Cognitive and Psychological Outcomes of Exercise in a 1-Year Follow-Up Study of Patients With Chronic Obstructive Pulmonary Disease

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This study evaluated outcomes of self-directed exercise activity on cognitive functioning and psychological well-being among 28 adults with chronic obstructive pulmonary disease (COPD). Participants had completed an intensive 10-week program of exercise training and were given an exercise prescription to follow. One year later, participants completed comprehensive assessments of physical, cognitive, and psychological functioning. At follow-up, 39% (n = 11) had continued with a regular program of moderate intensity exercise. Repeated measures analysis of variance indicated that exercise adherent participants maintained gains they had achieved in the initial exercise intervention, but nonexercise participants experienced declines in functional capacity, cognitive performance, and psychological well-being. Continued exercise among patients with COPD is associated with maintenance of physical, cognitive, and psychological functioning.

Key words: exercise activity, COPD, cognitive functioning, psychological well-being

Chronic obstructive pulmonary disease (COPD) is the fourth leading cause of death in the United States and a primary cause of disability among older adults (American Lung Association, 2002). The course of COPD is marked by a progressive decrease in physical endurance, increased shortness of breath, and substantial impairments in quality of life (Cugell, 1988). Patients with COPD may experience difficulty conducting activities of daily living such as dressing, showering, and doing housework (McSweeny, Grant, Heaton, Adams, & Timms, 1982). In addition, social roles often are compromised as patients experience reduced ability to engage in social activity and increased dependence on spouse or other family members (McSweeny et al., 1982). Patients with COPD also may experience mood changes, especially depression and anxiety, as well as impaired cognitive or neuropsychological performance (Agle & Baum, 1977; Emery, Leatherman, Burker, & MacIntyre, 1991). Cognitive impairment is especially relevant, because it has been suggested that neuropsychological impairment may be related to chronic reductions in blood oxygenation levels among patients with COPD (Grant et al., 1987). A number of studies among patients with COPD have documented deficits in neuropsychological performance, including impairments in memory, abstract reasoning, and psychomotor speed (Incalzi et al., 1997; Frigatano, Parsons, Wright, Levin, & Hawryluk, 1983).

Intervention studies have demonstrated that treatment with oxygen is associated with enhanced cognitive performance among patients with COPD (Block, Castle, & Keitt, 1974; Heaton, Grant, McSweeny, Adams, & Petty, 1983). In addition, data have indicated that exercise performance is associated with cognitive performance among patients with COPD (Etier et al., 1999) and that increased exercise performance is associated with enhanced cognitive functioning in this population (Emery, Schein, Hauck, & MacIntyre, 1998). In the latter study, participants were randomized to either a program of exercise combined with education and stress management, a program of only education and stress management without exercise, or a waiting list control group. Participants in the exercise program achieved a significant 16% improvement in cardiovascular fitness, reductions in anxiety, and improvement in cognitive functioning as measured by a test of verbal fluency. None of these changes were observed among participants in either of the control groups, suggesting that the exercise intervention was associated with enhanced verbal processing. These results have

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been supported by more recent data indicating a positive effect of exercise on similar cognitive tasks reflecting executive function (e.g., purposive behavior, self-control, ability to shift attention) among healthy older adults (Kharti et al., 2001; Kramer et al., 1999).

One long-term study among patients with COPD found an association of change in physical fitness with change in cognitive performance over the course of an 18-month intervention (Enier & Berry, 2001). Following 3 months of training, participants were randomly assigned either to continue in structured exercise or to follow exercise recommendations on their own for the remaining 15 months of the study. Although the study included an impressive long-term follow-up period, there was no indication of the degree to which participants adhered to the prescribed behavior. Thus, the study does not provide evidence of the effects of exercise adherence on physical and cognitive outcomes, especially among those participants who were not provided a structured exercise program during the follow-up. The present study expands upon this recent work by including a measure of adherence in a 1-year follow-up examination of verbal processing and other cognitive indicators of executive functioning among patients with COPD who had completed a 10-week exercise intervention. The purpose of the study was to evaluate change in performance associated with exercise during the follow-up period. In particular, it was of interest to determine cognitive outcomes associated with exercise adherence because no formal exercise intervention was provided during the 1-year follow-up. This study was designed to evaluate outcomes in a naturalistic context, after participants had completed a formal exercise intervention. The study hypothesis was that exercise adherence during the 1-year follow-up period would be associated with improved exercise performance, enhanced cognitive performance, increased psychological well-being, and improved perceptions of health status. No significant change was expected in pulmonary function or in participant knowledge of COPD, as both of these outcomes are relatively stable and would not be influenced by exercise activity.

