacity for organized verbal processing and is thought to be sensitive to frontal lobe impairment (Estes, 1974). Participants were given 1 min to name as many words as possible starting with a specified letter.

Health knowledge. Participants also completed a standardized pulmonary rehabilitation health knowledge test (Hopp, Lee, & Hills, 1989).

Data Analysis

The primary mode of data analysis was repeated measures multivariate analysis of variance (MANOVA) with group assignment as a between-participants variable and time as a within-participants variable. Variables were clustered according to the conceptual domain assessed by the instruments. For domains assessed with a single variable (e.g., health-related impairment or verbal processing) univariate analysis of variance (ANOVA) was used. Planned contrasts were used to evaluate interactions of (a) EXESM versus ESM + WL and time and (b) ESM versus WL and time, for domains in which it was hypothesized that only EXESM participants would improve and that no differences would be observed in the control groups (i.e., for cardiopulmonary endurance, health quality of life, and cognitive function). For domains in which it was hypothesized that both EXESM and ESM participants would improve to a similar degree (i.e., for psychological well-being and COPD knowledge), planned contrasts evaluated interactions of (a) EXESM + ESM versus WL and time and (b) EXESM versus ESM and time. When significant multivariate effects were observed, univariate effects were then evaluated, using the same a priori contrasts used in the MANOVA. Significant univariate interactions were followed by post hoc contrasts of T1 versus T2 within each of the three groups.

The secondary mode of data analysis included regression analysis to evaluate the extent to which increased physical endurance among the EXESM participants and increased knowledge among the EXESM and ESM participants were associated with changes in psychological well-being, quality of life, and cognitive function. In addition, correlational analysis was used to evaluate the extent to which cognitive outcomes were associated with blood oxygenation levels.

Results

Effectiveness of Randomization, Analysis of Dropouts, and Adherence

As shown in Table 1, random assignment was effective in that there were no significant group differences in age, gender distribution, or indicators of pulmonary function and physical endurance. Distribution of oxygen use and medications were not significantly different across groups. Moreover, there were no group differences in education or overall psychological distress (as indicated by the summary score for the SCL-90-R).

During the course of the study, a total of 6 participants dropped out of the study. Four dropped out of the EXESM condition, all because of illness, and 2 dropped out of the ESM condition because of transportation problems. Thus, a total of 73 participants completed the intervention, were assessed at T1 and T2, and were included in the data analysis. To evaluate differences between participants who completed the study ($n = 73$) and study dropouts ($n = 6$), t tests were conducted on demographic, physiological, psychological, and cognitive variables at T1. The dropouts were younger ($M = 60.2$ vs. 67.2 years) and were mostly male ($\frac{5}{6} = 83\%$). The analysis revealed no differences in cardiopulmonary function or psychological well-being. However, dropouts had significantly lower scores on the cognitive test of Verbal Fluency, $t(77) = 2.65, p < .01$.

Almost all participants (92%) completed the 10-week study ($n = 73$), although a somewhat lower proportion completed the exercise component (25 of 29; 86%). Among the 25 exercise participants who completed the study, the mean number of sessions attended was 29 ($SD = \pm 7$), or approximately three exercise sessions per week, which is well within standard guidelines for cardiac and pulmonary rehabilitation programming (American Association of Cardiovascular and Pulmonary Rehabilitation, 1993). The exercise participants attended approximately 89% of the education classes and 80% of the stress management groups, whereas the education group attended approximately 88% of both the education and stress management classes.

Physiological Functioning

Pulmonary function. Pulmonary function outcomes were analyzed with a MANOVA of four pulmonary function variables (FEV_1, % predicted FEV_1, FVC, MVV). The MANOVA revealed no significant effects of time or group and no interaction. As shown in Table 2, pulmonary function was not changed during the course of the intervention period for any of the three groups.

Cardiopulmonary endurance. A MANOVA of two physical endurance measures from the exercise testing (maximum HR and work) indicated a significant effect of time, $F(2, 68) = 4.07$, $p < .05$, and an interaction of Time × Group, $F(2, 66) = 3.45$, $p < .05$. Univariate analyses indicated a significant time effect, $F(1, 69) = 7.89$, $p < .01$, and a significant interaction, $F(2, 67) = 6.08$, $p < .01$, for work but no significant univariate effects for HR. Participants in the EXESM condition increased work significantly, whereas control participants did not, as is evident in Table 3. Because $\dot{V}O_2max$ data were not obtainable for 9 participants who were using continuous oxygen, a separate repeated measures ANOVA was calculated for the 64 participants without oxygen. The ANOVA indicated a significant Time × Group interaction, $F(2, 61) = 9.89$, $p < .001$, and no main effects. Participants in the EXESM condition achieved gains in $\dot{V}O_2max$ that were not evident in the control groups, as shown in Table 3.

