Relative Effects of Bronchial Drainage and Exercise for In-Hospital Care of Patients with Cystic Fibrosis

Bronchial hygiene therapy is a standard part of the treatment of patients with cystic fibrosis (CF). Coughing alone promotes sputum expectoration and is probably the primary effective component of standard bronchial hygiene therapy. The purpose of this study was to determine whether substituting regular exercise, which also promotes coughing, for two of three daily bronchial hygiene treatments would affect the expected improvements in pulmonary function and exercise response in hospitalized patients with CF. Seventeen patients with CF hospitalized (mean length of stay = 13.0 ± 2.6 days) for an acute exacerbation of their pulmonary disease participated in the study. The patients were randomly assigned to either a group that participated in two cycle ergometer exercise sessions and one bronchial hygiene treatment session per day (EX Group [n = 9]) or a group that participated in three bronchial hygiene treatment sessions per day (PD Group [n =8]). Pulmonary functions and responses to a progressive, incremental cycle ergometer exercise test were measured on admission and before discharge. Bronchial hygiene therapy consisted of postural drainage, in six positions, with chest percussion and vibration. Therapeutic exercise was of moderate intensity and was individually adjusted based on the patient's heart rate and arterial oxygen saturation response to the admission exercise test. Coughing was encouraged during and after all treatments. Pulmonary function and exercise response were significantly improved over the period of hospitalization in both groups; the improvements were the same in the two groups. These results indicate that, in some hospitalized patients with CF, exercise therapy may be substituted for at least part of the standard protocol of bronchial hygiene therapy. [Cerny FJ: Relative effects of bronchial drainage and exercise for in-hospital care of patients with cystic fibrosis. Phys Ther 69:633–639, 1989]

Key Words: Cystic fibrosis; Pediatrics, evaluation; Percussion; Pulmonary, bronchial drainage.

Chest physical therapy, including bronchial hygiene techniques consisting of postural drainage, chest percussion, vibration, forced expiration, and coughing, has been a standard part of the treatment for children with cystic fibrosis (CF).1-3 The objectives of bronchial hygiene therapy are to mobilize pulmonary secretions and promote sputum expectoration. Increased short-term sputum expectoration and improved lung function have been reported after bronchial hygiene therapy.4-11 The patient-parent time and effort required for two to four daily bronchial hygiene sessions often result in noncompliance and have led to a search for alternate means of producing the same effects. Studies that have examined the effects of the individual components of bronchial hygiene therapy suggest that coughing alone may be
the primary effective element in stimulating sputum expectoration. Mellins observed that in many patients exercise induced coughing, suggesting that exercise may be an alternative therapeutic modality for facilitating sputum expectoration in selected patients with lung disease.

In support of this suggestion, regular physical activity has been shown to result in improvements in lung function in patients with CF. It is unknown how incorporation of exercise into the physical therapy program of patients with CF hospitalized for an acute exacerbation of their lung disease will affect the changes in lung function and exercise capacity occurring during the inpatient time period. This report describes the effects of replacing two of three daily bronchial hygiene sessions with vigorous exercise on lung function and exercise adaptation in hospitalized patients with CF.

**Method**

**Subjects**

Patients in the study were admitted to the hospital for treatment of an acute exacerbation of their pulmonary disease. Admission was based on symptoms of increased shortness of breath, coughing, and sputum production and decreased lung function. Subjects who were able to perform pulmonary function tests and who gave written informed consent were randomly assigned to either a group that participated in two cycle ergometer exercise sessions and one bronchial hygiene treatment session per day (EX Group [n = 9]) or a group that participated in three bronchial hygiene treatment sessions per day (PD Group [n = 8]).

No attempt was made to match patients for disease severity. Patient characteristics are shown in the Table. Discharge was based on improvement in one or more of the following: pulmonary function test results, chest radiograph, shortness of breath, and elimination of fever.

