The Effect of Pulmonary Rehabilitation in Patients With Post-tuberculosis Lung Disorder*

Morihide Ando, MD, PhD; Atsushi Mori, MD, PhD; Hiroshi Esaki, MD, PhD; Tsuyoshi Shiraki, MD, PhD; Hiroyuki Uemura, MD, PhD; Mitsushi Okazawa, MD, PhD; and Hiroki Sakakibara, MD, PhD

Study objectives: Although the benefit of pulmonary rehabilitation (PR) has been demonstrated for patients with COPD, the benefit for patients with non-COPD lung disorders is still unclear. In the present study, we compared the effect of PR on patients with post-tuberculosis (TBC) lung disorders and patients with COPD.

Design: We performed a prospective nonrandomized open trial over a 9-week period.

Patients and methods: Thirty-two patients with post-TBC lung disorders (thoracoplasty, 25 patients; mean [± SD] age, 71 ± 5 years; FEV1, 0.84 ± 0.29 L) and 32 age-matched and FEV1-matched COPD patients were enrolled in the study. First, we compared the exercise tolerance between groups using a 6-min walking test. Next, we trained the patients using a 9-week outpatient PR program. We assessed improvement using clinical dyspnea ratings, a daily activity score, and the results of a 6-min walking test.

Results: When age and FEV1 were matched, the distance covered during the 6-min walking test did not differ between the groups. After rehabilitation, significant improvement was observed in both the post-TBC group and the COPD group in terms of Medical Research Council dyspnea grade, transition dyspnea index, activity score, and 6-min walking distance (42 m [p < 0.01] vs 47 m [p < 0.01], respectively). The magnitudes of the improvement in these parameters were comparable between the groups.

Conclusions: PR is as beneficial in post-TBC lung disorder patients as in COPD patients if the severity of the disability is similar.


Key words: exercise tolerance; obstructive lung diseases; pulmonary rehabilitation; pulmonary tuberculosis

Abbreviations: ADL = activity of daily living; BDI = baseline dyspnea index; MRC = Medical Research Council; PR = pulmonary rehabilitation; TBC = tuberculosis; TDI = transition dyspnea index; VC = vital capacity

Currently, pulmonary rehabilitation (PR) is regarded as an important treatment modality in the management of patients with COPD. Randomized controlled studies have proven the effectiveness of PR on exercise tolerance and dyspnea in these patients, and several official guidelines have been issued using these results. It is generally believed that PR can be beneficial in a variety of non-COPD lung disorders, which include cystic fibrosis, pulmonary fibrosis, and restrictive thoracic disease. However, we have little evidence to indicate whether PR is truly effective in the treatment of these lung disorders.

In Japan, lung tuberculosis (TBC) was the most serious pandemic disease for the first decade after World War II. More than 100,000 patients died annually from TBC. During that period of time, surgical therapy such as thoracoplasty with lung resection was the most effective therapeutic modality, since no effective anti-TBC drugs were available, and a total of 1 million patients with TBC underwent chest surgery. Thoracoplasty causes progressive restrictive pulmonary disorder due to thoracic deformity, and Mori and Phillips reported that many patients who underwent thoracoplasty developed significant cardiorespiratory failure after receiving chest surgery. In Japan, > 80,000 patients

From the Division of Respiratory Medicine and Clinical Allergy (Drs. Ando, Okazawa, and Sakakibara), Department of Internal Medicine, Fujita Health University, Aichi, Japan; and the Akutami Clinic (Drs. Mori, Esaki, Shiraki, and Uemura), Gifu, Japan. Manuscript received June 4, 2002; revision accepted November 8, 2002.

Reproduction of this article is prohibited without written permission from the American College of Chest Physicians (e-mail: permissions@chestnet.org).

