

Expiratory Training in Multiple Sclerosis

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Objective: To compare the effects of expiratory muscle training and sham training on respiratory muscle strength in patients with multiple sclerosis (MS).

Design: A randomized control trial; subjects were randomly assigned to either expiratory muscle training or sham training.

Setting: Training and measurement of respiratory muscle pressures were conducted in patients' homes. Weekly home visits were conducted to assure compliance with the training protocols and to obtain measurements.

Patients: Twenty subjects with clinically definite MS and decreased expiratory muscle strength entered the study; 10 subjects completed 3 months of expiratory training using a threshold training device and 5 subjects completed 3 months of sham training using the same device but without an expiratory training threshold load.

Measurement: Respiratory muscle strength was assessed at baseline and after 1, 2, and 3 months of training; maximal inspiratory and expiratory pressures were used as measures of respiratory muscle strength.

Results: There was a significant increase in expiratory muscle strength after 3 months of training when the expiratory training group was compared to the sham group ($p = .003$); no significant change in inspiratory muscle strength was observed.

Conclusions: The results of this pilot study suggest that the strength of the expiratory muscles of persons with MS can be increased through respiratory muscle training targeted to the expiratory muscles. Further research is indicated to determine if increasing the strength of the expiratory muscles in MS has an effect on clinical outcomes in this patient population.

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RESPIRATORY COMPLICATIONS are a major cause of morbidity and mortality in patients with multiple sclerosis (MS). A recent population-based study indicated that pneumonia and aspiration pneumonia are the most common disease-related causes of mortality in MS.¹ Aspiration and pneumonia secondary to bulbar weakness and immobility have long been recognized as common events in advanced MS.^{2,3} However, recent studies^{4,5} have found that expiratory muscle weakness is

common earlier in the course of MS than previously documented and that it occurs out of proportion to decreases in inspiratory muscle weakness. Expiratory muscle weakness has been observed in MS patients who are ambulatory and those who require assistive devices for ambulation, as well as those who are wheelchair-bound or bedridden.^{4,5}

Inability to generate an adequate cough is recognized as predisposing patients to respiratory complications and infection. Because a major function of the expiratory muscles is to produce a forceful cough, the expiratory muscle weakness observed in MS may be responsible in part for the complications seen in this population. Decreased expiratory muscle weakness may lead to these complications because of ineffective cough, retention of secretions, and inability to maintain a clear airway. Therefore, expiratory muscle training has the potential to increase the strength of the expiratory muscles and may provide a simple method to protect MS patients from these respiratory complications.

Efforts have been made to examine the effect of respiratory training on respiratory muscle strength or endurance in normal volunteers, subjects with chronic obstructive pulmonary disease (COPD),⁶⁻⁸ and in a small group of patients with neurological dysfunction.⁹⁻¹⁰ These studies have focused primarily on increasing inspiratory muscle strength or endurance; few studies have focused on increasing expiratory muscle strength or been directed toward those patients whose primary respiratory dysfunction is expiratory rather than inspiratory muscle weakness. In an effort to determine if the expiratory muscles in MS patients could be strengthened, this study compared the effect of expiratory training and sham training on expiratory muscle strength in patients with MS.

METHODS

An experimental study design was used. Patients who met inclusion criteria were randomly assigned to either the treatment (experimental training) group or to a control (sham training) group. Baseline pulmonary studies were obtained if a subject's history suggested that obstructive pulmonary disease might be present (a history of asthma or prolonged period of smoking). Patients with evidence of asthma or airway obstruction were excluded from the study. The study was approved by the appropriate institutional review boards.

Subjects

Subjects with clinically definite MS whose baseline maximal expiratory pressure (PE_{max}) values were between 45% and 60% of predicted were eligible for the study. They were informed about possible blind assignment to a sham group. Twenty subjects with a definite diagnosis of MS¹¹ were recruited for the study and randomly assigned to a training ($n = 10$) or sham training group ($n = 10$). However, only 15 subjects completed enough of the study to provide data for analysis, 10 in the experimental group and 5 in the control or sham training group. Reasons for attrition included family discord, placement of the patient in a nursing home, and general feeling of being too ill, too stressed, or too busy to participate.