Method

Sample and Procedure

Participants were 28 patients with COPD (71% women; mean age = 66.7 ± 6.5 years), all of whom had completed a 10-week exercise intervention, described in Emery et al. (1998). Criteria for participants to enter the initial study were as follows: age was greater than 50 years, airflow obstruction was demonstrated on spirometry, and clinical symptoms of COPD were evident for more than 6 months. The subsample for this 1-year follow-up evaluation was selected at random from the initial sample because resources were available only for evaluating half of the participants in the original cohort. Participants (n = 37; 25 women, 12 men) were selected at random, but 9 (5 women, 4 men) could not be contacted by telephone or mail for follow-up, resulting in 28 participants being available for this study. Demographic characteristics of the 9 unavailable participants did not differ significantly from the 28 participants, as shown in Table 1.

Although participants in the intervention study had been assigned at random to three groups (exercise group or one of two control groups), participants originally assigned to the control groups were subsequently provided with the exercise intervention, because of its positive impact (Emery et al., 1998). Thus, all 28 participants in this follow-up study had completed the exercise intervention and were available for follow-up. The intervention consisted of one 5-week component of relatively intensive exercise followed by a second 5-week component of maintenance exercise. During the intensive component, participants attended daily sessions (5 days a week) for up to 4 hr per day. Each session included 45 min of aerobic exercise as well as approximately 20 min of strength training. Sessions began with a 10-min warm-up period followed by aerobic exercise activities (i.e., stationary bicycle, arm ergometry, walking), strength training (i.e., leg extension, leg press, lateral rise, overhead press, pec fly, and bench press machines), and ending with a 15-min cooldown period of stretching. The exercise sessions also included approximately 4 hr-long educational lectures per week on topics relevant for COPD patients (e.g.,

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercise adherent (n = 11)</th>
<th>Nonadherent (n = 17)</th>
<th>Nonparticipant (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>65.7 ± 7.3</td>
<td>67.3 ± 6.1</td>
<td>65.7 ± 6.6</td>
</tr>
<tr>
<td>Body mass index</td>
<td>27.3 ± 6.8</td>
<td>27.1 ± 6.9</td>
<td>25.7 ± 4.6</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>10</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Black</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Work status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retired</td>
<td>10</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Part- or full-time</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Annual family income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; $45,000</td>
<td>7</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>≥ $45,000</td>
<td>4</td>
<td>1</td>
<td>80*</td>
</tr>
</tbody>
</table>

* Contrast of exercise-adherent and nonadherent. $\chi^2(1, N = 28) = 4.23, p = .04$.

Total frequency in this group does not equal 9 because 4 participants were unable or unwilling to provide this information at baseline.
anatomy and physiology of the lungs, medications for chronic lung disease). Participants also were provided a weekly 1-hr group meeting for stress management and psychosocial support. The remaining time during each 4-hr block was used for rest periods between exercise activities. Following the initial intensive 5-week period, participants completed the 5-week maintenance program consisting of exercise sessions 3 times a week for 60–90 min and the 1-hr-long weekly stress management class. During the maintenance component, participants continued the same exercise routine, with a 10-min warm-up, approximately 45 min of aerobic exercise, 15–20 min of strength training, and a 15-min cool-down. At the conclusion of the exercise intervention period, participants were given an individualized home exercise program and were encouraged to continue exercising either on their own or at an exercise facility.