**Procedure**

**Pulmonary function tests.** Patients performed pulmonary function and exercise tests on the morning after admission and on the morning of discharge. The first pulmonary function test was performed two hours after the first bronchial hygiene treatment. All patients had previously performed both pulmonary function and exercise tests on multiple occasions. Forced vital capacity (FVC), expiratory reserve volume (ERV), inspiratory capacity (IC), forced expiratory volume in one second (FEV1), and forced expiratory flow between 25% and 75% of FVC (FEF25-75%) were measured by spirometry; functional residual capacity (FRC) and airway resistance (Raw) were measured by body plethysmography. Residual volume (RV = FRC - ERV), total lung capacity (TLC = FRC + IC), and specific airways conductance (SGAW = 1/Raw x FRC) were calculated. Percentage of arterial oxygen saturation (Sao2) was estimated with an ear oximeter.

Pulmonary functions, with the exception of Sao2, were expressed as a percentage of predicted value. In addition, a pulmonary function score (PFS), based on the deviation from the predicted values for six pulmonary functions tests (FVC, FEV1, FEF25-75%, RV, SGAW, and Sao2), was calculated. Test results within two standard deviations of the expected value received a score of 0. Scores of 1, 2, and 3 were assigned for values greater than two, three, and four standard deviations from the normal mean, respectively. A total PFS of 0 to <3 was considered normal, and scores of 3 to 7, 8 to 12, and 12 to 18 were indicative of mild, moderate, and severe lung dysfunction, respectively. This score has been shown to correlate well with other clinical scores and is used as an indicator of general lung function.

**Exercise test.** The exercise test was performed on a cycle ergometer. The initial load of 0.3 W/kg was increased by 0.3 W/kg every 2 minutes. Exercise was stopped when the subjects could no longer continue despite encouragement or when Sao2 had decreased by >15% or to less than 75% of the baseline level. Arterial oxygen saturation, electrocardio-

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Table. Physical Characteristics of Patients

<table>
<thead>
<tr>
<th>Group¹</th>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>PFS²</th>
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<tbody>
<tr>
<td></td>
<td>Admission</td>
<td>Discharge</td>
<td>Admission</td>
<td>Discharge</td>
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<td></td>
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<td>X</td>
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<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>EX (n = 9)</td>
<td>15.4</td>
<td>4.9</td>
<td>149.5</td>
<td>14.6</td>
</tr>
<tr>
<td>PD (n = 8)</td>
<td>15.9</td>
<td>4.9</td>
<td>151.6</td>
<td>14.2</td>
</tr>
</tbody>
</table>

¹EX Group participated in two cycle ergometer exercise sessions and one bronchial hygiene treatment session per day; PD Group participated in three bronchial drainage treatment sessions per day, except for one patient who received four treatments per day.

²PFS = pulmonary function score.
graphic activity, and heart rate (HR) were monitored continuously. Subjects breathed from a low-dead space (50 mL), one-way valve to allow measurement of exhaled minute ventilation (VE) in a Tissot gasometer for the last 30 seconds of each work load.

**Treatment.** All patients were treated similarly with intravenous antibiotics, inhaled bronchodilators, pancreatic enzymes, and water-soluble vitamins A and E and multivitamin preparations. Physical therapy was given between 8 and 9:30 AM, 3 and 4:30 PM, and 7 and 9 PM. The PD Group received postural drainage with chest percussion and vibration in six positions for 20 to 40 minutes three times daily, with the exception of one patient who received two afternoon treatments for a total of four treatments per day. The postural drainage was preceded by inhaled β2-receptor agonist bronchodilators. The EX Group exercised during the first two sessions and received postural drainage during the third session. Coughing was encouraged during and after all therapy sessions. Coughs were counted for 15 minutes following each therapy session.

Exercise therapy was performed on a cycle ergometer. The ear oximeter was worn at all times. Exercise intensity was adjusted to attain a target HR established as a percentage of the heart rate reserve (HRR = peak exercise HR - resting HR) so that target HR = HRR × percentage desired + resting HR. Resting HR was measured in the laboratory after the patient had been sitting quietly for 10 minutes. Work loads in the first two days were set to elicit a HR of 25% to 40% of the HRR. This was a level that could be tolerated for 5 to 10 minutes and would not result in arterial oxygen desaturation (Sao2 = >2%), except in two patients who received supplemental oxygen at a level to maintain Sao2 above 90% on Days 1 and 2. After 3 to 4 days, all subjects were able to exercise at a work level that elicited a HR of at least 40% of their peak HRR. From Day 4 to discharge, exercise time was increased to a target duration of 15 to 20 minutes. By the end of the hospitalization, each patient was able to work at an intensity of between 45% and 65% of the HRR.