The sample included 7 men and 8 women. Time since MS symptoms were first experienced was reported by subjects to range from 5 to 27 years (mean = 18.3, SD ± 6.6). Time since

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MS was diagnosed ranged from 4 to 25 years (mean = 14.1, SD \pm 6.6). Kurtzke disability scores ranged from 6.5 to 9.5. Nine of the 15 subjects reported being previous or current smokers; pack years in previous or current smokers ranged from less than a year to 40 years (mean = 15.7, SD \pm 13.7). Five (53.3%) of the women subjects and 5 men (46.7%) of the subjects were assigned to the experimental group. Age, years since onset of MS and diagnosis of MS, smoking history, and Kurtzke disability scores did not differ for subjects in the experimental and control groups. No subject experienced an exacerbation or change in MS symptoms during participation in the study.

Expiratory Muscle Training

The specificity and overload principles of exercise training¹² were employed to train the expiratory muscles. The *specific* target of training was the strength of the expiratory muscles. The *overload* principle was implemented by a high intensity exercise of short duration expected to strengthen the expiratory muscles.

Threshold respiratory muscle training devices⁴ were used for expiratory muscle training. To train the expiratory muscles, subjects had to generate a specific amount of positive pressure during expiration. The design of the threshold respiratory muscle training device eliminates the unreliable pressure loads possible with use of a nonlinear resistive breathing device.⁷

Experimental group. The threshold load of the training device was based on each patient's PEmax. Inspiration was not loaded. Other investigators have determined the initial threshold level by reducing the load from subject's PEmax by 10% with each failed attempt by the subject to complete the 3 sets of 15 repetitions of the training exercises. In this study, however, the fatigue that is so common in MS mitigated against this method. Instead, during the first training session an initial threshold level was established based on subject's PEmax values and increased or decreased on the basis of observations of the subject's ability to perform the training exercise and subject's report of difficulty doing so.

Once the training threshold load was determined, subjects were instructed to train their expiratory muscles seven days a week. They were asked to perform two complete training sessions per day at home, separated by a minimum of 4 hours between sessions. A complete training session consisted of three sets of 15 repetitions with 5 minutes of rest between each set. Subjects were instructed to breathe out against the expiratory threshold load with every other breath. The threshold load was increased periodically as PEmax developed by expiratory muscle contraction increased with training. Home visits were made weekly to assist patients with the protocol as needed and to assess and encourage their compliance with the procedures. At each visit, subjects were observed during performance of a complete training session. As the training proceeded and on the basis of subject's observed and reported ability to perform the respiratory training exercise, the threshold load was gradually increased.

Control group. The control group underwent sham respiratory muscle training for comparison. The control group received training using the identical respiratory muscle training device but configured to train the inspiratory rather than the expiratory muscles. Subjects were instructed to breathe in against the inspiratory threshold load with every other breath. The threshold load was increased periodically during the 3-month program but at very small increments too small to affect inspiratory muscle strength. Other than the difference in type of training exercise and level of threshold load, the control group underwent "training," testing, and follow-up in the same manner as the experimental group. Before beginning the study, all subjects

were informed that they had an equal chance of being in the respiratory muscle training group or a sham training group and were blind to group assignment. Testing and follow-up were identical to that of subjects in the experimental group.

Measures

Measures included baseline pulmonary function for screening if history suggested the presence of obstructive or other primary pulmonary disease, maximal inspiratory pressure (PI_{max}) and maximal expiratory pressure (PE_{max}),¹³ and demographic and clinical data (duration of MS, smoking history, Kurtzke score, etc). Patients were informed that personal and telephone contact would be maintained with them weekly during the training program to answer their questions about the protocol, obtain measurements of PI_{max} and PE_{max}, assess their compliance with the training program, make changes in the respiratory threshold training load as indicated, and note changes in their clinical status. Patients were asked to keep a daily record of their training sessions; these records were collected by the researcher during weekly visits to the patient's home.

