**Long-term effects of outpatient rehabilitation of COPD: A randomized trial**
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# Long-term Effects of Outpatient Rehabilitation of COPD*

## A Randomized Trial

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*Objective:* To examine the short- and long-term effects of an outpatient pulmonary rehabilitation program for COPD patients on dyspnea, exercise, health-related quality of life, and hospitalization rate.

*Setting:* Secondary-care respiratory clinic in Barcelona.

*Methods:* We conducted a randomized controlled trial with blinding of outcome assessment and follow-up at 3, 6, 9, 12, 18, and 24 months. Sixty patients with moderate to severe COPD (age $65 \pm 7$ years; $FEV_1$ $35 \pm 14\%$) were recruited. Thirty patients randomized to rehabilitation received 3 months of outpatient breathing retraining and chest physiotherapy, 3 months of daily supervised exercise, and 6 months of weekly supervised breathing exercises. Thirty patients randomized to the control group received standard care.

*Results:* We found significant differences between groups in perception of dyspnea ($p < 0.0001$), in 6-min walking test distance ($p < 0.0001$), and in day-to-day dyspnea, fatigue, and emotional function measured by the Chronic Respiratory Questionnaire ($p < 0.01$). The improvements were evident at the third month and continued with somewhat diminished magnitude in the second year of follow-up. The PR group experienced a significant ($p < 0.0001$) reduction in exacerbations, but not the number of hospitalizations. The number of patients needed to treat to achieve significant benefit in health-related quality of life for a 2-year period was approximately three.

*Conclusion:* Outpatient rehabilitation programs can achieve worthwhile benefits that persist for a period of 2 years. *(CHEST 2000; 117:976–983)*

**Key words:** COPD; health-related quality of life; pulmonary rehabilitation

**Abbreviations:** CRQ = Chronic Respiratory Questionnaire; HRQL = health-related quality of life; MRC = Medical Research Council; PR = pulmonary rehabilitation; RV = residual volume; Wmax = maximal work load in progressive effort test; 6WT = 6-min walking test

C OPD gradually impairs a patient's overall physical ability and reduces health-related quality of life (HRQL). Its prevalence is high, and the economic impact is great. Pulmonary rehabilitation (PR) has proved to be effective in improving exercise capacity and HRQL in COPD patients.[1-3] Recent guidelines for treating COPD issued by European and American pulmonary societies reflect these re-

sults.[4,5] PR is costly,[6,7] however, and its benefits have been reported to be of short duration.[1] As a result, controversy regarding PR continues, as investigators

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explore more economical and equally effective alternatives to conventional PR protocols, particularly home programs.[8,9] Another controversy in PR surrounds the relative contribution of exercise and other components of rehabilitation.[10] As part of an effort to develop a PR protocol with cost-effective, enduring benefit, we hypothesized that some of the benefit obtained by COPD patients through PR can be achieved using simple techniques and that enduring benefits can result if maintenance strategies are applied. The aim of this study was therefore to examine the short- and long-term effects on lung

function variables at rest and during exercise, HRQL, exacerbations, hospitalization rate, and long-term oxygen-therapy prescriptions in COPD patients participating in our outpatient PR program. We performed a controlled, randomized trial in which exercise was added only after the first 3 months, and in which we followed patients for 2 years.

## MATERIALS AND METHODS

### Patients

We enrolled 60 COPD patients[5] from among those presenting to our hospital's outpatient clinic. Participants were age ≤ 75 years and had an $FEV_1 < 70\%$ of reference values, $FEV_1/FVC < 65\%$, and $PaO_2 > 55$ mm Hg at rest with no indication for prescribing home oxygen therapy. None had experienced an exacerbation or been hospitalized in the previous month; all were free of clinically apparent heart disease or relevant bone or joint disease. We enrolled consecutive eligible patients interested in participating in our program. Of 65 patients approached, five who declined to participate in the study because of lack of interest were excluded and not randomized. The hospital ethics committee approved the study, and all patients gave informed consent.

