Specific Expiratory Muscle Training in COPD*

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Background: **There are several reports showing that expiratory muscle strength and endurance can be impaired in patients with COPD. This muscle weakness may have clinically relevant implications. Expiratory muscle training tended to improve cough and to reduce the sensation of respiratory effort during exercise in patients other than those with COPD.**

Methods: **Twenty-six patients with COPD (FEV_1 38% predicted) were recruited for the study. The patients were randomized into two groups: group 1, 13 patients were assigned to receive specific expiratory muscle training (SEMT) daily, six times a week, each session consisting of 1/2 h of training, for 3 months; and group 2, 13 patients were assigned to be a control group and received training with very low load. Spirometry, respiratory muscle strength and endurance, 6-min walk test, Mahler baseline dyspnea index (before), and the transitional dyspnea index (after) were measured before and after training.**

Results: **The training-induced changes were significantly greater in the SEMT group than in the control group for the following variables: expiratory muscle strength (from 86 ± 4.1 to 104 ± 4.9 cm H_2O, $p < 0.005$; mean difference from the control group, 24%; 95% confidence interval, 18 to 32%), expiratory muscle endurance (from 57 ± 2.9% to 76 ± 4.0%, $p < 0.001$; mean difference from the control group, 29%; 95% confidence interval, 21 to 39%), and in the distance walked in 6 min (from 262 ± 38 to 312 ± 47 m, $p < 0.05$; mean difference from the control group, 14%; 95% confidence interval, 9 to 20%). There was also a small but not significant increase (from 5.1 ± 0.9 to 5.6 ± 0.7, $p = 0.14$) in the dyspnea index.**

Conclusions: **The expiratory muscles can be specifically trained with improvement of both strength and endurance in patients with COPD. This improvement is associated with increase in exercise performance and no significant change in the sensation of dyspnea in daily activities.**

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Key words: exercise performance; expiratory muscle training; sensation of dyspnea

Abbreviations: BDI = baseline dyspnea index; PEmax = maximal expiratory pressure; PEmPeak = peak expiratory pressure; PImax = maximal inspiratory pressure; PImPeak = peak inspiratory pressure; SEMT = specific expiratory muscle training; TDI = transition dyspnea index

It is well known that patients with significant COPD have respiratory and peripheral muscle weakness, but it does not affect all muscles to a similar extent.[1] The inspiratory muscles have been extensively investigated in patients with COPD. It has been shown that most patients with COPD have inspiratory muscle weakness,[2,3] which may contribute to the perception of dyspnea, that they can be trained, and that exercise performance[4,5] and dyspnea may improve as a result of such training.[6]

Surprisingly, there is a paucity of data related to the expiratory muscles (abdominal muscles and the internal intercostal muscles) in patients with COPD. These muscles have been found to be recruited in such patients both at rest and during loaded breathing. The significance of this activation has not been well defined; however, it is considered to be a mechanism that provides the system with functional reserve.[7] There are several reports showing that expiratory muscle strength[3,8] and endurance[9] can be impaired in patients with COPD and therefore decrease functional reserve.

The contraction of the expiratory muscles increases the intrathoracic pressure, diminishes lung volume, and facilitates expiratory flow in the absence

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of flow limitation. In addition, for cough to be effective, the flow caused by the expiratory muscles should be high.

The expiratory muscles have been specifically trained in several settings. It has been shown that such training tended to enhance expiratory muscle strength, and to improve cough efficacy in severely disabled patients with multiple sclerosis,[10] to improve the perception of dyspnea in children with neuromuscular disease,[11] and to reduce the sensation of respiratory effort during exercise in healthy subjects.[12] When patients with COPD were nonspecifically trained with normocapnic hyperpnea,[13] the strength of both inspiratory and expiratory muscle strength were increased, with beneficial effect on exercise performance and quality of life. The effect of specific expiratory muscle training (SEMT) in patients with COPD has not yet been studied. In the present study, we wanted to test the effects of SEMT, not only on the expiratory muscle performance, but also on exercise performance and the sensation of dyspnea in patients with significant COPD.