All participants were contacted 1 year after completing the exercise intervention. At the follow-up evaluation, participants completed a self-report measure of exercise activity, as well as a battery of assessments (pulmonary function, exercise endurance, cognitive functioning, and psychological well-being) that was a subset of the measures completed before and after the exercise intervention. In addition, participants completed a life events scale and health care questionnaire at follow-up.

**Measures**

**Exercise activity.** Exercise activity was self-reported in a format based on the Minnesota Leisure Time Physical Activity (LTPA) assessment (Taylor et al., 1978). Respondents reported retrospective accounts of each exercise activity engaged in during the prior 12 months. For each activity reported, respondents indicated the number of times per month that they engaged in the activity and the amount of time spent in each exercise session. Scoring of the LTPA requires assigning metabolic equivalent (MET) scores to each reported exercise activity (Ainsworth et al., 1993) and calculating a summary energy expenditure score for each participant. Conservative MET values were used in calculating this summary score to adequately reflect physical limitations among patients with COPD. The LTPA was developed for use in longitudinal studies of the relationship between physical activity and disease and has been shown to be a valid indicator of physical activity (Richardson, Leon, Jacobs, Ainsworth, & Serfass, 1994) with good test–retest reliability in middle aged and older adults (B6; Folsom, Jacobs, Caspersen, Gonzalez-Marin, & Knudson, 1986).

Because participants had maintained exercise logs throughout the structured component of the study, they were familiar with this type of record form and reported no difficulty with completing the records.

**Pulmonary function.** Pulmonary function was assessed with standard pulmonary function equipment to perform spirometry consistent with American Thoracic Society (1995) standards. Measurements derived from the spirometry assessment included forced expiratory volume in 1 (FEV₁) and forced vital capacity (FVC). The FEV₁/FVC ratio provides a marker of progression of lung disease and is used commonly in the diagnosis of COPD.

**Exercise endurance.** Cardiopulmonary endurance was assessed with the participant sitting upright on an isokinetic, magnetically braked, bicycle ergometer (Quinton Corval 400, Bothell, WA). Exercise began at 0 Watts and the load was increased 12.5 Watts 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 was analyzed over 20-s intervals (SensorMedics 2900, Yorba Linda, CA) to calculate oxygen consumption (VO₂). This procedure was identical to that used in prior studies from this laboratory (Emery et al., 1991, 1998) and is consistent with clinical standards for exercise testing among patients with COPD (American College of Sports Medicine, 1991). All exercise assessments were supervised by a physician.

**Cognitive assessment.** On the basis of prior results indicating that cognitive indicators of executive function, such as verbal processing, have been most responsive to exercise interventions in this population (Emery, Honi, Diaz, Lebowitz, & Frid, 2001; Emery et al., 1998; Elsnier & Berry, 2001), the cognitive test battery evaluated several domains of executive functioning including psychomotor functions and verbal processing. Three measures of executive functioning were used. First, the Verbal Fluency test was included as an indicator of the participant's capacity for organized verbal processing. This test is thought to be sensitive to frontal lobe impairment (Estes, 1974) and has excellent test–retest reliability (88; Spreen & Strauss, 1991). Participants were given 1 min to name as many words as possible starting with a specified letter. Second, the Digit Symbol subscale from the Wechsler Adult Intelligence Scale—Revised (WAIS–R) has high test–retest reliability (88; Wechsler, 1981) and was included as a measure reflecting psychomotor speed, sequencing ability, and implicit memory functions. Third, the Trail Making Test (Parts A and B) was included to evaluate the ability to shift mental sets and sequence information (Reitan, 1958). Test–retest reliability coefficients range from .70 to .90 (Spreen & Strauss, 1991).