### Study Design

This prospective randomized trial included serial follow-up. Randomization was not concealed, but the likelihood of bias introduced by unconcealed randomization was reduced by re-cruitment of consecutive patients. Conventional medical treatment for patients in both groups, including salbutamol, ipratro-pium bromide, and inhaled budesonide, at usual doses, was established before the first visit and maintained unchanged throughout the study. In response to an exacerbation, we added antibiotics (β-lactam or macrolide agents) if a respiratory infection was the cause and oral steroids (prednisone) if dyspnea increased. After an exacerbation, patients returned to their previous treatment. The PR group, in addition to the drug regimen, followed a 6-month intensive rehabilitation program followed by a 6-month maintenance program. Patients in both groups were examined and interviewed for study follow-up at baseline and 3, 6, 9, 12, 18, and 24 months later. The same physician (R.G.) saw the patients at each follow-up visit and encouraged them to contact her at any time if a medical problem arose. The technicians who collected data for outcome measures at every visit, as explained below, were blinded to a patient's allocation to PR or control groups.

### PR Program

Table 1 summarizes the different parts of the PR program followed throughout the study.

During the first 3 months of PR, patients participated in two 30-min sessions each week (breathing retraining). Each session included breathing retraining with relaxation techniques, di-rected breathing retraining (self-conscious breathing control, diaphragmatic breathing control, chest wall exercises, and ab-dominal muscle wall work).[11] We asked patients to practice a low-level home exercise program, which involved going up and down stairs and walking on flat surfaces. If indicated, patients also received chest physiotherapy, which involved teaching effective cough and postural drainage. PR patients also attended educa-

#### Table 1—Treatments Followed by the PR Group

| Components | Baseline | Months 1 to 3 | Months 4 to 6 | Months 7 to 12 | Months 13 to 24 |
|---|---|---|---|---|---|
| Standard care | X | X | X | X | X |
| Breathing retraining | | X | | | |
| Exercise training | | | X | | |
| Maintenance | | | | X | |
| Follow-up | | | | | X |

tional sessions on the anatomy and basic physiology of the respira-tory system as well as on the nature of their disease and of PR.

In the second 3-month period (exercise training), PR patients engaged in an exercise training program of five 30-min sessions weekly on a stationary cycle ergometer, without supplemental oxygen. Exercise started with a workload equivalent to 50% of the maximal load (Wmax) achieved during the baseline progressive exercise test. The load increased in increments of 10 W provided the patient's heart rate, arterial oxygen saturation, and BP were stable and exercise was well tolerated. During this period, patients also began a program of home exercise with either 30 min of pedaling on a stationary cycle or 1 h of walking.

During the subsequent 6 months, patients attended, in groups of six, a single weekly session during which they performed exercises for breathing and arm-leg coordination in sitting posi-tion (maintenance). The patients did not participate in controlled exercise training during this period, nor did they have exercise intensity targets. Subsequently, we instructed patients to con-tinue doing their exercises at home without supervision, and they were followed for 1 year (follow-up).

### Outcome Measures

Lung function testing included spirometry (FVC, $FEV_1$, $FEV_1/FVC$) and assessment of maximum voluntary ventilation mea-sured with a Datospir 91 spirometer (SibelMed; Barcelona, Spain).[12] Lung volumes (functional residual capacity, residual volume [RV], total lung capacity) were determined by the dilution technique, and lung diffusing capacity by the single-breath method (PFL 2450; Sensor-Medics; Yorba Linda, CA).[13] We measured arterial blood gases at rest (pH, $PaO_2$, $PaCO_2$) using an ABL 500 device (Radiometer; Copenhagen, Denmark), and maximum respiratory pressures using a Manometer 163 (SibelMed).

All the patients performed two exercise tests. One was the 6-min walking test (6WT),[14] conducted along a flat hospital corridor (25 m). Each patient was instructed and received standardized encouragement to walk from one end to the other, covering as much ground as possible during the allotted time.[15] The second test was a progressive exercise test limited by symptoms[16] on a cycle ergometer (Collins/CPX; Braintree, MA), with breath-by-breath monitoring of oxygen and carbon dioxide output, breathing frequency, and tidal volume. Simultaneously, heart rate and arterial oxygen saturation were also measured. The patient was seated on the saddle, and adjustments were made to ensure a comfortable cycling position. The patient was then instructed to pedal without any added load to obtain the target pedaling frequency and to become accustomed to breathing through a mouthpiece. Then, the progressive loading began. The technician encouraged and coached the patient. Patients assessed their breathlessness during the tests using a modified Borg scale.