Correspondence to: Morihide Ando, MD, Department of Internal Medicine, National Kinki-Chuo Hospital for Chest Diseases, 1180 Nagasone-cho, Sakai, Osaka, 591-8555, Japan; e-mail: m-ando@koh.hosp.go.jp
are currently receiving long-term oxygen therapy, and one fifth of them are patients with post-TBC lung disorder.9

Since patients who have post-TBC lung disorder show stable restrictive or mixed ventilatory disorders and seldom show pure obstructive disorder, they could constitute a good model for studying the effect of PR on restrictive thoracic diseases such as kyphoscoliosis and neuromuscular diseases. Because post-TBC patients have limited exercise tolerance10 and a significant disability affecting daily living, much like patients with COPD, they appear to be good candidates for PR. The current study was designed to investigate the degree of disability and the efficacy of PR on patients with post-TBC lung disorder in comparison with COPD patients.

**Materials and Methods**

**Subjects**

Thirty-two patients (24 men) with post-TBC lung disorder were enrolled in the study. These patients visited the Akutami Clinic between October 1996 and February 2000. They exhibited shortness of breath on exertion, had to limit their daily activities, and produced an FEV1 of <70% of the predicted value. Patients who had apparent complications from COPD were excluded from the study. Twenty-five of the study enrollees had undergone thoracoplastic surgery 30 to 40 years ago. The remaining seven patients had severe sequelae from old cases of pleuritis. Thirty-two age-matched and FEV1-matched COPD patients (30 men) who visited the Akutami Clinic during the same period were selected as the control group. Patients with COPD received diagnoses using the guidelines of the American Thoracic Society.11 None of the patients in either group were receiving therapy with oral corticosteroids. Sixteen patients in the post-TBC group and all patients in the COPD group were ex-smokers, and the others were nonsmokers. None of the patients showed any evidence of ischemic heart disease, musculoskeletal disorders, or other disabling disorders that could limit participation in the rehabilitation program. All patients agreed to participate in our outpatient PR program. This study was approved by the Medical Ethics Committee of Fujita Health University.

**Methods**

The study was conducted in two parts. First, we compared the baseline disabilities between the post-TBC group and the COPD group. We selected FEV1-matched patients and investigated the correlation of various parameters to FEV1 to ascertain whether FEV1 reflected disease severity in patients with post-TBC lung disorder. If disease severity was not reflected by FEV1, then we investigated the correlation among variables to find the parameter that commonly reflected the severity of disabilities in both the post-TBC and COPD groups. In the second part of our study, we selected patients with a comparable degree of disability from each of the two groups using the parameter selected in the first part of the study. After assuring the homogeneity of the disability between members of the newly selected groups, we conducted a prospective nonrandomized trial to compare the effect of PR between these groups.

**Comparison of Disability**

The first step was a simple comparative study. All patients were assessed after an observation period of >2 weeks. The assessment consisted of lung function (ie, vital capacity [VC] and FEV1), blood gas analysis, dyspnea grade, functional status, limitation in daily activities, and 6-min walking distance. We used the Medical Research Council (MRC) dyspnea grade12 and the baseline dyspnea index (BDI)/transition dyspnea index (TDI)13 to evaluate dyspnea and functional status. Briefly, MRC grade was determined by a five-item questionnaire in which patients categorized their own level of disability. Grading was based on the responses to the following questions: grade 1, “Are you ever troubled by breathlessness except on strenuous exertion?”; grade 2 (if yes), “Are you short of breath when hurrying on the level or walking up a slight hill?”; grade 3 (if yes), “Do you have to walk slower than most people on the level? Or do you have to stop after a mile or so (or after 30 min) on the level at your own pace?”; grade 4 (if yes to either), “Do you have to stop for breath after walking about 100 yards (or after a few minutes) on the level?”; grade 5 (if yes), “Are you too breathless to leave the house, or breathless after undressing?” The BDI is a multidimensional instrument based on the three following components that evoke dyspnea: functional impairment; magnitude of task; and magnitude of effort. Each component is scored from 0 (severe impairment) to 4 (not impaired). A baseline focal score is obtained as the sum of the three components (range, 0 to 12).