Table 3
Means and Standard Deviations for Cardiopulmonary Endurance Measures at Times 1 and 2

Measure	EXESM (*n* = 25) Time 1	EXESM Time 2	ESM (*n* = 23) Time 1	ESM Time 2	WL (*n* = 25) Time 1	WL Time 2
Work (kilopond-meters)						
M	66.3	77.6**	64.1	65.9	59.2	59.1
SD	29.8	34.8	23.6	22.9	24.9	27.7
Max HR						
M	135	138	127	131	125	122
SD	24	29	16	16	18	17
$\dot{V}O_2max$ (ml/kg/min)						
M	12.4	14.4**	12.0	11.7	11.1	10.8
SD	4.3	4.5	3.4	2.9	3.5	3.3

Note. EXESM = exercise, education, and stress management; ESM = education and stress management; WL = waiting list; work = maximum workload achieved during bicycle test; Max HR = maximum heart rate during bicycle test; $\dot{V}O_2max$ = maximal oxygen consumption during bicycle test.
$^{**}p < .01$. The *p* values indicate within-group comparisons across time.

Psychological Well-Being

Depression. Depressed mood was analyzed in a MANOVA of CES-D, SCL-Depression, and Affect-Balance scores. The analysis indicated a significant time main effect, $F(3, 68) = 7.76$, $p < .001$, and a significant Time × Group interaction, $F(3, 66) = 2.31$, $p < .05$. Univariate tests indicated a significant time main effect for CES-D, $F(1, 70) = 12.8$, $p < .001$, SCL-Depression, $F(1, 70) = 22.02$, $p < .001$, and Affect Balance, $F(1, 70) = 9.03$, $p < .01$, with a significant univariate interaction only for SCL-Depression, $F(2, 68) = 4.26$, $p < .05$. Contrary to the experimental hypothesis, planned group contrasts indicated significant differences between the EXESM and ESM groups, $F(1, 68) = 8.52$, $p < .01$. Post hoc analysis of within-group change across time indicated significant reductions in depressive symptoms in both the EXESM and WL groups but no change in the ESM group, as shown in Table 4.

Table 2
Means and Standard Deviations for Pulmonary Function Measures at Times 1 and 2

Measure	EXESM (*n* = 25) Time 1	EXESM Time 2	ESM (*n* = 23) Time 1	ESM Time 2	WL (*n* = 25) Time 1	WL Time 2
FEV_1 (L)						
M	1.29	1.31	1.15	1.07	1.02	1.04
SD	0.63	0.61	0.45	0.46	0.37	0.40
% predicted FEV_1						
M	47	48	44	41	39	39
SD	17	18	18	20	16	16
FVC (L)						
M	2.53	2.65	2.62	2.41	2.40	2.38
SD	0.95	0.96	0.98	0.85	0.66	0.96
MVV						
M	51.6	55.9	43.6	41.8	39.5	41.6
SD	28.6	33.1	19.0	20.1	17.5	18.6

Note. EXESM = exercise, education, and stress management; ESM = education and stress management; WL = waiting list; FEV_1 = forced expiratory volume in 1 s; L = liters; FVC = forced vital capacity; MVV = maximal voluntary ventilation.

Anxiety. Anxiety was analyzed with State Anxiety from the STAI and the Anxiety subscale from the SCL-90. Results indicated no group or time main effects but a significant Time × Group interaction, $F(2, 68) = 2.83$, $p < .05$. Univariate tests indicated that the interaction was significant for SCL-Anxiety, $F(2, 69) = 3.13$, $p < .05$, and that there was a trend for the State Anxiety scale, $F(2, 69) = 2.81$, $p < .07$. Contrary to the hypotheses, contrasts indicated a significant difference between EXESM and ESM, $F(2, 68) = 3.13$, $p < .05$. Post hoc evaluation of within-group change across time indicated significant reductions in anxiety among EXESM participants but not among ESM or WL participants, as evident in Table 4.