To determine the immediate effects of exercise or bronchial hygiene therapy on pulmonary functions, spirometry was performed each day immediately before the morning treatment, 15 minutes after the morning treatment, and every hour for 5 hours after the morning treatment. Daily sputum volume expectorated was determined by measuring and summing the amounts of sputum accumulated during the following time intervals: from the time of awakening (7–8 AM) to the beginning of treatment, during, and for one-half hour following treatment, from 9:30 to 11:30 AM, from 11:30 AM to 2:30 PM, from 2:30 to 8:30 PM, and from 8:30 PM to wake-up. Sputum volume, wet weight, and dry weight (after 4 days of drying in an oven) were recorded and expressed in units per hour.

**Data Analysis**

Significance of within-group changes in each measurement of pulmonary function and exercise adaptation, from admission to discharge, was determined using paired Student’s t tests. In addition, to determine whether the extent of these changes was different between the groups, a Delta value for each pulmonary function test and measure of exercise adaptation was calculated (Delta value = discharge value – admission value) and averaged for each group. Between-group comparisons of these Delta values were made using the unpaired Student’s t test. Between-group statistical comparisons for the pulmonary function changes over the five hours following physical therapy were made on Days 1 and 7 using an analysis of variance for repeated measures. Significance was accepted at the .05 level.

**Results**

The mean duration of the hospitalization was 13 days (s = 3) for the EX Group and 13 days (s = 2.6) for the PD Group. Results of the pulmonary function tests on admission and at discharge are shown in Figure 1. There were no PFS differences between the EX and PD Groups at admission or discharge. Compared with the EX Group, the admission FEV1 and FEF25–75% were significantly lower in the PD Group (p < .05). The PFS, FVC, and FEV1 improved significantly in both groups, whereas FEF25–75% improved only in the PD Group. Within-group changes in the other pulmonary function tests were not statistically significant. There were no significant differences in the Delta values, indicating that the extent of the changes in all tests was the same for both groups.

Results of the exercise tests performed on admission and at discharge are shown in Figure 2. On admission, no significant between-group differences were observed in any of the exercise variables. Peak VE (p < .02) and peak HR (p < .05) improved from admission to discharge in both groups. To adjust peak VE and peak HR values for potential changes in the load at which they were attained, the ratios for peak VE to peak load and peak HR to peak load were calculated and compared. The peak HR-to-peak load ratio improved (p < .05) only in the EX Group. The between-group comparison of admission to discharge Delta values revealed no significant differences.

All postural drainage treatments were completed as required for the study, and 96% of the scheduled exercise therapy sessions were completed. Both treatments induced a productive cough and an equal number of coughs. An acute (15 minutes post-treatment), but not statistically significant, improvement in pulmonary functions, which lasted over the 5-hour follow-up period, was noted after 85% of the treatment sessions (Fig. 3). These trends were the same on Day 1, the first full day of treatment, as on Day 7 of the treatment protocol, with no significant differences between groups (Fig. 3). There were no differences in 24-hour spu-
Discussion

Some form of bronchial hygiene has been part of the treatment program for patients with CF since 1959 when Doyle suggested that it may enhance mobilization and expectoration of sputum. Exercise may have similar pulmonary hygiene effects. In this study, hospitalized patients who substituted exercise for two of three bronchial hygiene treatments showed improvements in lung function and exercise adaptation comparable to patients who received the usual three daily bronchial hygiene treatments.

Comparisons of the PD and EX Groups are valid only if clinical status was similar at admission. Although between-group differences in admission FEV<sub>1</sub> and FEF<sub>25%–75%</sub> were observed, clinical status, as indicated by the PFS, was the same in both groups. Nickerson et al have shown that individual pulmonary function tests in patients with CF are significantly more variable than in healthy subjects such that the assessment of pulmonary status on the basis of a single test could be artifactual. For this reason, a combination of measures, such as the PFS, can be a more reliable indicator of clinical status. Also supporting the suggestion that the groups in this study were similar in status is the fact that published reports of improvement in pulmonary function during hospitalization and exercise adaptation were qualitatively the same as those in this study for either group.