Table 1—*Characteristics of Patients With COPD**

Characteristics	SEMT Group (n = 12)	Control Group (n = 11)
Age, yr	63.3 ± 2.9	61.1 ± 2.8
Male/female sex, No.	9/3	10/1
Weight, kg	72.6 ± 2.4	70.7 ± 2.6
Height, m	1.69 ± 3.7	1.71 ± 3.5
FVC, L	2.42 ± 0.8	2.31 ± 0.5
% predicted	68 ± 4.2	69 ± 3.2
FEV_1, L	1.32 ± 0.4	1.41 ± 04
% predicted	37 ± 2.4	39 ± 2.9
Pa_{O_2}, mm Hg	77 ± 4.1	76 ± 4.0
Pa_{CO_2}, mm Hg	38 ± 1.1	39 ± 1.0
6-min walk distance, m	262 ± 38	286 ± 44
% predicted†	45 ± 3.0	47 ± 3.2
PImax, cm H_2O	59 ± 3.5	56 ± 2.9
% predicted	67 ± 4.0	61 ± 3.9
PImPeak, cm H_2O	41 ± 2.5	42 ± 2.3
PEmax, cm H_2O	86 ± 4.1	82 ± 4.0
% predicted	75 ± 5.0	71 ± 4.9
PEmPeak, cm H_2O	57 ± 2.9	58 ± 2.8

*Values are expressed as mean ± SEM unless otherwise indicated.
†Reference values are from Troosters et al.[15]

Patients and Methods

Subjects

Twenty-six patients, 22 men and 4 women, with spirometric evidence of significant chronic airflow limitation ($FEV_1 < 50\%$ predicted, $FEV_1/FVC < 70\%$ predicted) who received a diagnosis of COPD according to the criteria of the American Thoracic Society[14] were recruited for the study. They were all observed during a 4-week run-in period, when their regular treatment was maintained, to verify stability in their clinical and functional status. Their characteristics are summarized in Table 1. Patients with cardiac disease, poor compliance, a requirement of supplemental oxygen, or carbon dioxide retention were excluded from the study.

Study Design

All tests were performed before and within 1 week after the completion of the training period. The patients were randomized into two groups: 13 patients were assigned to receive SEMT for 3 months, and 13 patients were assigned to be a control group and received training with the minimal possible load with the training device (7 cm H_2O). In all patients, we performed several practice tests before the baseline value in order to correct possible training and learning effect. All the data were collected by the same collector who was blinded to the training group, as well as the patients themselves who were also blinded to the mode of treatment. The study protocol was approved by the institutional ethics committee, and informed consent was obtained from all the subjects.

Tests

Spirometry: FVC and the FEV_1 were measured three times on a computerized spirometer (Compact; Vitalograph; Buckingham, England), and the best trial is reported.

6-Minute Walk Test: The distance the patient was able to walk in 6 min was determined in a measured corridor as described by McGavin and coworkers.[16] The patients were instructed to walk at their fastest pace and cover the longest possible distance over 6 min under the supervision of a physiotherapist. The test was performed twice, and the best result is reported.

Respiratory Muscle Strength: Respiratory muscle strength was assessed by measuring the maximal inspiratory pressure (PImax) and maximal expiratory pressure (PEmax), at residual volume and total lung capacity, respectively, as previously described by Black and Hyatt.[17] The value obtained from the best of at least three efforts, measured at 2-min intervals, was used.

Respiratory Muscle Endurance: To determine inspiratory muscle endurance, a device similar to that proposed by Nickerson and Keens[18] was used. Subjects inspired through a two-way Hans-Rudolph valve, the inspiratory port of which was connected to a chamber and plunger to which weights could be added externally. Inspiratory elastic work was then increased by the progressive addition of 25- to 100-g weights at 2-min intervals, as was previously described by Martyn and coworkers,[19] until the subjects were exhausted and could no longer inspire. The pressure achieved with the heaviest load (tolerated for at least 60 s) was defined as the peak inspiratory pressure (PImPeak).

To determine expiratory muscle endurance, the subjects inspired through a two-way Hans-Rudolph valve (Hans Rudolph; Kansas City, MO), the inspiratory port of which was open to room air with no load, and the expiratory port was connected to the expiratory port of a threshold muscle trainer (Threshold; HealthScan; Cedar Grove, NJ). The expiratory load was then increased by the progressive addition of 10 to 20 cm H_2O (maximal pressure achieved through the increased load) at 2-min intervals until the subjects were exhausted and could no longer continue. Ten to 20 cm H_2O were applied in order to get not less than five intervals and not more than seven intervals until exhaustion. The pressure achieved with the highest load (tolerated for at least 60 s) was defined as the peak expiratory pressure (PEmPeak).