**Assessment of psychological well-being and perceived health status.** Psychological well-being was assessed with self-report scales measuring the domains of depression and anxiety. Because symptoms of depression and anxiety are common among patients with COPD and were responsive to exercise in the intervention component of the study, the Depression and Anxiety subscales from the Symptom Checklist—Revised (SCL–90–R) were evaluated. The SCL–90–R is a 90-item scale of psychiatric and somatic symptoms providing nine clinical subscales and a summary score (Derogatis, 1983), with t scores derived on the basis of adult outpatient norms. Internal consistency and test–retest reliability estimates range from .77 to .90 (Lezak, 1995).

Perceived health status was assessed with the Sickness Impact Profile (SIP), a 136-item checklist of symptoms and physical limitations in activities of daily living (e.g., sleep, mobility, household management, social interaction, and recreation) with excellent internal consistency (.94) and test–retest reliability (87; Bergner, Bobbitt, Carter, & Gilson, 1981). The SIP has been validated in multiple studies of medical patients, and research has demonstrated greater impairment on the SIP among COPD patients than among healthy adults (McSweeney et al., 1982). This study evaluated the summary score from the SIP (the number of symptoms reported divided by the total symptoms listed).

**COPD knowledge.** Participants completed a COPD (pulmonary rehabilitation) knowledge test with good reliability and validity (Hopp, Lee, & Hills, 1989). The knowledge test was included to evaluate retention of information that had been taught during the earlier intervention.

**Life events and medical care.** Participants completed a 28-item scale of life events (e.g., moving, death of spouse, personal injury or illness, death of a close friend) adapted from a standard life events inventory (Holmes & Rabe, 1967). Participants were provided with a list of life events and marked those that had occurred during the prior year. In addition, participants completed two questions indicating the number of doctor visits and hospital admissions they had required during the intervening year.

**Exercise Adherence Groups**

Exercise adherence during the 1-year follow-up period was quite variable. Although most participants (82%) reported engaging in at least some exercise activity during the intervening year, 18% (n = 5) reported no exercise activity during the follow-up period and another 43% (n = 12) did not maintain an exercise program consistent with the training they had received (i.e., participants either exercised for less than 12 months or exercised at a lower intensity level). Participants who maintained an exercise regimen consistent with the training they had received would have been engaged in exercise activity requiring energy expenditure of ≥23 METs per week (or ≥1,200 METs per year). Thus, this cutoff level was used to identify participants who maintained the prescribed exercise routine. Because this minimal level of exercise compliance was deemed to be critical to maintain improvements in health and well-being, data were analyzed to evaluate differences in functioning at 1-year follow-up be-
between the exercise adherent group (EXAD) and the exercise nonadherent group (NONEX). At 1-year follow-up, 39% (n = 11) of the sample had maintained the prescribed exercise regimen, whereas the remaining 61% had not.

Data Analysis

Data were analyzed using the SAS (V8.02) statistical program for Windows (general linear model procedure). Repeated measures analysis of variance (ANOVA) was used to evaluate change in performance over time on the primary outcome measures. Exercise adherence group (EXAD vs. NONEX) served as a between-subjects variable and time (pretest = pre-follow-up vs. posttest = post-follow-up) was a within-subjects variable. Effect sizes for all hypothesized interactions are reported as partial eta squared ($\eta^2_p$). In the presence of a significant Time × Group interaction, repeated measures ANOVA was used to evaluate change over time within groups. In addition, when the ANOVA indicated significant change on cognitive measures, regression analysis was used to evaluate exercise performance (VO$_{2\text{peak}}$) and psychological well-being (SCL—Depression, SCL—Anxiety) as predictors of cognitive change. Life events and medical care data were analyzed with ANOVA and chi-square analyses. Because of random missing data for some outcomes, there was variability in sample size available across analyses. For example, VO$_{2\text{peak}}$ data were not available for several participants who were using supplemental oxygen. However, missing values for this outcome and for other outcomes were approximately evenly distributed across both the EXAD and NONEX groups.

Results

As shown in Table 1, the EXAD and NONEX groups were similar with regard to demographic characteristics, although the EXAD group reported a higher income level. As evident in Table 2, the groups did not differ in pulmonary function or cognitive function at pretest. However, as expected, the EXAD group reported significantly greater levels of exercise activity at posttest than did the NONEX group (1.575 ± 272 vs. 460 ± 401), F(1, 26) = 65.2, p < .01.