Patients rated their dyspnea in daily activities using a 10-cm visual analog scale[17] bounded by the descriptors "no shortness of breath at all" and "maximum shortness of breath," and using the

Medical Research Council (MRC) scale modified by Cotes[18] which specifies eight levels of dyspnea. To assess HRQL, we administered the Chronic Respiratory Questionnaire (CRQ), translated and validated for use in Spanish.[19] The questionnaire includes 20 items in four domains: dyspnea (five items), fatigue (four items), emotional function (seven items), and mastery (four items), each item being graded on a seven-point scale.

We defined exacerbations as episodes of either increased dyspnea, or dry or productive cough, whether sputum was purulent or not. Patients were admitted to the hospital when exacerbations included marked increases in airflow obstruction and severe hypoxemia or hypercapnia. We used standard criteria to determine the need for long-term domiciliary oxygen.[20]

*Statistical Analysis*

Data are presented as means ± SD and ranges. Mann-Whitney tests were used to compare patients who withdrew with those who continued, and to compare the patients who withdrew from the PR group with those who left the control group. A repeated measures analysis of variance using baseline score as a covariate was used to examine the effects of time, treatment, and the interaction between the two. We excluded patients with missing data from this analysis. We calculated mean differences between groups in change from baseline to the 24-month follow-up and in change from baseline to the final follow-up available (whether 6, 9, 12, or 24 months) in all patients and calculated confidence intervals around those differences.

We examined the minimal important difference, defined as the smallest change in the CRQ score that is perceived by the average patient. Considerable data suggests that the minimal important difference value for CRQ is approximately 0.5 per domain.[21–23] Differences between patient CRQ scores at baseline and at the end of the study (24 months) were used for this analysis and to calculate the number needed to treat.[24] Using recently established methodology,[25] for each domain we calculated the proportion of rehabilitation and control patients who had score changes of > 0.5 (improved), between −0.5 and 0.5 (unchanged) and more negative than −0.5 (deteriorated). We

constructed a three-by-three table (the rows being the patients in the rehabilitation group who improved, remained the same, or deteriorated, and the columns being the control patients who improved, remained the same, or deteriorated) and estimated the individual cell values by multiplying the row and column proportions. We used these values to calculate the proportion of patients who received benefit from the treatment. The number needed to treat was taken to be the reciprocal of that proportion.

An unpaired $t$ test was used to compare the number of exacerbations and hospitalizations in the two groups, and a $\chi^2$ test, to compare the number of patients experiencing exacerbations or requiring hospitalizations. We interpreted p values of < 0.05 as statistically significant.

RESULTS

*Patient Demographics, Enrollment, and Compliance*

We randomly assigned 30 patients to the control group and 30 to rehabilitation. All 60 patients were men whose mean age was 65 ± 7 years (range, 46 to 74 years) and mean lung function values were FVC, 63 ± 15% of reference value (33 to 94%); $FEV_1$, 35 ± 14% of reference value (15 to 68%); $FEV_1/FVC$, 40 ± 11% (23 to 64%); RV, 179 ± 45% of reference value (87 to 278%); total lung capacity, 112 ± 20% of reference value (82 to 190%); $PaO_2$, 70 ± 9 mm Hg (56 to 89 mm Hg); and $PaCO_2$, 44 ± 5 mm Hg (34 to 54 mm Hg). Table 2 shows the baseline characteristics of all patients in both groups. All patients experienced moderate degrees of dyspnea as indicated by visual analog and MRC scales and CRQ dyspnea scores.