Dyspnea: Dyspnea in daily activities was assessed with the Mahler baseline dyspnea index (BDI) and by the transition dyspnea index (TDI), following training.[20]

Training Protocol

Subjects in both groups trained daily, six times a week, each session consisting of 1/2 h. The subjects received SEMT with a threshold inspiratory muscle trainer (Threshold; HealthScan). The subjects started breathing through the expiratory port of the threshold muscle trainer at a resistance equal to 15% of their PEmax for 1 week. The resistance was then increased incrementally, 5 to 10% each session, to reach 60% of their baseline PEmax at the end of the first month. SEMT was then continued at 60% of the PEmax, adjusted weekly to the new PEmax achieved. Lung volume was not monitored throughout the training, although it is likely that the end-expiratory lung volume increased during the training. Patients in the control group trained with the same device, but with a fixed resistance of 7 cm H_2O. The training was performed under the supervision of a physiotherapist twice weekly, and the patients were encouraged to train by daily phone calls.

Data Analysis

The results are expressed as mean ± SEM. Comparisons of lung function, respiratory muscle strength and endurance, the 6-min walk test, and rating of dyspnea within and between the two groups were carried out using two-way, repeated measures, analysis of variance. *Post hoc* analysis was performed using the Student Newman-Keuls test.

Results

One patient from the study group and two patients from the control group withdrew from the study. We report the results of the remaining 23 patients. There were no differences between the two groups in age, height, and weight at the entrance to the study.

Spirometry

Mean baseline FEV_1 and FVC were similar in the training group and in the control group (Table 1). Following the SEMT period, there was no significant change in the FEV_1 or FVC either in the training group or in the control group.

Blood Gas Analysis

Following the SEMT period, there were no significant changes in the blood gas values either in the training group or in the control group.

Respiratory Muscle Strength and Respiratory Muscle Endurance

Before the training period, there was no difference in PImax, PEmax, PImPeak, or PEmPeak between the training group and the control group. Following the SEMT period, there was a statistically significant increase of 21% in the PEmax (from 86 ± 4.1 to 104 ± 4.9 cm H_2O, $p < 0.005$) in the training group but not in the control group. The PImax remained unchanged following the training period, in both groups, emphasizing the specificity of the training (Fig 1).

The expiratory muscle endurance, as assessed by the PEmPeak, also increased significantly by 33% (from 57 ± 2.9 to 76 ± 4.0 cm H_2O, $p < 0.001$) in the training group but not in the control group. The inspiratory muscle endurance, as assessed by the

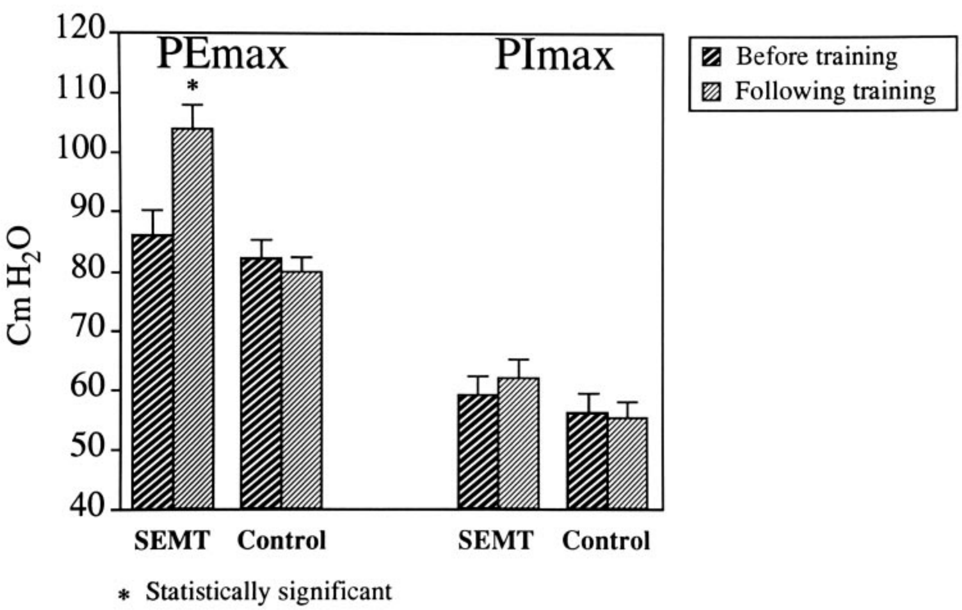

FIGURE 1. Respiratory muscle strength as assessed by PEmax and PImax before and following the SEMT period.