Pulmonary Function and Functional Capacity

Consistent with experimental hypotheses, repeated measures ANOVA revealed no significant changes over time in FEV$_1$ or in the FEV$_1$/FVC ratio. However, the ANOVA of oxygen consumption (VO$_{2\text{peak}}$) revealed a significant Time × Group interaction, F(1, 18) = 6.06, p = .02, $\eta^2_p = .25$, with oxygen consumption remaining stable in the EXAD group, F(1, 7) = 1.87, p = .21, $\eta^2 = .20$, but declining significantly among those in the NONEX group, F(1, 11) = 5.45, p = .04, $\eta^2 = .33$, as shown in Table 2.

Cognitive Functioning

Repeated measures ANOVA of Verbal Fluency scores indicated no significant interaction ($\eta^2_p = .03$). However, the ANOVA for Digit Symbol scores revealed a significant Time × Group interaction, F(1, 23) = 5.02, p = .04, $\eta^2_p = .18$, with scores in the NONEX group decreasing significantly, F(1, 13) = 29.5, p < .01, $\eta^2 = .69$, whereas scores of the EXAD group did not change, F(1, 11) = 2.12, p = .18, $\eta^2 = .17$, as shown in Table 2. ANOVA of Trail Making A and Trail Making B indicated no significant interactions ($\eta^2_p = .06$ and $\eta^2_p = .01$, respectively).

Psychological Well-Being and Perceived Health Status

Repeated measures ANOVA revealed a significant Time × Group interaction for SCL—Depression, F(1, 26) = 4.06, p = .05, $\eta^2 = .13$. The NONEX group experienced increased symptoms of depression, F(1, 16) = 13.51, p < .01, $\eta^2 = .46$, whereas the EXAD group did not change, F(1, 10) = 0.04, p = .85, $\eta^2 = .01$, as shown in Table 2. Similarly, there was a significant Time ×

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**Table 2**

**Pulmonary Function, Physical Endurance, Cognitive Function, and Psychological Well-Being Among Exercise Adherents and Nonadherents**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exerciser adherent (n = 11)</th>
<th>Nonadherer (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>FEV$_1$</td>
<td>1.07</td>
<td>±0.45</td>
</tr>
<tr>
<td>FEV$_1$/FVC</td>
<td>0.47</td>
<td>±0.17</td>
</tr>
<tr>
<td>VO$_{2\text{peak}}$ (ml/kg/min)</td>
<td>14.64</td>
<td>±3.92</td>
</tr>
<tr>
<td>Verbal Fluency</td>
<td>32.27</td>
<td>±6.48</td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>50.73</td>
<td>±12.08</td>
</tr>
<tr>
<td>Trail Making Test A (s)</td>
<td>33.12</td>
<td>±7.60</td>
</tr>
<tr>
<td>Trail Making Test B (s)</td>
<td>91.36</td>
<td>±31.40</td>
</tr>
<tr>
<td>SCL—Depression</td>
<td>56.00</td>
<td>±6.53</td>
</tr>
<tr>
<td>SCL—Anxiety</td>
<td>53.82</td>
<td>±7.99</td>
</tr>
<tr>
<td>SIP—Total</td>
<td>9.02</td>
<td>±8.16</td>
</tr>
<tr>
<td>COPD knowledge</td>
<td>33.13</td>
<td>±4.67</td>
</tr>
</tbody>
</table>

Note. Higher scores reflect better functioning on all measures except Trail Making Test, SCL—Depression, SCL—Anxiety, and SIP. All p values reflect within-group comparisons across time. FEV$_1$ = forced expiratory volume in 1 s; FVC = forced vital capacity; VO$_{2\text{peak}}$ = peak oxygen consumption; SCL = Hopkins Symptom Checklist; SIP = Sickness Impact Profile; COPD = chronic obstructive pulmonary disease.