It could be argued that the equivalent changes in lung function in the EX Group were due to the single evening bronchial hygiene treatment. Desmond et al reported that a single bronchial hygiene treatment given after a three-week no-treatment period resulted in significant increases in FVC and rate of airflow at 60% of TLC (V<sub>max 60 TLC</sub>), but not FEF<sub>25%–75%</sub>. After this single treatment were “similar” to values measured prior to cessation of treatment. It is unclear from these results as to what the effects of a single, daily treatment might be. The sputum data from the present study do not support the idea that the single evening bronchial hygiene session could account for the similarity in the groups. Sputum volumes collected in this study were greatest after the first treatment in the morning, regardless of whether the treatment was postural drainage or exercise, and daily volumes were the same for both groups. These data would suggest that a single bronchial hygiene treatment, although having some positive effect on lung function, would not account for the lack of differences between the groups.

Early studies suggested that lung function was improved after postural drainage. More recent studies showed no short-term changes in pulmonary function in patients with chronic obstructive pulmonary disease (COPD) or CF. It is difficult to compare these studies because a variety of pulmonary function tests were used for evaluation, the severity of disease was dissimilar between studies, and the patients were not homogeneous within studies. Desmond et al’s study emphasizes the effect that previous therapy history might have on the effectiveness of the therapy session being evaluated.

Studies examining the effectiveness of bronchial hygiene therapy have confirmed an enhanced sputum expectoration or rate of mucus clearance as a result of treatment. Others have reported that coughing was the primary effective component of bronchial hygiene treatments.
chial hygiene therapy in patients with CF and COPD. Because coughing was common to both types of therapy in this investigation, the similarity of the five-hour posttreatment response in pulmonary function would support the suggestion that coughing is the important element in bronchial hygiene therapy, regardless of how it is elicited.

Regular exercise has been shown to result in improvements in lung function in nonhospitalized patients with CF. These improvements were attributed to ventilatory muscle training but may also be explained, in part, by exercise-induced coughing or acceleration of ciliary mucus clearing. This suggestion is in agreement with Oldenberg et al., who showed that exercise was more effective than postural drainage but less effective than directed coughing in the removal of sputum. The EX Group did not receive bronchodilator therapy before the exercise therapy session. It is unknown how pretreatment with bronchodilators affects the effectiveness of subsequent standard bronchial hygiene treatments, and therefore this issue cannot be addressed.

Although the EX Group in this study did show greater improvement in several exercise variables than the PD Group, these changes were small. The short time of training (less than 13 days) and the low level of exercise in the first seven days after admission were below those levels required to elicit a significant conditioning effect.

**Conclusion**

Substitution of exercise treatments for two of three daily bronchial hygiene treatment sessions over a nearly two-week hospitalization in this study produced similar benefits in lung function and exercise capacity, suggesting that postural drainage and exercise were equally effective in promoting pulmonary hygiene. This study made no attempt to isolate the effects of coughing alone on lung function or exercise response over the period of hospitalization. In view of the available evidence, it is suggested that under all conditions where sputum expectoration should be promoted, coughing must be encouraged. Because exercise can be carried out only when patients feel reasonably well, standard bronchial hygiene or other methods of inducing coughing may be required to promote sputum expectoration under certain conditions. This study found no negative effects of exercise therapy performed by inpatients. A limited, individualized exercise program offers an opportunity for patients with CF to improve their functional exercise capacity and lung function with no apparent negative consequences. In selected inpatients, exercise should be considered an adjunct to, or substitute for, traditional physical therapy. Guidelines for exercise testing and exercise prescription for patients with CF are available from either the Cystic Fibrosis Foundation or the author.

**Acknowledgments**

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**References**

1 Guide to the Diagnosis and Management of Cystic Fibrosis. Atlanta, GA, Cystic Fibrosis Foundation, 1971
4 Lorin ML, Denning CR: Evaluation of postural drainage by measurement of sputum vol-

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Fig. 2. Means and standard deviations of changes in measures of exercise adaptation during hospitalization in patients with cystic fibrosis. The PD Group (n = 8) received three bronchial drainage treatments per day, except for one patient who received four treatments per day; the EX Group (n = 9) participated in two cycle ergometer exercise sessions and one bronchial hygiene treatment session per day. Delta shows change for each group over period of hospitalization. (Ve = exhaled minute ventilation; HR = heart rate.)