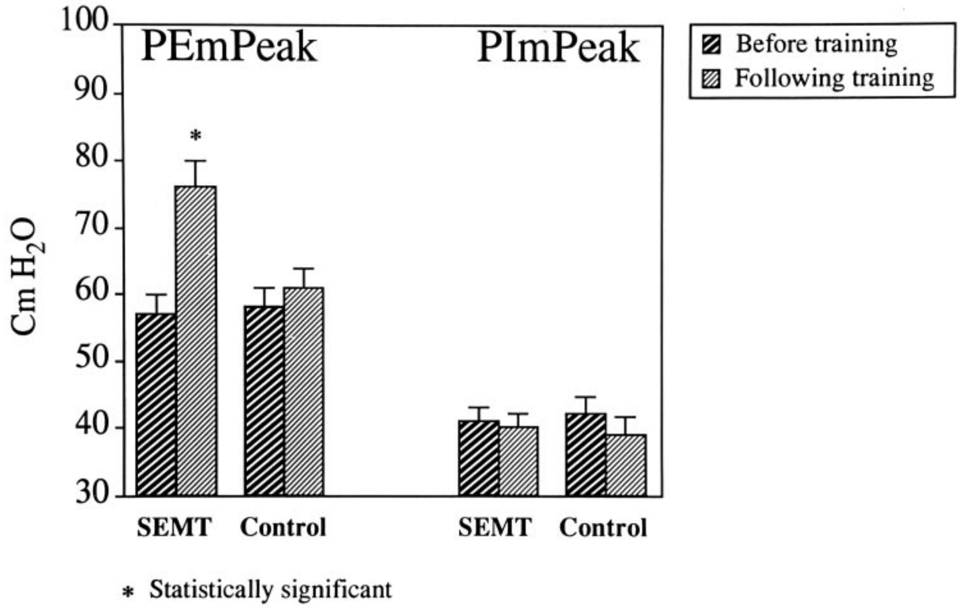

FIGURE 2. Respiratory muscle endurance as assessed by PEmPeak and PImPeak before and following the SEMT period.

PImPeak remained unchanged following the training period, in both groups (Fig 2).

6-Minute Walk Test

There was no statistically significant difference between the two groups in the 6-min walk test before the study (Table 1). Following the training period, there was a small but significant increase of 19% (from 262 ± 38 to 312 ± 47 m, $p < 0.05$) in the distance walked in 6 min, in the study group but not in the control group (Fig 3).

Dyspnea

Dyspnea in daily activities was assessed with the Mahler BDI. There was no statistically significant difference between the two groups in the different

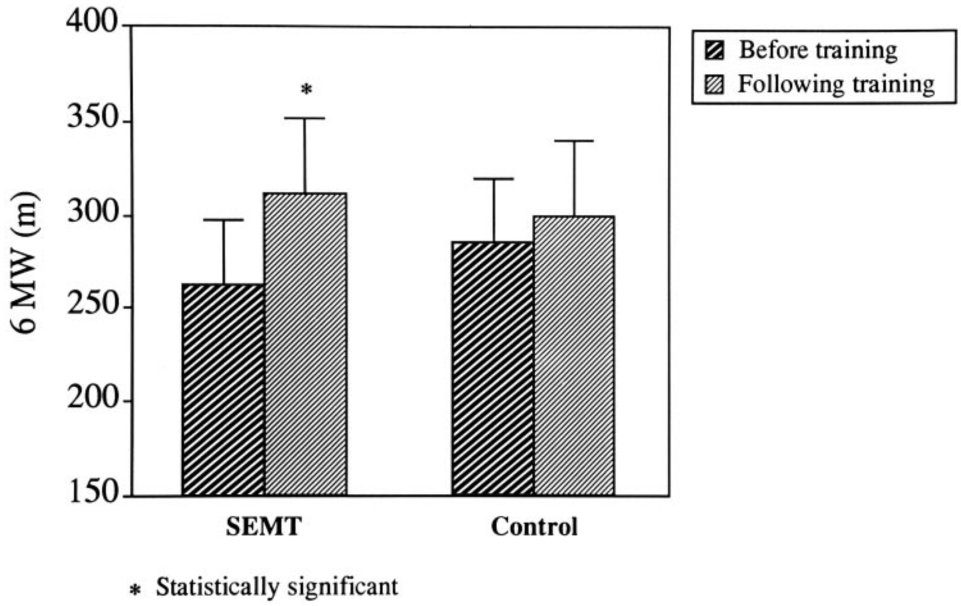

FIGURE 3. The distance walked in 6 min before and following the SEMT period.

components of the BDI (Table 2). Following the training period, there was a small but not significant increase in the focal score for the TDI (+ 0.4 ± 0.3, p = 0.34) in the study group and no change in the control group.