*p < .05. **p < .01.
Group interaction for SCL—Anxiety, $F(1, 26) = 5.74, p = .02, \eta^2 = .18$. Tests of simple effects indicated no change in the EXAD group, $F(1, 10) = 0.27, p = .61, \eta^2 = .03$, and a significant increase in anxiety in the NONEX group, $F(1, 16) = 10.1, p = .01, \eta^2 = .39$, as shown in Table 2.

Repeated measures ANOVA of SIP total scores revealed no statistically significant interaction, although the effect size ($\eta^2 = .16$) was similar to that for Digit Symbol and SCL—Anxiety scores. Mean scores are included in Table 2.

**COPD Knowledge, Life Events, and Medical Care**

As expected, repeated measures ANOVA of the COPD knowledge test indicated no significant interaction for COPD knowledge ($\eta^2 = .00$), as shown in Table 2. ANOVA of the life events summary scores indicated no significant differences between groups during the 1-year period. Mean scores indicated an average of approximately 3–4 major life events for both groups (EXAD, 3.5 events; NONEX, 4.1 events). ANOVA of doctor visits indicated no significant differences between groups during the follow-up period $\text{EXAD} = 6.2 (\pm 3.8) \text{ visits}, \text{NONEX} = 7.4 (\pm 6.5) \text{ visits}$. Mean number of days hospitalized was low for both groups, $\text{EXAD} = .27 (\pm .47) \text{ days}, \text{NONEX} = .59 (\pm .80) \text{ days}$. Although a larger proportion of the NONEX participants had been hospitalized during the follow-up period (47% of NONEX vs. 27% of EXAD participants), this difference was not statistically significant, $\chi^2(1, N = 28) = 1.10, p = .30$.

**Regression Analyses**

Change scores were calculated for the hypothesized mediator variables (VO_{2peak}, SCL—Depression, SCL—Anxiety) and multiple regression was used to evaluate the influence of change in VO_{2peak}, depression, and anxiety on cognitive function. Because of the small sample size, three regression analyses were conducted, each predicting posttest scores on the Digit Symbol test. Predictors for each regression included the pretest score on the Digit Symbol test in addition to one of the three change scores.

Results indicated that change in VO_{2peak} and SCL—Depression was not associated with change in cognitive performance. However, there was a positive relationship between increased anxiety and worse cognitive performance ($\beta = 0.151, \Delta R^2 = .02, p = .05$).

**Discussion**

Results of this study indicate that patients with COPD who adhered to a program of regular exercise over a 1-year follow-up period maintained gains that they had achieved during a 10-week exercise intervention. However, those who did not maintain a regular exercise routine experienced decreases in physical performance, cognitive performance, and emotional well-being. Thus, the data confirm that continued participation in regular exercise may be associated with not only physical functioning but also cognitive and psychological effects. Although decreases in physical fitness would be expected following termination of an exercise program, this is the first study to document decreases in both cognitive performance and psychological well-being associated with exercise nonadherence among patients with COPD.

It was somewhat surprising that continued exercise did not lead to further gains in physical endurance and cognitive functioning. Instead, exercise was associated with maintenance of gains already achieved. It is possible that further gains would have been achieved if participants had continued in a supervised program of exercise or if the home exercise program was closely monitored, with graduated increases in intensity and duration. Indeed, Etnier and Berry (2001) found significant increases in 6-min walk distance after a 15-month follow-up. It is also possible that the exercise testing underestimated exercise capacity in this sample because not all participants continued to exercise on a stationary bicycle during the follow-up period. However, it appears that participants had reached a plateau following the initial exercise training and that significant further gains in functioning would occur only with a marked increase in the exercise stimulus. Thus, continued exercise was associated with maintenance of exercise capacity. Conversely, one of the most important practical conclusions from these results is that lack of regular exercise was associated with decreases in performance.