All 60 patients completed 6 months of follow-up. Seven control group and six treatment group patients

Table 2—*Age, Pulmonary Function, and HRQL Data for All Recruited Patients at Baseline**

| Status | Control Group | | | PR Group | | |
| --- | --- | --- | --- | --- | --- | --- |
| | Completed | Withdrawn | All | Completed | Withdrawn | All |
| No. | 23 | 7 | 30 | 24 | 6 | 30 |
| Age, yr | 65 ± 6 | 68 ± 4 | 66 ± 6 | 63 ± 8 | 66 ± 7 | 64 ± 7 |
| FVC, % pred | 66 ± 15 | 58 ± 12 | 64 ± 15 | 63 ± 14 | 58 ± 18 | 62 ± 15 |
| $FEV_1$, % pred | 41 ± 15† | 30 ± 5† | 39 ± 14 | 32 ± 12 | 27 ± 13 | 31 ± 12 |
| RV, % pred | 156 ± 44† | 207 ± 27† | 168 ± 46 | 195 ± 40 | 175 ± 51 | 191 ± 42 |
| TLC, % pred | 67 ± 20 | 118 ± 15 | 108 ± 18 | 83 ± 23 | 105 ± 16 | 117 ± 21 |
| $PaO_2$, mm Hg | 70 ± 8 | 71 ± 9 | 71 ± 9 | 73 ± 8 | 71 ± 9 | 72 ± 9 |
| $PaCO_2$, mm Hg | 42 ± 6 | 44 ± 5 | 43 ± 5 | 45 ± 5 | 43 ± 6 | 44 ± 5 |
| Walking test, m | 296 ± 56 | 336 ± 38‡ | 305 ± 59 | 315 ± 61 | 278 ± 48 | 308 ± 59 |
| Wmax, Kpm | 465 ± 164 | 471 ± 180 | 467 ± 185 | 558 ± 193 | 417 ± 117 | 530 ± 185 |
| Dyspnea VAS | 5.7 ± 1.6 | 5.8 ± 1.8 | 5.7 ± 1.7 | 5.6 ± 2.1 | 6.1 ± 2.9 | 5.7 ± 2.2 |
| Dyspnea MRC | 3.9 ± 0.8 | 4.1 ± 1.1 | 3.9 ± 0.9 | 3.6 ± 1.1 | 4.8 ± 1.5† | 3.8 ± 1.2 |
| CRQ dyspnea | 3.3 ± 1.0 | 2.9 ± 1.0 | 3.2 ± 1.0 | 3.1 ± 1.0 | 2.8 ± 0.6 | 3.1 ± 1.0 |
| CRQ fatigue | 4.8 ± 1.3 | 3.7 ± 1.6 | 4.5 ± 1.4 | 4.4 ± 1.1 | 4.5 ± 0.6 | 4.4 ± 1.0 |
| CRQ emotional | 5.3 ± 1.2 | 4.5 ± 1.1 | 5.1 ± 1.4 | 4.4 ± 1.2 | 4.8 ± 1.4 | 4.5 ± 1.3 |
| CRQ mastery | 5.4 ± 1.2 | 4.6 ± 1.7 | 5.2 ± 1.4 | 5.1 ± 1.5 | 4.2 ± 1.9 | 4.9 ± 1.6 |

*VAS = visual analog scale; TLC = total lung capacity.
†Significant difference (p < 0.05) between patients who completed treatment and patients who withdrew.
‡Significant difference (p < 0.05) between patients who completed treatment and patients who withdrew in both arms.

withdrew during the course of the rest of the study. In the period between the 6- and 9-month visits, three patients in the control group and one patient in the PR group withdrew from the program. One of the three control group patients died of bronchial carcinoma. The other two withdrew for personal or work-related reasons that made visits to our hospital difficult. The PR group patient who withdrew did so after deciding to follow alternative therapy. In the period from month 9 to month 12, two control group patients and one PR group patient withdrew. One control patient died of respiratory failure and the other experienced family problems. The PR group patient died of pneumothorax leading to irreversible respiratory failure. During the follow-up period from 12 to 24 months, two control group patients and four PR group patients withdrew. One control patient refused to continue performing tests and the other died of respiratory failure 1 month before the study ended. The four PR patients who withdrew at this late stage of the study died of mycosis fungoides infection, renal cancer, multiple infection (*Strongyloides stercoralis* plus *Pseudomonas aeruginosa*), and bronchial carcinoma.

