

Effect of Inspiratory Muscle Training in Patients With Multiple Sclerosis

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Objective: To evaluate whether inspiratory muscle training (IMT) improves inspiratory muscle strength, respiratory capacity, fatigue, and subjective perception of physical endurance in patients with advanced multiple sclerosis (MS).

Design: Randomized controlled trial.

Setting: Outpatient clinic in Sweden.

Participants: Fifteen severely disabled patients with MS, randomized to a training or control group.

Intervention: Seven patients trained with a Threshold inspiratory muscle trainer, twice every other day, with 3 sets of 10 loaded inspirations (40%–60% of patients' maximal inspiratory pressure [P_{imax}]) over a 10-week period.

Main Outcome Measures: Spirometry, P_{imax}, maximal expiratory pressure (P_{Emax}), clinical assessments, and questionnaires on the patients' fatigue severity and physical endurance were evaluated.

Results: After training, the P_{imax} ($P < .008$) and P_{Emax} ($P < .02$) increased in the training group. The improvement in P_{imax} after 10 weeks of training was higher than the improvement in the control group ($P < .01$) and was maintained 1 month after the training period ended. The training affected neither respiratory function nor the patients' symptoms.

Conclusions: IMT had a beneficial effect on inspiratory muscle strength in patients with MS and is recommended as a complement to ordinary physical training.

Key Words: Multiple sclerosis; Physical therapy techniques; Rehabilitation; Respiration.

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MULTIPLE SCLEROSIS (MS) is a chronic inflammatory disease of the central nervous system (CNS); this disease affects mostly young and middle-aged adults and is associated with selective destruction of the myelin sheaths. This leads to the formation of large demyelinated plaques dispersed throughout the CNS, with a predilection for the optic nerves, brainstem, spinal cord, and periventricular white matter. In particular, in cases with progressive disease, severe neurologic deficit axonal destruction and loss can be profound.¹⁻³ MS is

confirmed through laboratory tests. The disease presents either with an exacerbating-remitting pattern, which is characterized by periods of impairment followed by full or partial remission of symptoms, or with a chronic, progressive pattern. This latter pattern can be subdivided into progressive from the onset and secondarily progressive, in which there is a steady worsening of symptoms over time, with ataxia, visual loss, weakness, spasticity, fatigue, bladder dysfunction, and so on.⁴⁻⁶

When a neuromuscular disorder is progressive, symptomatic respiratory muscle weakness is inevitable. The MS plaques are often found in the brainstem and upper cervical spinal cord.⁷ Pathophysiology and clinical features of MS vary in each patient. As a result of the demyelinated plaques, abnormalities of speech and weakness of muscle groups responsible for speech and/or swallowing are common. In addition, patients with bulbar lesions may have both laryngeal and pharyngeal dysfunction, causing symptoms such as dysphonia, dysphagia, and aspiration.⁷ Severe respiratory muscle weakness can be expected in patients with MS who are severely paraplegic, and the weakness increases as the upper extremities become increasingly involved.⁸⁻¹⁰ Respiratory complications are a major cause of morbidity and mortality in patients with MS.¹¹ Aspiration and pneumonia secondary to bulbar weakness and immobility have long been recognized as common events in advanced MS.¹²

Inspiratory muscle weakness often occurs in neuromuscular disorders. It is sometimes associated with a chronic increase in arterial carbon dioxide tension.¹³ Immobility reduces lung volume and can lead to postural hypotension, constipation, urine retention, osteoporosis, depression, and deconditioning.¹³ Patients with MS show a poor exercise tolerance, with fatigue and dyspnea on exertion, which limits their ability to perform activities of daily living¹⁴ (ADLs).

Fatigue is a particular problem in patients with MS. Its mechanism and precise etiology remain unresolved,³ because fatigue does not correlate with the degree of neurologic impairment or disability in these patients.^{15,16}

Efforts have been made to examine the effect of training of respiratory muscle strength and endurance by using different resistive breathing devices. In several studies, a Threshold inspiratory muscle training (IMT) device has been used in patients with chronic obstructive pulmonary disease (COPD) or asthma to improve inspiratory muscle strength and endurance.¹⁷⁻²³ The usefulness of the IMT device in patients with neurologic dysfunction has been shown by several researchers^{24,25} who have explored the influence of this training method on inspiratory muscle strength and endurance. Few studies have, however, focused on increasing respiratory muscle function in patients with MS to improve respiratory function and/or the patients' symptoms.

This study evaluated whether 10 weeks of supervised training of inspiratory muscles in patients with MS would affect their respiratory muscle strength, respiratory capacity, and general well-being, as measured by indices such as fatigue and subjective perception of physical endurance, without causing any adverse effects. Furthermore, our aim was to establish

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whether any effects of training would be evident 1 month after training ended.