Maximal respiratory pressures (PI_{max} and PE_{max}) were measured from residual volume and total lung capacity, respectively, by the method of Black and Hyatt.¹³ Values obtained by these measures are considered valid and reliable estimates of respiratory muscle strength and are strongly correlated with more direct measures of respiratory muscle strength in which intraesophageal pressure is recorded. PI_{max} is the maximal negative pressure which can be measured at the mouth after exhaling to residual volume and performing a maximal inspiratory effort against an occluded airway. PE_{max} is the maximum positive pressure which can be measured at the mouth after inhaling to total lung capacity and performing a maximal expiratory effort against an occluded airway. Standards for PI_{max} and PE_{max} appear in the literature.¹³ PI_{max} and PE_{max} were measured prior to initiation of training and every month of training for 3 months.

PI_{max} and PE_{max} were measured with a no. 2000 100-cm manometric pressure gauge.^b This gauge measures pressures from 0 to \pm 100cm of water in increments of 2cm. The pressure gauge was zeroed before each use. A plastic mouthpiece, 2.7cm in diameter, was connected to the pressure gauge. Tubing connected the pressure gauge to a three-way valve,^c and the three-way valve to the mouthpiece. One arm of the three-way valve is connected to the mouthpiece; the second arm is open to room air; the third arm is sealed with a rubber stopper but with a small leak created by inserting a 16-gauge needle. The small leak prevents generation of spuriously high pressures by the buccal muscles and assists subjects to maintain an open glottis during the measurements. Use of the three-way valve permits subjects to position and seal the mouthpiece before the maneuver is performed; this is intended to reduce the measurement errors associated with tremor or lack of hand coordination observed in some MS patients in the laboratory setting. Measurements were obtained with subjects seated and wearing a nose clamp.

With the three-way valve open to room air, the mouthpiece was inserted in the subject's mouth; subjects were asked to form a seal around the mouthpiece with their lips. For PE_{max}, the three-way valve was opened to room air and subjects inserted the mouthpiece in their mouth, forming a seal around it with their lips. They were asked to inhale to total lung capacity; the three-way valve was then turned to the closed position (connected to the gauge), and subjects were instructed to exhale with their maximal expiratory effort. For PI_{max}, subjects were asked to exhale to residual volume, the three-way valve was then turned to the closed position (connected to the gauge), and

Table 1: Mean Baseline PEmax and PImax in Experimental and Control Groups

	Baseline PEmax	Baseline PImax
Experimental Group	53.6 ± 14.9	47.6 ± 19.3
Control Group	63.2 ± 18.9	42.9 ± 11.1

Values reported as cmH₂O.

subjects were instructed to inhale with their maximal inspiratory effort. For measurements to be considered technically acceptable, no air leaks could be detected around the mouthpiece and subjects were required to maintain the pressure for a minimum of one full second. To minimize the effect of time of day on patients' level of subjective fatigue and measurements, all measurements were obtained on a subject at approximately the same time of day.

Achievement of PEmax and PImax (unlike many other clinical laboratory tests) requires motivation, practice, and effort. Numerous authors have demonstrated the effect of learning with repeated measures of PImax and PEmax in both normal subjects and those with airway obstruction.¹⁴⁻¹⁶ Therefore, to take into account learning or mastery of the technique of PImax and PEmax measurement, 10 measurements of PImax and PEmax were obtained on four occasions approximately 1 week apart before training was initiated. The mean PImax and PEmax values obtained at the fourth testing session were used as subjects' baseline. Because complete pulmonary function studies were not obtained on most subjects, no corrections¹⁷ were made in PImax and PEmax for increased residual volume or decreased total lung capacity.

Data Analysis

Unpaired *t* tests were used to examine differences in baseline PEmax and PImax values and differences in pretraining to post-training PEmax and PImax values. A *p* value of .05 was used to determine statistical significance.

RESULTS

Baseline PEmax values (reported in cmH₂O) ranged from 29.6 to 81.8 (mean = 56.8 ± 16.4) for the total sample. When compared to values predicted for them on the basis of age and gender,¹³ the percentage of predicted values ranged from 12.5% to 60% of predicted (mean = 36.9 ± 14.6). Baseline PImax values ranged from 24.2 to 80.4 cmH₂O (mean = 46 ± 16.7); percentage of predicted values ranged from 19.1% to 72.4% (mean = 45.8 ± 17.1). These pretraining values indicate inspiratory and expiratory muscle weakness in the total sample. Mean baseline PEmax and PImax values of the experimental and control groups are listed in table 1.