Baseline characteristics of the patients who withdrew during the study (Table 2) were similar to those who continued, and dropouts from the two groups were generally similar. Those who withdrew in the control group had lower $FEV_1$ ($p = 0.03$) and

greater RV ($p = 0.005$) than those who continued, whereas those who withdrew in the PR group had higher MRC dyspnea scores ($p = 0.04$). The only statistically significant difference between the patients who withdrew in the two groups was that control patients had somewhat higher 6WT scores than did withdrawing PR patients ($p = 0.04$).

Patients in the PR group completed 92% of their rehabilitation sessions. Sixteen (53%) PR patients required chest physiotherapy during the first 3 months, and two (7%) needed such therapy only during exacerbations. The workload achieved by patients in the last month of the exercise training period (month 6 from the start of the study) was 80% of baseline Wmax in 12 patients and 65% of baseline in the remaining 18.

## Main Effects

Figures 1 through 3 depict the changes with time in treatment and control groups in FVC, $FEV_1$, 6WT, Wmax, dyspnea scales, and quality of life. In the formal statistical analysis, no significant effect of time on any variable was observed. However, we observed significant treatment effects in FVC ($p = 0.04$), the 6WT ($p = 0.0001$), dyspnea as measured by the visual analog ($p = 0.0001$) and MRC scales ($p = 0.0001$), and all CRQ domains (dyspnea
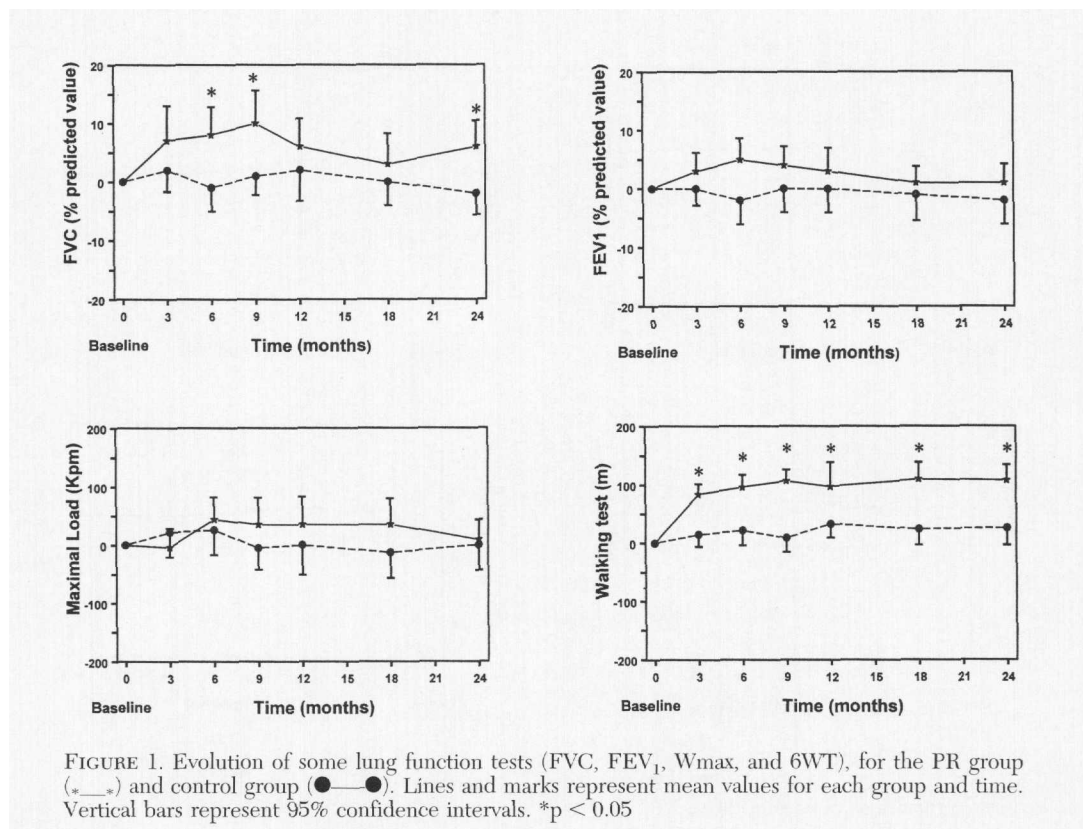