Health Quality of Life

Generalized health attributions. A MANOVA of the three Health Locus of Control subscales (Internal, Powerful Others, and Chance) revealed no effects of group or time and no interaction effect. Attributions of control remained stable during the intervention, with participants in all three groups attributing the greatest degree of control to internal factors and the least degree of control to chance factors, as shown in Table 5.

Illness-related impairment. Analysis of the SIP total score indicated a significant time main effect, $F(1, 69) = 16.37$, $p < .001$, and a significant Time × Group interaction, $F(2, 69) = 3.86$, $p < .05$. However, contrary to the hypothesis, planned contrasts indicated significant differ-

Table 4
Means and Standard Deviations for Depression and Anxiety at Times 1 and 2

Measure	EXESM (*n* = 25) Time 1	EXESM (*n* = 25) Time 2	ESM (*n* = 23) Time 1	ESM (*n* = 23) Time 2	WL (*n* = 25) Time 1	WL (*n* = 25) Time 2
CES-Depression						
M	14.2	9.4	13.0	11.9	14.0	12.5
SD	9.8	7.3	8.3	9.3	7.4	7.9
Affect-Balance						
M	6.8	7.5	6.8	7.5	6.9	7.7
SD	2.3	1.9	2.0	2.3	2.1	1.8
SCL-Depression						
M	59.2	53.8***	55.5	55.2	60.0	56.9*
SD	7.6	5.7	5.3	4.8	7.7	6.9
SCL-Anxiety						
M	54.3	51.3**	54.0	54.3	53.4	52.0
SD	7.2	4.8	5.3	6.9	4.5	5.8
STAI-State Anxiety						
M	36.9	33.2*	37.9	36.7	34.6	37.0
SD	8.9	8.7	9.9	7.9	7.3	8.7

Note. Higher scores reflect greater distress for all measures except Affect-Balance. EXESM = exercise, education, and stress management; ESM = education and stress management; WL = waiting list; CES = Center for Epidemiological Studies; SCL = Hopkins Symptom Checklist-90—Revised; STAI = State–Trait Anxiety Inventory.
*$p < .05$. **$p < .01$. ***$p < .001$. The *p* values indicate within-group comparisons across time.

ences in change scores for ESM and WL groups, $F(1, 69) = 4.2$, $p < .05$. Post hoc analysis of within-group change indicated that participants in both the EXESM and WL groups reported decreases in impairment over time, as shown in Table 5.

Cognitive Functioning

Attention. A repeated measures ANOVA of Digit Vigilance performance revealed no significant effects, as shown in Table 6.

Motor speed. A repeated measures MANOVA of the Finger Tapping test revealed no significant main effects or interaction effects, as shown in Table 6.

Mental efficiency. Results of a MANOVA of Trail Making and Digit Symbol indicated a significant time main effect, $F(3, 70) = 21.94$, $p < .001$, with participants in all three groups achieving improved performance but no interaction effect. Univariate tests indicated time effects for all three measures: Trail Making A, $F(1, 72) = 14.35$, $p < .001$; Trail Making B, $F(1, 72) = 10.51$, $p < .01$; and Digit Symbol, $F(1, 72) = 51.22$, $p < .001$.

Organized verbal processing. An ANOVA of Verbal Fluency performance indicated both a time main effect, $F(1, 70) = 9.05$, $p < .01$, and a Time × Group interaction, $F(2, 70) = 8.15$, $p < .001$. As shown in Table 6, participants in the EXESM condition improved significantly, but those in the control conditions did not change.

Illness Knowledge

A repeated measures ANOVA of COPD knowledge revealed a time main effect, $F(1, 70) = 49.2$, $p < .001$, as well as a Time × Group interaction, $F(2, 70) = 12.5$, $p < .001$. Planned contrasts were consistent with the hypothesized changes. Post hoc within-group comparisons across time indicated that both EXESM and ESM groups achieved significant increases in test scores (EXESM: 28.2 ± 5.5 to 31.9 ± 5.2, $p < .001$; ESM: 23.7 ± 7.4 to 29.2 ± 6.7, $p < .001$), but the WL group did not change (26.6 ± 7.3 to 27.8 ± 5.8, *ns*).

Evaluation of Mediating Variables

To evaluate the extent to which change in cardiopulmonary endurance ($\dot{V}O_2max$) was associated with change in cognitive function and psychological well-being in the EXESM group, a series of multiple regression analyses was performed. Regressions were conducted on each variable for which a significant interaction had been observed, including SCL-Depression, SCL-Anxiety, STAI-State Anxiety, SIP, and Verbal Fluency. For each analysis, the T2 score was first regressed on the T1 score, followed by a change score calculated for $\dot{V}O_2max$ (T2 − T1). Results indicated that change in $\dot{V}O_2max$ was not a significant predictor of any of the outcomes.