Initially, it was surprising that verbal fluency was not influenced by exercise activity, given data from prior intervention studies (Emery et al., 1998, 2001). However, the overall results of this study suggest that exercise maintenance may have been associated with prevention of decline rather than enhanced performance. Prior studies have documented consistent impairments in Digit Symbol performance among patients with COPD (Grant et al., 1987; Prigatano et al., 1983). These data suggest that exercise during the 1-year follow-up was associated with maintaining aspects of cognitive function that might otherwise decline, but exercise was not associated with enhancement of cognitive performance.

Although there is substantial documentation of the importance of continued exercise for maintenance of physical performance (e.g., Convertino, Bloomfield, & Greenleaf, 1997), there are few data addressing the mechanism by which cessation of exercise may lead to changes in cognitive functioning and psychological well-being. Clearly, factors that may have contributed to enhanced cognitive and psychological functioning during exercise training were no longer present following exercise cessation. Results of this study support the notion that physical exercise may be associated with maintenance of cognitive performance. However, regression analysis did not point to a mechanism explaining the decline in cognitive performance. Changes in cardiopulmonary endurance and depression were not associated with the decline in cognitive performance. Only anxiety was associated with the decline in cognitive performance, but anxiety accounted for a negligible amount of variance in cognitive change. Given that symptoms of anxiety often are associated with excitation of the nervous system, and that exercise-related changes in nervous system activity may contribute to maintenance of cognitive performance (Dustman et al., 1990; Emery et al., 2001), the relationship of anxiety and cognitive performance during exercise may be a fruitful area for further investigation.

Results of this study must be interpreted with caution because multiple comparisons were made for measures of cognitive functioning and psychological well-being. These data also are limited by the fact that 9 potential participants could not be reached and because participants were self-selected into groups, resulting in data that are essentially correlational. An optimal research design to test these effects would compare structured, supervised exercise.
with nonexercise activity. The study by Etter and Berry (2001) provides additional evidence of the importance of exercise for cognitive performance, but it did not document nonstructured exercise activity among patients with COPD.

Demographic variables also posed potential problems for this study. Women were relatively overrepresented in the sample. Although incidence of COPD among women has increased over the past decade and prevalence of chronic bronchitis is now greater among women than men (American Lung Association, 2002), the prevalence of emphysema and the death rate from COPD are still greater among men. However, prior data from our laboratory indicate no gender differences in psychological or cognitive changes associated with exercise among patients with COPD (Emery et al., 1991). Thus, although there is underrepresentation of men in this sample, there is no reason to believe that outcomes were biased by the sample composition. In addition, it is important to note that the EXAD group had a higher income level than the NONEX group, which may have contributed to observed group differences in health behavior and psychological well-being.

This study also was limited by the use of self-report measures of medical care and exercise activity, the presence of missing data, and by the small sample size. Although self-reported exercise activity could have been influenced by a number of factors, including cognitive functioning, the data were corroborated by results of the exercise testing that, in this case, supported the validity of the exercise reports. The small sample limited statistical power of the data analyses and may have contributed to the nonsignificant trends for several outcomes.

The study design ensured that all participants received an intensive exercise intervention prior to the follow-up period. One advantage of this strategy is that ecological validity of the study was increased. The two self-selected groups were statistically equivalent on most indicators prior to the 1-year follow-up, as reflected in the pretest assessment data. These results demonstrate the unfortunate reality that patients with COPD who complete an intensive exercise intervention may not be able to sustain a consistent level of exercise activity for an additional year without a structured program. However, the 39% adherence rate in this sample may have been reasonable given that among healthy adults it is common to find a 50% exercise nonadherence rate within 6 months of initiating exercise (Dishman, 1982).

Although it was hypothesized that exercise adherence would be associated with further increases in physical, cognitive, and psychological functioning, the data indicate that exercise was associated with maintenance of function rather than enhancement. Nonadherence was associated with declines in function. Thus, the results confirm the hypothesis that exercise is associated with all three aspects of functioning, but the data provide stronger evidence for exercise deconditioning than for exercise conditioning. From a practical perspective, these data provide support for the importance of long-term exercise adherence among patients with COPD for maintenance of physical, cognitive, and psychological functioning.

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