FIGURE 1. Evolution of some lung function tests (FVC, $FEV_1$, Wmax, and 6WT), for the PR group (*___*) and control group (●——●). Lines and marks represent mean values for each group and time. Vertical bars represent 95% confidence intervals. *p < 0.05
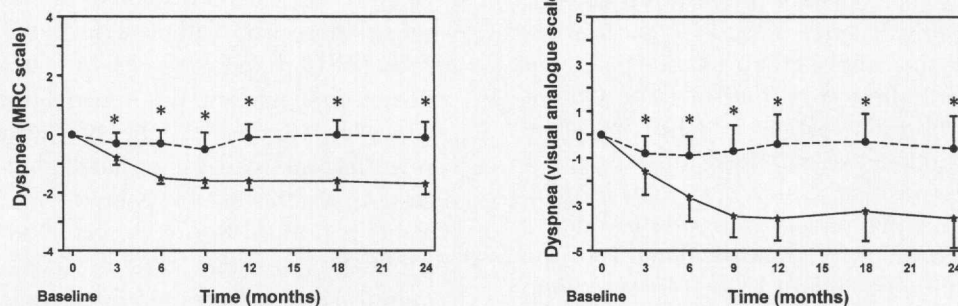
FIGURE 2. Evolution of perception of dyspnea, during daily activities, for the PR group (*___*) and control group (●——●); assessments were recorded with the patient at rest. *Left,* dyspnea measured by visual analog scale. *Right,* dyspnea measured by MRC scale. Lines and marks represent mean values for each group and time. Vertical bars represent 95% confidence intervals. *p < 0.05

[p = 0.007], fatigue [p = 0.02], emotional function [p = 0.03], and mastery [p = 0.03]).

There was a significant interaction between time and treatment in dyspnea on the visual analog (p = 0.001) and MRC (p = 0.001) scales, and on the CRQ domains (dyspnea [p = 0.04], fatigue [p = 0.03], emotional function [p = 0.04], and mastery [p = 0.02]). The nature of the interaction is that larger treatment effects occurred early in the study, and the treatment effects diminished but did not disappear with time (Fig 2, 3).

The absolute benefit of rehabilitation is expressed by the difference between groups in the mean changes from baseline to 24 months of follow-up. These differences between groups for functional and HRQL outcomes were as follows: 81 m (95% confidence interval, 38 to 125) on the 6WT; −4.1 (−2.1 to −6.1) for the visual analog scale estimate of dyspnea; and −1.8 (−1.1 to −2.5) for the MRC dyspnea rating. For the dyspnea, fatigue, mastery, and emotional function domains of the CRQ, the results were 1.0 (0.2 to 1.7), 1.1 (0.2 to 1.7), 1.0 (0.3 to 1.6), and 1.0 (0.2 to 1.8), respectively. Because patients who withdrew could be less responsive to rehabilitation and could alter these results, we have used the same calculations for baseline and final follow-up for each
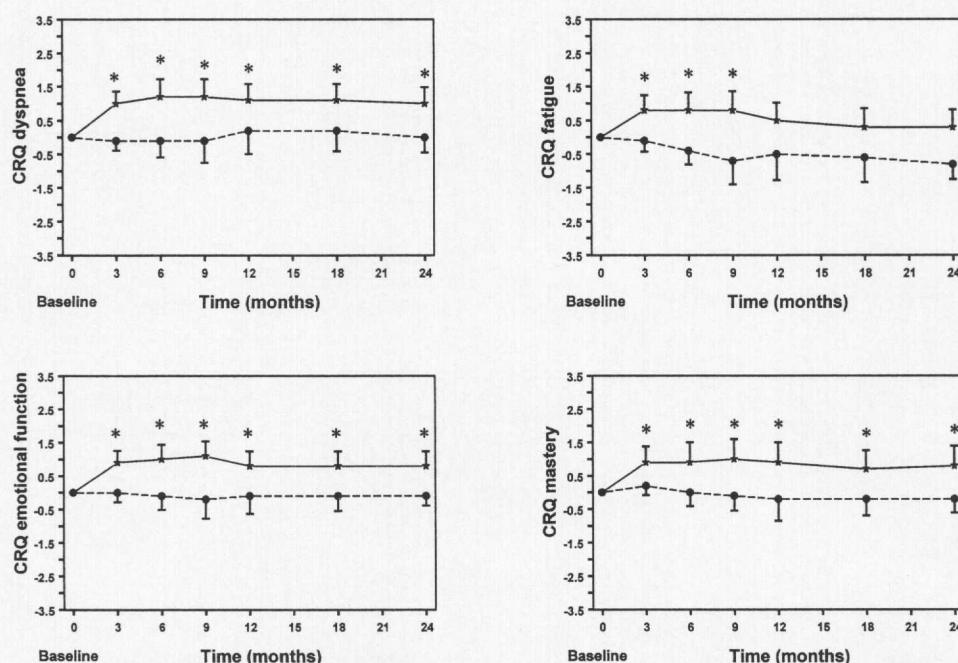