The TDI provides specific criteria for each of the three components to measure the change from the baseline state. Changes in each component are scored from −3 (ie, major deterioration) to +3 (ie, major improvement). A TDI focal score is obtained by adding the scores of the three components (range, −9 to +9). We used the activities of daily living (ADL) and instrumental ADL scoring system of Spector et al14 to evaluate daily activities. This scoring system evaluates six fundamental daily activities (ie, feeding, transfer, dressing, bathing, shopping, and transportation) depending on whether the patient is independent (score, 1) or dependent (score, 0). The total score was used as the patient’s ADL score. VC and FEV1 were measured in the standing position using an auto spirometer (SPIROSOFT SP-400; Fukuda Electronics; Tokyo, Japan). Blood gases were sampled after the patient had lain on a bed in a supine position for 15 min and were analyzed using a blood gas analyzer (ABL-330; Radiometer; Copenhagen, Denmark). Thirteen post-TBC patients and 9 COPD patients were receiving supplemental oxygen, and blood gas analyses were undertaken with oxygen supplementation for those patients. Six-minute walking tests were performed on a flat circuit (24 m around) using the protocol proposed by Steel.15 Prior to the walk, baseline parameters including dyspnea rating (10-point Borg scale16), BP, and pulse rate were measured. The supplemental oxygen was used as prescribed by those patients in whom a requirement for oxygen inhalation during exercise had been diagnosed. During the walk, arterial oxygen saturation was monitored using a pulse oximeter (Pulsor-5 portable pulse oximeter; Minolta; Tokyo, Japan) attached to the index finger. Before the start of the test, patients were instructed to walk as far as possible during 6 min, and no further encouragement was given during the test. The nonencouragement method tends to result in low subject exertion. However, it can minimize the variance due to coaching by different examiners.15 Immediately following the completion of the walk, we again measured the parameters that had been measured at baseline. The walking test was performed twice on the same day, and the longer distance of the two trials was recorded as the walking distance.
Comparison of the Effect of PR

In the second part of our study, we performed a prospective nonrandomized open trial over a 9-week period to compare the effect of PR between the post-TBC and COPD groups. First, we selected patients with a comparable degree of disability from each group using the parameter selected in the first part of the study, and we enrolled those patients into the second part of the study.

The patients were randomly divided into 12 groups of five to eight patients and were trained using an original program. The patients came to the clinic once a week for 9 consecutive weeks. Since most of the patients were >70 years old, we requested an infrequent clinic visit for PR based on a study that showed sufficient overall effectiveness of the once-a-week program. At each visit, patients performed 1 h of exercise under the supervision of a physiotherapist and a respiratory physician. Patients also were instructed to practice daily exercise at home. Compliance with daily exercise was assessed weekly using a training diary filled out by the patients at home. Any other treatments, including medication and oxygen inhalation, remained unchanged during the PR period. All patients received the same PR program regardless of their underlying disease. The assessments were repeated 9 weeks after the beginning of the PR program.

The PR protocol included breathing retraining, exercise, and education. Breathing retraining consisted of relaxation, pursed-lip breathing, and slow-deep breathing with training occurring in both the supine and sitting positions using the classic method of Milley with slight modifications. All patients received the same instructions. Exercise training included low-intensity strength training of the upper and lower extremities for 30 min and level walking for 15 min as endurance training. Low-intensity strength training was conducted according to the protocol reported by Clark et al with some modifications. In the level walking exercise, each patient was instructed to walk at >90% of his or her initial 6-min walking test speed to achieve sufficient exercise intensity. To maintain the selected speed, patients were instructed to cover the prescribed number of rounds of the circuit within 15 min. Patient education was performed for 20 min during each visit by a chest physician using an original textbook. The contents of the lectures were as follows: (1) lung anatomy; (2) physiology of various lung impairments; (3) exercise physiology; (4) benefit and method of daily training; (5) nutrition; (6) drug therapy; (7) oxygen therapy; (8) how to cope with exacerbation; and (9) how to manage daily lives.

To investigate the long-term effect of PR, we repeated the 6-min walking test at the third and sixth month after the termination of the 9-week program. Patients were instructed to continue with the home rehabilitation program during this period.