A similar set of regression analyses was then performed, regressing change on the COPD knowledge test on T2 indicators of psychological well-being, after first entering the T1 value for each indicator. Among the EXESM participants, COPD knowledge was not a significant predic-

Table 5
Means and Standard Deviations for Health Quality of Life at Times 1 and 2

Measure	EXESM (*n* = 25) Time 1	EXESM (*n* = 25) Time 2	ESM (*n* = 23) Time 1	ESM (*n* = 23) Time 2	WL (*n* = 25) Time 1	WL (*n* = 25) Time 2
MHLC-Internal						
M	25.5	24.5	22.6	21.9	23.5	24.1
SD	4.0	3.9	5.8	7.7	5.0	5.0
MHLC-Powerful Others						
M	21.1	19.2	20.8	19.3	22.1	21.1
SD	5.1	5.5	5.3	7.5	4.6	3.7
MHLC-Chance						
M	15.7	14.7	16.1	17.0	15.8	16.3
SD	5.2	4.8	6.8	7.2	5.1	5.1
Sickness Impact Profile						
M	11.1	5.8***	10.9	10.7	14.2	10.4***
SD	8.1	5.2	9.9	7.4	8.6	7.8

Note. Higher scores reflect stronger endorsement of MHLC attribution and greater impairment on the Sickness Impact Profile. EXESM = exercise, education, and stress management; ESM = education and stress management; WL = waiting list; MHLC = Multidimensional Health Locus of Control.
***$p < .001$. The *p* values indicate within-group comparisons across time.

Table 6
Means and Standard Deviations for Cognitive Measures at Times 1 and 2

	EXESM (n = 25)		ESM (n = 23)		WL (n = 25)	
Measure	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Digit Vigilance[a]						
M	196.0	198.6	223.3	220.3	192.6	195.0
SD	54.5	45.9	51.8	50.0	35.2	38.8
Finger Tapping						
Dominant hand						
M	41.8	43.3	38.7	39.8	41.5	42.1
SD	1.8	2.1	1.9	1.7	1.4	1.4
Nondominant hand						
M	37.3	37.4	35.1	35.4	36.9	37.7
SD	1.3	1.4	1.5	1.6	1.3	1.1
Trail Making A[a]						
M	40.5	33.5	46.6	40.5	38.6	34.5
SD	16.2	9.7	22.7	16.2	17.7	13.5
Trail Making B[a]						
M	152.4	102.6	175.5	149.3	131.4	111.0
SD	126.4	50.0	113.8	123.3	49.9	67.4
Digit Symbol						
M	46.0	51.0	38.4	41.9	43.8	48.2
SD	13.4	12.3	11.1	10.1	12.4	12.6
Verbal Fluency						
M	28.6	33.9***	27.8	27.6	29.4	29.8
SD	6.2	7.2	6.4	7.0	8.1	8.7

Note. Higher scores indicate better cognitive performance except on Digit Vigilance and Trail Making (A and B). EXESM = exercise, education, and stress management; ESM = education and stress management; WL = waiting list.
[a]Expressed in seconds.
***$p < .001$. The p value indicates within-group comparison across time.

tor of psychological well-being. However, when the regressions were repeated with the ESM participants, change in COPD knowledge was strongly associated with SCL-Anxiety ($\beta = .514$, partial $r^2 = .26$, $p < .02$), but in a negative direction, suggesting that greater COPD knowledge was associated with increased anxiety.

Interrelationship of Pulmonary Function and Cognitive Function

To explore the hypothesis that blood oxygenation would be associated with cognitive performance, Pearson correlations were conducted of PaO_2 with baseline values for each cognitive measure as well as change scores (T1 − T2) for each cognitive measure. The correlations were uniformly small and were not statistically significant. Correlations of FEV_1 with cognitive variables were also relatively small and nonsignificant.