Discussion

This study shows that in patients with significant COPD, the expiratory muscles can be specifically trained with improvement of both expiratory muscle strength and endurance, and that the training results in increased exercise performance. Expiratory muscle recruitment has been observed, under different circumstances, in patients with COPD as well as in patients with asthma.[7,21] They were recruited during experimentally induced bronchoconstriction,[22] while submitting to expiratory resistance,[23] and at the end of the expiration,[24] resulting in a passive onset of the next inspiration. The mechanism and the results by which airflow limitation is followed by expiratory muscle recruitment are not completely clarified. Younes[25] pointed out that expiratory muscle contraction during expiration may be a nonspecific natural component of the response of the respiratory system to the increased respiratory stimulus. More recent data[22] suggest that abdominal muscle recruitment during expiration allows preservation of diaphragm muscle fiber length and the force-generating ability of the diaphragm at the onset of inspiratory muscle contraction, despite lung hyperinflation.

Besides airflow obstruction, many other features are present in patients with COPD, and one of these is respiratory muscle weakness. Although inspiratory muscle weakness is more pronounced than the expiratory muscle weakness in patients with COPD,[1] there are several reports showing that the expiratory muscle strength is impaired in most patients with significant COPD.[3,9,26] While the inspiratory muscle weakness is usually considered to be caused by hyperinflation placing the inspiratory muscles at a mechanical disadvantage, the expiratory muscles partake in the generalized muscle weakness observed in patients with COPD.[27] In addition to the expiratory muscle weakness, it was recently shown that the endurance of the expiratory muscles is decreased in patients with COPD.[9] This decrease was related to the severity of airflow obstruction and to the decrease of the strength of different muscle groups. These investigators have used both the incremental loading test and the constant submaximal load test for measuring the expiratory muscle endurance. We are using the incremental loading test to assess the endurance and not the measurement of the time breathing against a constant submaximal load, because it allows the subject to learn a breathing strategy, is not influenced by learning or choice of breathing, and is reproducible.[19]

There is, therefore, a rationale for hypothesizing that the impairment of the expiratory muscle performance would have clinically relevant implications. The decreased expiratory muscle performance was associated with reduced exercise tolerance and reduced quality of life in patients with COPD.[27] In addition, it is well documented that failure to cough efficiently is associated with expiratory muscle weakness.[28]

Several studies have shown that specific inspiratory muscle training may diminish the sensation of respiratory effort,[29] increase the capacity to walk, and improve the quality of life in patients with COPD.[30] It has also been shown[13] that training both inspiratory and expiratory muscles by normocapnic hyperpnea results in improved exercise performance, health-related quality of life, and dyspnea in daily activities.

The expiratory muscles were specifically trained in our patients with an increase in exercise performance. In previous settings other than COPD, expiratory muscle training tended to improve cough efficacy,[10] improve the perception of dyspnea in children with neuromuscular disease,[11] and reduce the sensation of respiratory effort during exercise in healthy subjects.[12] Therefore, if the decreased expiratory muscle performance is associated with reduced exercise tolerance in patients with COPD, it is

Table 2—*Baseline (BDI) and Following Training Values (TDI) for Dyspnea**

Variables	SEMT Group (n = 12) BDI	SEMT Group (n = 12) TDI	Control Group (n = 11) BDI	Control Group (n = 11) TDI
Functional impairment	1.7 ± 0.2	+ 0.2 ± 0.2	1.7 ± 0.2	− 0.1 ± 0.2
Magnitude of task	1.8 ± 0.2	+ 0.0 ± 0.2	1.6 ± 0.2	+ 0.2 ± 0.2
Magnitude of effort	1.6 ± 0.2	+ 0.2 ± 0.2	1.6 ± 0.2	− 0.1 ± 0.2
Focal score	5.1 ± 0.9	+ 0.4 ± 0.3	4.9 ± 0.7	0.0 ± 0.3

*Values are expressed as mean ± SEM.

rational to assume that in the trained subjects the increased expiratory muscle strength and endurance contributed to the improved performance at the end of the study. Since no other general exercise training was applied in our protocol, the improvement of the exercise performance should be attributed to the SEMT.

As for all types of muscle training, the training stimulus should be adequate to induce the appropriate physiologic response.[31] In our group of patients, the training load induced significant and adequate increase in the expiratory muscle performance. Cough efficiency was not evaluated in the present study. In addition, the present study is limited by the fact that it was performed only in normocapneic patients, with no comparison with other forms of training. However, the significant increase in the 6-minute walk test results in our study is encouraging, may suggest a better daily activities handling, and therefore SEMT may be considered in individual patients with COPD.

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