METHODS

Participants

The patients in this study were recruited from 3 rehabilitation outpatient clinics in Stockholm, Sweden. All patients met the criteria of Poser et al⁴ for the diagnosis of MS, presented with a progressive pattern of MS, and scored between 6.5 and 9.5 on the Expanded Disability Status Scale²⁶ (EDSS). This evaluation scale was used to describe symptoms and to quantify neurologic deficits, based on a neurologic examination. Patients who did not meet the diagnostic criteria, according to EDSS, scored 0.0 to 6.0, were excluded from the study, as were patients with chronic obstructive airways, asthma, emphysema, and cystic fibrosis. Also excluded were patients with heart insufficiency, patients with chronic pain, and patients with another diagnosis or other disorders. Patients who had difficulty in understanding instructions and patients who were already participating in other projects were likewise excluded.

Altogether, 22 patients with MS expressed interest in the study. The first contact between the examiner (JHN) and the potential participants was by telephone, for the purpose of assessing their physical and mental status, as determined by the EDSS, and to inquire about what medications they were taking—with special emphasis on their history of respiratory illness—and about their use of tobacco. We also wanted to establish whether the patients had medical problems or histories that were probably not related to MS. Two patients had had other diagnoses, such as stroke; 1 patient had rheumatism and chronic airway obstruction; 1 patient had another neurologic disorder and a probable MS diagnosis; and 2 patients said they were too busy to participate. These 6 patients were excluded from the study. In all, 16 patients met the inclusion criteria and were sent a letter assigning them an individual examination date at the clinic. The patients were randomized to a training (n=8) or a control (n=8) group. One patient in the training group dropped out after 4 weeks, having failed to cooperate, and was excluded from data analysis.

Data were analyzed for 15 patients (9 women, 6 men) between the ages of 37 and 61 years (mean age, 49y). All gave their informed consent to participate in the study, which was approved by the local ethics committee. The training group was composed of 6 women and 1 man. No patient had acute respiratory or cardiac failure at the time of the study, and none experienced an exacerbation or a relapse during the study. All patients were wheelchair bound, and 3 patients were essentially bedridden but were able to sit up for a few hours every day. Time since MS was diagnosed ranged from 3 to 35 years (mean \pm standard deviation [SD], 17 ± 7.8 y). Patients had disabilities ranging from ataxia to quadriplegia, and the median EDSS score was 8 (range, 6.5–9.0). Most patients showed laryngeal and pharyngeal dysfunction, as indicated by the symptoms of dysphonia, dysphagia, and aspiration. They required individual attention from 0 to 24 hours per day. Four patients reported being current or former smokers. EDSS score, age, medications, and smoking history did not differ for patients in the training and the control groups.

The patients' characteristics are presented in table 1. Most had undergone therapy with interferon-beta and baclofen and had also received physical therapy (PT)—which included balance, coordination, gait, transfer, and strength training, as well as range of motion therapy—1 to 2 times a week. The duration and intensity of PT was the same for all patients.

Table 1: Patient Characteristics and Pretraining Respiratory Function Measures of the Training Group (n=7) and Control Group (n=8)

Variable	Training Group, Median (Range)	Control Group, Median (Range)
Male/female	6/1	3/5
Age (y)	46 (37–49)	52.5 (38–61)
Diagnosis of MS (y)	12 (3–19)	20 (12–35)
EDSS score	7.5 (6.5–8.0)	8.0 (6.5–9.0)
FEV ₁ (L)	2.2 (1.0–3.3)	2.3 (1.3–5.0)
FEV ₁ (% predicted)	80 (40–100)	72 (43–116)
FVC (L)	2.7 (1.0–3.4)	2.6 (1.3–6.7)
FVC (% predicted)	78 (36–93)	69 (38–127)
VC (L)	2.4 (0.5–3.4)	2.1 (0.5–6.2)
FEV% ^a	83 (82–100)	88 (81–100)
PEF (L/s)	269 (126–335)	286 (101–711)

NOTE. No significant differences were observed between the groups.

Abbreviations: FEV₁, forced expiratory volume in 1 second; FEV%, forced expiratory volume in percent of FVC; FVC, forced vital capacity; PEF, peak expiratory flow; VC, vital capacity.