FIGURE 3. Evolution of CRQ domains (dyspnea, fatigue, emotional function, and mastery) for the PR group (*___*) and control group (●——●). Lines and marks represent mean values for each group and time. Vertical bars represent 95% confidence intervals. *p < 0.05

patient, but now including those 13 patients who withdrew. These differences were then 95 m (95% confidence interval, 58 to 133) for the 6WT; −3.7 (−1.9 to −5.3) for the visual analog scale estimate of dyspnea; and −1.9 (−1.3 to −2.5) for the MRC dyspnea rating. For the dyspnea, fatigue, mastery, and emotional function domains of the CRQ, the results were 0.9 (0.4 to 1.5), 1.1 (0.5 to 1.7), 1.0 (0.4 to 1.5), and 0.9 (0.1 to 1.8), respectively. We observed that the analysis in which we included the final follow-up available from all patients yielded similar results to that in which we used only patients with data at 24 months.

The mean change from baseline to follow-up in PR and control groups exceeded the minimal important difference of 0.5 in all four CRQ domains. The number needed to treat, to achieve a small but important improvement calculated from the proportion of patients that improved vs those who deteriorated in the two groups, was 2.94, 3.8, 2.5, and 2.9 for dyspnea, fatigue, emotional function, and mastery CRQ domains, respectively.

### Exacerbations, Hospitalizations, and Long-term Home Oxygen Therapy Prescriptions

Control group patients experienced 207 exacerbations, with an average of 6.9 ± 3.9 exacerbations per patient, ranging from 0 to 16 exacerbations during 24 months. The PR group experienced 111 exacerbations with an average of 3.7 ± 2.2 exacerbations per patient, ranging from 0 to 9 exacerbations during 24 months. The difference was statistically significant ($p < 0.0001$).

The total number of hospitalizations in the control group was 39 with an average of 1.3 ± 1.8 hospitalizations per patient, ranging from 0 to 6. The total number in the PR group was 18 with an average of 0.6 ± 1.0 hospitalizations per patient, ranging between 0 and 4. The difference was not statistically significant ($p = 0.57$). Ten (33%) patients from the control group and two (7%) patients from the PR group received home oxygen therapy during the course of the study ($p = 0.03$).

### DISCUSSION

This study is consistent with previous reports,[1-3] showing that a PR program for COPD patients encompassing education, breathing retraining, and chest physiotherapy followed by exercise training leads to improvement in dyspnea, functional exercise capacity, and HRQL. The strengths of our study include the randomized design, the blinding of supervisors and technicians who measured outcome

variables, and our maintenance of long-term follow-up in a population likely to have many reasons for dropping out.

Our study is limited by its relatively small sample size. Another limitation is that we did not perform practice walking tests before the baseline walking, although we did use encouragement.[15] It is likely, then, that some of the improvement in walking distance in both the treatment and control groups resulted from learning effects.[26,27] However, randomization makes it likely that learning effects were equal in the two groups, and we observed a statistically significantly greater increase in 6WT distance in the PR group than in the control group. Moreover, the magnitude of the treatment effect is substantially greater than the learning effect demonstrated in prior studies[26,27] and previous studies of PR effects.[2] Finally, the observed increase was not an isolated outcome; rather, it paralleled improvements in FVC, dyspnea, and, particularly, HRQL. We therefore believe that improvements can be attributed to adaptation to exercise rather than learning.