Statistical Analysis

We used the Fisher direct method to compare the man/woman ratio between groups during the first part of our study. We used the Kolmogorov-Smirnov test to evaluate the normality of the distribution of each variable. If normal equivalent distribution was assured, we used the Student t test to compare the variables between groups. If it was not assured, we used a nonparametric method (the Mann-Whitney U test) to compare the variables. We used the Spearman rank correlation coefficient to evaluate the correlation between the parameters.

In the second part of our study, we used a paired t test and a paired Wilcoxon test to evaluate the effect of PR within each group, and we used the Student t test and the Mann-Whitney U test to compare the magnitude of improvement between groups. A p value of <0.05 was considered to be significant. All values are presented as the mean (SD) and 95% confidence interval, unless stated otherwise.

RESULTS

Comparison of Disability

All patients completed the initial assessment, the results of which are shown in Table 1 and Figure 1. The Borg scores after the walking test were relatively low in both groups because we used the nonencouragement method while subjects performed the 6-min walking test. The ADL score (full score = 6) of Spector et al was high in both groups, since all patients were outpatients and were independent during their daily activities. The man/woman ratio was not significantly different between the two groups. Anthropometric parameters, blood gas values, and 6-min walking distances were comparable between the groups, too. On the other hand, VC was significantly smaller (p < 0.01) and the FEV1/FVC ratio was significantly greater (p < 0.01) in the post-TBC group than in the COPD group, reflecting the restrictive nature of the respiratory dysfunction in post-TBC patients. The distributions of MRC grade, BDI focal score, and ADL score were not significantly different between groups.

The correlations of MRC grade, BDI focal score, and 6-min walking distance to FEV1 are shown in

<table>
<thead>
<tr>
<th>Table 1—Baseline Characteristics of the Subjects*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Age, yr</td>
</tr>
<tr>
<td>Anthropometric data</td>
</tr>
<tr>
<td>Height, cm</td>
</tr>
<tr>
<td>Weight, kg</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
</tr>
<tr>
<td>Lung function</td>
</tr>
<tr>
<td>VC, mL</td>
</tr>
<tr>
<td>VC, % predicted</td>
</tr>
<tr>
<td>FEV₁, mL</td>
</tr>
<tr>
<td>FEV₁, % predicted</td>
</tr>
<tr>
<td>FEV₁/FVC, %</td>
</tr>
<tr>
<td>Blood gas data†</td>
</tr>
<tr>
<td>Pao₂, mm Hg</td>
</tr>
<tr>
<td>PacO₂, mm Hg</td>
</tr>
<tr>
<td>6-min walking test</td>
</tr>
<tr>
<td>Distance, m</td>
</tr>
<tr>
<td>Borg score</td>
</tr>
<tr>
<td>Desaturation, %</td>
</tr>
</tbody>
</table>

*Values given as mean (SD):  
†p < 0.01 compared to post-TBC patients.  
‡p < 0.05 compared to post-TBC patients.  
§Thirteen patients of the post-TBC group and 9 patients of the COPD group inhaled oxygen (mean flow rates, 0.7 and 1.1 L/min, respectively).
Table 2. The MRC scale correlated significantly to FEV$_1$ in both groups. The 6-min walking distance showed weak correlation to FEV$_1$ in both groups. The BDI focal score tended to correlate to FEV$_1$ in the COPD group; however, it did not correlate to FEV$_1$ in the post-TBC group.

The correlations of MRC grade, BDI focal score, and ADL score to the 6-min walking distance are shown in Table 3. All three parameters correlated significantly to 6-min walking distance in both groups. Therefore, we used 6-min walking distance results to select patients with a comparable degree of disability in the second part of the study.

Comparison of the Effect of PR

To compare the effect of PR, we first selected patients from the two groups matched on the basis of baseline 6-min walking distance. Because there were no differences in the mean values and variances of baseline 6-min walking distances between the groups, all 64 patients could be enrolled into the second part of the study.