Evaluation

All tests were performed at the beginning and at the end of a 10-week period and again 1 month after the training ended. Respiratory muscle strength was assessed by measuring maximal inspiratory pressure (P_{imax}) and maximal expiratory pressure (P_{emax}), according to the method of Black and Hyatt,²⁷ by using a handheld mouth pressure meter (Micro MPM).^a The Micro MPM consists of a pressure transducer and electronic calculator with a liquid crystal display screen. The patient, while comfortably seated and wearing a nose clip, performed maximal inspiratory and expiratory efforts, starting from near residual volume and near total lung capacity, into an obstructed flanged mouthpiece with a small air leak to prevent generation of high buccal pressures. For measurements to be considered technically acceptable, no air leaks could be detected around the mouthpiece, and the patient had to maintain the pressure for least 1 second. All measurements were taken at approximately the same time of day to minimize the effect of time of day on patients' level of subjective fatigue.²⁸

Achievement of P_{imax} and P_{emax} in clinical laboratory tests requires motivation, practice, and effort. Numerous researchers^{28,29} have shown the effect of learning with repeated measures of P_{imax} and P_{emax} in both able-bodied people and patients with airway obstructions. Therefore, taking into account the learning of the technique of P_{imax} and P_{emax} measurement, the patients were verbally encouraged to achieve maximal strength and coordination so that baseline values could be obtained. The maneuver was repeated at least 3 times or until 2 reproducible efforts were obtained (ie, within 5% of each other). An interval of about 1 minute was allowed between the measurements to avoid short-term fatigue of the respiratory muscles. The reliability of maximal respiratory pressure has been described by several authors.^{30,31} The higher of 2 reproducible values was considered in the data analysis. P_{imax} and P_{emax} were expressed as absolute values in cmH₂O and as percentages of the predicted normal value, according to Wilson et al.³²

Respiratory function through dynamic spirometry was assessed, with the subjects sitting, by use of a handheld spirometer (Micro Loop).^a Pollard et al³³ have shown that the Micro Loop is reliable. The patients wore a nose clip during the test. The method has been previously described.³⁴ The vital capacity

(VC), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV₁), forced expiratory volume in percent (FEV%), and peak expiratory flow (PEF) were measured. The values were expressed as both an absolute value in liters and a percentage of the predicted normal value, according to the European Coal Community standards.³⁵ No patient had previous experience with spirometry. The patients were verbally encouraged to achieve maximal effort, and the best of 3 trials was accepted. The Micro MPM and Micro Loop were calibrated to meet the requirements of the American Thoracic Society³⁶ before and after the examinations.

Patients' subjective perceptions of fatigue were examined through the Fatigue Severity Scale (FSS), as described by Krupp et al.³⁷ The FSS score is established through answers to a questionnaire containing a 9-point test about both mental and physical fatigue. In this study, the FSS was used to detect clinical change in fatigue over time. Each item is scored from 1 to 7, with 1 indicating strong disagreement and 7 indicating strong agreement with each statement in the questionnaire. The mean score is obtained so that the test result range is 1 to 7. Predicted scores for healthy adults are expressed for this questionnaire. A high total score indicates severe fatigue.

Patients were asked to estimate their degree of perceived physical exertion on the Borg 6–20 Ratings of Perceived Exertion (RPE) scale³⁸ after they had bathed and dressed in the morning. The perceived physical exertion on the RPE scale was ranked from 6 (not strenuous at all) to 20 (extremely strenuous at the physical task or exercise level).

Inspiratory Muscle Training

The specificity and overload principles of exercise training were used to train the respiratory muscles, as described in the study by Smeltzer et al.³⁹ The specific target of training in our study was to strengthen the inspiratory muscles. The overload principle was implemented through high-intensity exercise of short duration twice every other day. A Threshold IMT device^b was used for IMT. The valve on this device blocks airflow until the patient generates sufficient inspiratory pressure to overcome the resistance provided by the spring-load valve. The threshold pressure is independent of airflow or breathing frequency. The pressure settings are adjustable in $-2\text{cmH}_2\text{O}$ increments (range, -7 to $-41\text{cmH}_2\text{O}$). The device has been evaluated in several studies.^{17-20,24,25}

Training Group

Before starting the training, the patients had a 1-week run-in period to become familiar with the Threshold IMT device. Each patient was asked to record home practice sessions in a logbook and to do the training at home for 10 minutes twice every other day, with at least 4 hours between each training session. Over a 10-week period, this totaled 70 training sessions. A complete training session consisted of 3 sets of 10 loaded inspirations, with a 1-minute rest between sets. The initial training load was submaximal, was based on 40% to 60% of the patient's P_{max}, and, at the end of the training session, was not to be perceived as more than 17 (very hard) on the Borg 6–20 RPE scale. Patients were encouraged to interrupt the training if they reached 17 before the end of the session. The perceived sense of 17 on the RPE scale was defined as very strenuous. Expiration was unloaded, and each patient was free to choose his/her respiratory rate. The patients were also asked to estimate degrees of perceived physical exertion on the RPE scale after bathing or dressing and to record the degrees in the logbook. Patients were asked to make a note of all their activities during the week that were not related to their ordinary ADLs.