Our study contributes additional information regarding the impact of breathing retraining and the duration of benefits of PR. Our results suggest that a period of breathing retraining and chest physiotherapy combined with low-level exercise may have beneficial effects on exercise capacity and HRQL independent of more structured exercise training. This is true despite the fact that we would anticipate variability in the extent to which patients complied with advice about home exercise.

Our finding of substantial impact of breathing retraining, chest physiotherapy, and low-level exercise supports previous data from randomized trials suggesting that simple and less costly outpatient programs can provide benefits similar to those of more resource-intensive inpatient programs.[8,9] Recently Clark et al[28] and Cambach et al[29] also found that less strenuous exercise performed with minimal facilities provide significant improvement in exercise tolerance and HRQL. It remains likely, however, that patients must undertake a formal, more intensive exercise training program to achieve the greatest benefit.[30,31]

Although providing important information about the impact of low-level exercise and breathing retraining, the design of our study limits us in that we cannot make strong inferences about the impact of formal exercise training. We did not begin formal exercise training from the outset of rehabilitation for two reasons. First, we wished to replicate our current program, which begins with 3 months of physiotherapy, breathing retraining, and informal home exercise. Second, we wished to assess the impact of this

part of the program in the first 3 months, and the randomized trial design allows us to do so.

The initial improvement in FVC suggests the possibility that patients may have been suboptimally treated with bronchodilators before beginning rehabilitation. We consider this unlikely. We carefully adjusted patient medication before having patients begin the study, and rigorously documented their medication use. Patients in both treatment and control groups stayed on the same medications throughout the study, other than during periods of exacerbation. We also noted that $FEV_1$ remained unchanged in both treatment and control groups.

Why did the FVC improve in the actively treated patients? One possibility is simply the play of chance, although the low p value associated with this finding makes that a less likely explanation. Another possibility is that breathing retraining, including physiotherapy, facilitated increases in the flexibility of the chest wall and improvements in the respiratory muscle strength. Because FVC is dependent on muscular effort whereas $FEV_1$ is not, such changes could explain our findings.

A second important finding of our study is the more sanguine picture of the long-term benefits of PR than the only other randomized controlled trial that has reported long-term follow-up of PR.[1] We demonstrated that patients can maintain useful benefit up to 24 months after beginning a formal program, and up to 12 months after its completion. One factor in maintaining improvement may have been the psychological and social support received by patients participating in a self-help association for chronic respiratory patients organized with the assistance of the rehabilitation team.

The third finding of note from our study is data suggesting that the monetary costs of rehabilitation may be offset by savings in other resource-intensive aspects of health care, including the management of exacerbations and the prescription of long-term domiciliary oxygen. Our findings are not consistent with those of other studies, which found no significant influence of PR on the number of exacerbations or hospitalizations.[1,32] The significant reduction in exacerbations, and our failure to demonstrate a significant reduction in hospitalizations, constitute important findings of this study. A recent review of PR noted the limited strength of evidence regarding the impact of PR on health-care resource utilization.[3] The current study is one of the few randomized controlled studies that has addressed this issue. A previous rigorously conducted economic analysis of an inpatient respiratory rehabilitation program was based on a randomized trial with results similar to ours, but with follow-up limited to 6 months. Those investigators found that the incremental cost

of the program per patient improved was approximately $30,000 (Canadian).[7] However, most of the additional costs were associated with the inpatient component of the program.

Finally, we provided an estimate of the proportion of patients likely to benefit from PR. Our results suggest that for every three patients who complete a rehabilitation program, clinicians can expect at least one to achieve HRQL improvement. This is similar to, for instance, the proportion of asthmatic patients who experience improvement in HRQL with the addition of a long-acting β-agonist to their treatment regimen.[25]

We conclude that clinicians can anticipate that a third of the outpatients they enroll in PR programs will obtain beneficial effects from even simple, inexpensive regimens and that benefits can last not only for the duration of the PR program but can also be maintained for at least 1 year thereafter.

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