All patients completed our 9-week rehabilitation program and the second assessments. The training diary assured good compliance in home training from members of both groups. The changes in lung functions, blood gas data, exercise tolerance, symptoms, and ADL after training are shown in Table 4 and Figure 2. Patients in both groups showed significant improvement in 6-min walking distance, MRC grade, TDI score, and ADL score. MRC grade deteriorated in one patient each in both the post-TBC and COPD groups, and improved in nine and eight patients, respectively. The mean values of MRC grade were 3.4 before rehabilitation and 3.1 after rehabilitation in the post-TBC group, and 3.4 and 3.2, respectively, in the COPD group. ADL score improved in seven patients in the post-TBC group and in eight patients in the COPD group. The mean values of ADL score were 5.5 before rehabili-
itation and 5.8 after rehabilitation in the post-TBC group, and 5.2 and 5.6, respectively, in the COPD group. The 6-min walking distance improved in 25 patients in the post-TBC group and in 29 patients in the COPD group, and the mean improvement was 42 ± 110 m in the post-TBC group and 47 ± 49 m in the COPD group. The mean values of 6-min walking distance were 342 ± 77 m before rehabilitation and 384 ± 62 m after rehabilitation in the post-TBC group and 333 ± 91 and 380 ± 95 m, respectively, in the COPD group.

There was no significant difference in the magnitude of improvement in 6-min walking distance, MRC grade, or ADL score between the groups. TDI was not significantly different between the groups, either. There were no significant changes in blood gas data and FEV1 in either group. VC did not change after PR in the COPD group; however, VC in the post-TBC group showed significant increase after PR.

The long-term effect of PR on 6-min walking distance is shown in Figure 3. Seven patients in the post-TBC group and nine patients in the COPD group withdrew within 6 months after the 9-week program; however, the improvement was well maintained for 6 months in the remaining patients in both groups. The mean values of the 6-min walking distance were 394 ± 78 m (26 patients) at 3 months and 398 ± 76 m (24 patients) at 6 months after the termination of the program in the post-TBC group, and 384 ± 78 m (26 patients) at 3 months and 406 ± 68 m (23 patients) at 6 months after the termination of the program in the COPD group.

**Discussion**

In the first part of our study, we compared the degree of disability between members of the post-TBC and COPD groups. The results showed that the
The degree of disability was comparable between the groups when FEV₁ was equal and the disabilities could be represented by 6-min walking distance in both groups. In the second part of the study, we compared the effect of PR between the post-TBC and COPD groups. Our data showed that the effects of a 9-week PR program on members of both groups were quite similar and that the improvement of 6-min walking distance was maintained for 6 months after the termination of the PR program in both groups, suggesting that PR is effective in post-TBC patients too.

In the present study, we selected post-TBC lung disorder as being representative of non-COPD lung disorders. The complications after thoracoplastic surgery in these patients resulted in a stable restrictive or mixed ventilatory disorder due to loss of thoracic volume, so this disorder is a good model of restrictive thoracic disorders. Because patients with post-TBC lung disorder usually have no neuromuscular disorders, exercise training with sufficient intensity can be administered, unless they have cardiac or other organ disorders.

In this study, we first matched FEV₁ between the post-TBC group and the COPD group because FEV₁ has been commonly used to evaluate patients with COPD. However, there are no data showing that FEV₁ reflects the severity of the lung disorder in patients with restrictive thoracic disease, as is the case in patients with COPD. Therefore, we compared the disabilities between the groups and investigated which parameter commonly reflected the disease severity. Phillips et al. showed that post-TBC patients who underwent thoracoplasty had significant exercise limitation as a result of their limited ventilatory capacity. This is the same as what occurs in COPD patients, although the mechanisms of the limitation of ventilation are quite different. Thus, we expected that the degree of disability of post-TBC patients would be comparable to that of COPD patients if their ventilatory capacities were equivalent. This expectation was supported by the fact that FEV₁-matched patients with post-TBC lung disorders and patients with COPD showed comparable 6-min walking distances in the present study. However, the BDI had poor correlation to FEV₁ in patients with post-TBC lung disorder, suggesting that FEV₁ is not a good indicator of disease severity in this group. On the other hand, 6-min walking distance correlates well to MRC grade, BDI, and ADL score in both groups, suggesting that 6-min walking distance is a better common indicator of the severity of disabilities in both post-TBC and COPD patients than is FEV₁.