Although the experimental group had a baseline PEmax of almost 10 cmH₂O lower than that of the control group, by unpaired *t* tests the differences in the baseline PEmax and PImax values of the two groups were not statistically significant.

The mean of posttraining PEmax for the total sample was 69.3 (SD ± 19.6) with a range from 41.8 to 107.3 cmH₂O. Difference scores were calculated by obtaining the difference between the PEmax and PImax values obtained after 3 months of training and the baseline PEmax and PImax scores. The mean difference scores of the experimental and control groups are listed in table 2.

There was a significant difference in the change in expiratory muscle strength (PEmax) between the expiratory and control or sham groups with an increase of 19.4 cmH₂O in the experimental group and no increase in the control group. There was no significant difference in the PImax values of the control and experimental groups.

All patients in the experimental group experienced an increase in PEmax; the increase in PEmax values ranged from 2.8 cmH₂O to 35.9 cmH₂O. Fifty percent of the experimental subjects (*n* = 5) had increases in PEmax greater than 20 cmH₂O. Only one member of the control group experienced an increase in PEmax following training; that patient experienced an increase of 13.8 cmH₂O.

Anecdotal reports from study patients included their statements that through participation in the training program they had become more aware of their breathing and consequently deliberately took deep breaths periodically. Others indicated that their respirations had been shallow and that as a result of the training (or their participation in the study) their respirations had become deeper. Other patients reported that they were able to lie flat in bed without becoming as short of breath as previously, that their voices were described by others unaware of their participation in the study as stronger and louder than before training, and that they had fewer episodes of choking during eating. These unsolicited reports were obtained from subjects in both the experimental and the control groups.

DISCUSSION

The results of this pilot study demonstrate that a program of expiratory muscle training can increase expiratory muscle strength as measured by PEmax in patients with MS. While the effectiveness of inspiratory training has been demonstrated in healthy control subjects, those with respiratory disease, and in patients with spinal cord injury and muscular dystrophy, fewer efforts have focused on expiratory training. Increased expiratory muscle strength following expiratory muscle training has been demonstrated in normal controls and in patients with spinal cord injury. However, no previous effort has specifically examined the effects of respiratory training in MS or shown that expiratory muscle strength can be increased in this group of patients through expiratory muscle training.

The findings of this study suggest that decreased expiratory muscle strength observed in patients with MS may be due, at least in part, to deconditioning. Deconditioning of the expiratory muscles in MS may occur because their usual stimulus, strenuous activity, is often severely limited because of the fatigue, general muscle weakness, or balance problems associated with MS. The findings of this study suggest that this deconditioning can be reversed, again at least in part, through a respiratory training program targeted to the expiratory muscles. It is not known, however, if the increased expiratory muscle strength demonstrated in this study will persist, nor is it known if the expiratory muscle strength could be increased further by training for longer than 3 months.

While increased respiratory muscle strength is a desirable outcome of respiratory muscle training, a more important issue is its effect on clinical outcomes. Increased expiratory muscle strength in MS patients may result in a more effective cough and airway clearance, decreased work of breathing, and increased respiratory reserve. However, to date no study has addressed the effect of respiratory muscle training on patients' ability to generate an effective cough needed to clear and protect the airway and on the incidence of respiratory complications in

Table 2: Comparison of Mean Differences in Baseline and 3-Month Posttraining PEmax and PImax in Experimental and Control Groups

	PEmax*	PImax
Experimental Group	19.4 ± 9.9	3.3 ± 16.1
Control Group	-1.2 ± 11.1	9.2 ± 11.9

Values reported as cmH₂O.

* Unpaired *t* value = 3.65, *df* = 13, *p* = .003.

patients at increased risk for such complications. Further research with larger and more diverse samples is necessary to determine the effect of increasing expiratory muscle strength on clinical outcomes (cough effectiveness, frequency of respiratory complications) in patients with MS. Additionally, the effect of inspiratory muscle training or combined inspiratory and expiratory muscle training on cough needs to be addressed through research.

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Suppliers

- a. HealthScan, Inc., 870 Pompton Avenue, Cedar Grove, NJ 07009.
- b. Dwyer Instruments, Inc., PO Box 373-T, Michigan City, IN 46360.
- c. Model/catalogue no. 21043; Warren E. Collins, Inc., 220-T Wood Road, Braintree, MA 02184.