Discussion

The data are consistent with previous studies demonstrating the beneficial effects of exercise rehabilitation for cardiopulmonary endurance among patients with COPD. Furthermore, changes in endurance occurred despite the absence of significant change in pulmonary function. Thus, although lung mechanics of COPD patients are stable and the condition is irreversible, EXESM participants achieved significant functional gains in the context of limited pulmonary capacity. The significant increase of approximately 16% in $\dot{V}O_2max$ among EXESM participants is consistent with other training studies among healthy older adults (Blumenthal et al., 1989) and indicates the effectiveness of the intervention for enhancing endurance levels. This increase is larger than the 9% increase in $\dot{V}O_2max$ reported recently by Ries et al. (1995), but it may reflect the somewhat longer (10 weeks vs. 8 weeks) and more intense (37 sessions vs. 12 sessions) nature of this intervention.

As hypothesized, EXESM participants experienced reductions in symptoms of distress, including reduced depression and anxiety. Although it was hypothesized that ESM participants also would experience decreased symptomatology as a result of increased social support and greater knowledge of disease processes, the data did not support the hypothesis. In fact, the regression analyses suggested that greater knowledge may have been associated with increased distress in the ESM group. This unexpected finding is consistent with results of one previous report of increased psychological distress associated with an educational intervention among COPD patients (Scherer, Janelli, & Schmieder, 1989). Thus, education alone may have limited value for physical and psychological functioning of patients with COPD. However, further study of education interventions among patients with COPD will help to clarify the extent to which such interventions may be useful.

EXESM participants also indicated reductions in illness-related physical and emotional impairment that were not observed among ESM participants, further supporting the value of the EXESM intervention over the ESM condition. Improvement in SIP scores among WL participants may, in part, reflect regression to the mean because the magnitude of T2 scores in this group was comparable to the T1 scores in the EXESM and ESM groups. Because the WL group also indicated reduced symptoms of depression, however, it is possible that awareness of being included in the research study contributed to positive expectations leading to reduced distress and enhanced quality of life.

Results from the cognitive testing indicated that there were no effects on tests of attention and motor speed and only practice effects on tests of mental efficiency. However, the significant interaction for the Verbal Fluency test suggests that EXESM was associated with greater efficiency of verbal processing. These data support the notion that exercise may have an effect on tasks assessing executive function (i.e., self-control and self-monitoring) associated with frontal lobe functioning.

EXESM was associated with changes not found in either of the control conditions, suggesting that exercise-related processes contributed to the observed changes. Possible mechanisms by which exercise might affect mood and cognitive processes are through changes in release and uptake of brain neurotransmitters and changes in sympathetic nervous system activity (Dustman et al., 1990; Spirduso, 1983). However, changes in cardiopulmonary fitness (VO_2max) per se were not significantly associated with either mood or cognitive performance, and blood oxygen level (PaO_2) was not associated with cognitive performance, as observed among more impaired COPD patients (Grant et al., 1987).

Adherence to the exercise program may have been limited by the nature of COPD, which is unpredictable and variable, often rendering patients severely debilitated. Given the obstacles posed by the illness, adherence rates were adequate, as is substantiated by the improvements in exercise endurance and in COPD knowledge. The EXESM intervention contributed to significant gains in function, but the longer-term effects of the intervention are unknown because the study involved a relatively brief 10-week follow-up. Improvements in cardiopulmonary endurance are likely to dissipate rapidly without continued exercise, and recent data from Ries et al. (1995) suggest that benefits of exercise among COPD patients are not likely to be maintained over a longer-term, one-year follow-up. Reliable models for predicting exercise adherence in this population are needed because adherence is likely to be complicated by numerous factors, including symptom perception, social support, and limitations in the patient's capacity to comprehend the intervention. Past work by Kaplan and colleagues (Kaplan, Atkins, & Reinsch, 1984) suggests that compliance with walking may be mediated by perceived self-efficacy. Results of our study indicate that exercise behavior may offer intrinsic rewards through reductions in symptoms of distress and physical impairment as well as increases in functional capacity. In addition, at the T1 assessment, participants in all groups had high internal health-related attributions of control (relative to attributions of control by powerful others or chance) that may have contributed to study adherence. It was striking that the 6 study dropouts had significantly lower scores on the Verbal Fluency task than did the 73 participants who completed the study, suggesting that aspects of cognitive function may be important to include in models of adherence among patients with COPD.

The results of this study diverge from past studies in which minimal psychological changes were observed among exercising COPD patients (e.g., Gayle et al., 1988; Lewis & Bell, 1995; Ries et al., 1995), possibly because the exercise intervention in this study was relatively intense. Further study is needed to evaluate optimal amounts of exercise for producing physiological, psychological, and cognitive benefits among patients with COPD, with particular attention to mechanisms underlying exercise-related psychological and cognitive change.

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