Although the exercise capacity of COPD patients is limited primarily by ventilation limitation, physical deconditioning brought about by their sedentary lifestyle also affects their exercise capacity. Although physical deconditioning can occur in any sedentary subject, it has not been proven whether
physical deconditioning exists in non-COPD patients. The results of the first part of our study showed similar disabilities between the post-TBC and COPD groups when age and FEV₁ were matched. However, the contribution of physical deconditioning to the disabilities of post-TBC patients remains to be investigated.

The effect of PR can be maintained for at least a year in patients with COPD if an appropriate support program is provided. In our program, a home exercise program was provided to study subjects, and they were supervised by a physician at the clinic and by visiting nurses at home. The improvement of 6-min walking distance was maintained for 6 months in both the COPD and post-TBC groups, suggesting that the effect of PR can be maintained in patients with post-TBC lung disorders as well as in patients with COPD.

To date, several reports have suggested the efficacy of PR in patients with non-COPD lung disorders, but most studies were inconclusive. The American Thoracic Society recently published a guideline for the diagnosis and management of pulmonary fibrosis. The guideline recommends PR as one of the treatment modalities but could not show any scientific evidence to prove its efficacy. Novitch and Thomas reported that PR was effective in patients with pulmonary fibrosis; however, their study did not have a control, and the patients in the study were too severely ill and their exercise tolerance was too poor to evaluate the real effect of an exercise program. Foster and Thomas compared the effect of PR in the non-COPD patients with that in the COPD patients and reported that PR improved exercise tolerance in the non-COPD patients, but the non-COPD group was very heterogeneous and included patients with neuromuscular disease whose exercise tolerance could be limited by the disease itself. The background characteristics of members of the non-COPD and COPD groups were not the same, so it was difficult to compare the effect of PR between the groups. Crouch and MacIntyre reported a similar comparison and also showed equivalent effectiveness of PR among those patients. However, detailed data were not shown in their report. There are many trials of exercise training in cystic fibrosis patients; however, thus far there have not been any randomized controlled trials of sufficient sample size. Our patients were relatively homogeneous, and the background disabilities were comparable between the COPD and non-COPD groups, so we believe the results demonstrated the efficacy of PR in non-COPD patients.

Our study had some limitations. To elucidate the effectiveness of PR on non-COPD patients, a prospective, randomized, controlled study is necessary. In the current study, however, we could not prepare nonrehabilitation control patients at a private clinic for ethical reasons. Another limitation of our study is the difficulty of proving statistical equivalence. In general, to prove statistical equivalence one needs a large sample size. For example, because 6-min walking distance results vary widely among people, thousands of patients are needed to prove statistical equivalence between the two groups if we choose type I probability (α) of 0.05 and power (1-β) of 0.8. Although 64 is a sufficient number to prove difference between groups, it is far less than the number that is needed to show equivalence. Thus, further study is needed to prove the equivalent effects of PR on non-COPD patients and COPD patients.

The magnitude of improvement in the 6-min walking distance in the present study was +42 m in the post-TBC group and +47 m in the COPD group. Improvement was smaller than the minimum clinical important difference in 6-min walking distance (54 m) shown by Redelmeier et al. However, the size of improvement in our study was comparable to that of the result of a meta-analysis made by Lacasse et al. Because our study had no control groups, we could not show the effect size of our program on patients with post-TBC lung disorder and on patients with COPD. Random variation of the effect could be included in +42 and +47 m distances, and in any case these improvements were greater than those noted in a previous report that showed test-to-test variances >4 weeks of 8.5%. Our long-term results showed that test-to-test variances in 3 and 6 months in each patient were small when pulmonary symptoms were stable.

In summary, our study results cast light on the effectiveness of PR as a therapeutic modality for non-COPD lung disorders. PR appears to have merit when it is given to patients with post-TBC lung disorders who are disabled by dyspnea.

References
6 Mori M. Tuberculosis sequelae in Japan. Kekkaku 1999; 74:1–4
19 Clark CJ, Cochrane L, Mackay E. Low intensity peripheral muscle conditioning improves exercise tolerance and breathlessness in COPD. Eur Respir J 1996; 9:2590–2596