The patients were visited in their homes every other week by the authors to exchange logbooks and to help them with logbook entries, as needed. During these visits, changes were made in the inspiratory threshold training load, as indicated by the P_{max} and RPE scale, and any changes in the patients' clinical status were noted. Furthermore, patient compliance with the procedures was assessed, and, at each visit, they performed a complete training session. Patients were assured that personal and telephone contact would be maintained with them weekly during the training program to answer their questions and to provide them with feedback. Patients in the control group were contacted repeatedly by telephone, but they were given no specific feedback about the study. Deep-breathing exercises were, however, a routine part of their ordinary physical therapy treatment.

Statistics

Descriptive nonparametric statistics were used to calculate median and range and to characterize variables. Mean and SD were used for variables with normal distribution. The Wilcoxon rank-sum test was used to compare the groups, and the Wilcoxon signed-rank test was used to characterize changes that took place after training in each group. Finally, the Spearman rank-order correlation coefficient was used to highlight the relation between the FSS and the EDSS. Statistical significance was defined as *P* less than .05.

RESULTS

Pretraining

All 15 patients passed the initial series of tests. The baseline respiratory muscle function did not differ between the groups, and the P_{max} and P_Emax values were significantly lower than predicted normal values. The mean P_Emax value was $54 \pm 31\text{cmH}_2\text{O}$ ($48\% \pm 17\%$ of the predicted value), and the mean P_{max} value was $53 \pm 30\text{cmH}_2\text{O}$ ($59\% \pm 25\%$ of the predicted value); they are presented with median values and range in table 2.

The baseline respiratory function values did not differ between the groups, and the observed values in all respiratory parameters were markedly reduced compared with predicted

Table 2: Pre- and Posttraining Values of Maximal Inspiratory and Expiratory Pressures, FSS Scores, and Borg RPE Scale Scores in 15 Patients With MS

Variable	Pretraining Median (Range)	Posttraining Median (Range)
Training group (n=7)		
P _{max} (cmH ₂ O)	42 (28–74)	67* (55–110)
P _{max} (% predicted)	58 (38–93)	92 (67–137)
P _E max (cmH ₂ O)	46 (36–58)	63† (44–80)
P _E max (% predicted)	49 (39–58)	68 (47–79)
FSS score	5.3 (2.5–5.9)	5.2 (1.8–5.9)
Borg RPE scale score	13 (9–16)	12 (8–15)
Control group (n=8)		
P _{max} (cmH ₂ O)	52 (15–120)	54 (10–126)
P _{max} (% predicted)	49 (21–113)	51 (14–119)
P _E max (cmH ₂ O)	51 (20–147)	51 (18–147)
P _E max (% predicted)	39 (22–99)	38 (20–99)
FSS score	4.2 (2.8–6.0)	5.1 (2.0–6.7)
Borg RPE scale score	14 (9–17)	14 (10–17)

NOTE. Borg RPE scale score was measured after washing and dressing in the morning.

**P*<.008; †*P*<.02.

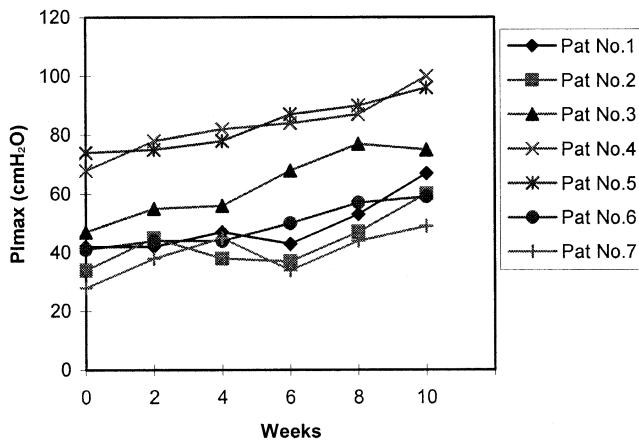


Fig 1. P_{imax} (cmH₂O), measured by mouth pressure meter, from baseline to 10 weeks of IMT in 7 patients with MS. Abbreviations: Pat, patients.

normal values. The mean FVC was 2.7 ± 1.5 L, the mean FEV₁ value was 2.3 ± 1.1 L, the mean VC was 2.5 ± 1.4 L, and the mean PEF was 292 ± 152 L/s. All are presented with median and range in table 1.

The baseline FSS score did not differ between the training group (mean, 5.0 ± 1.3) and the control group (mean, 4.5 ± 1.3), but their scores were significantly higher than scores for able-bodied healthy adults (mean, 2.3 ± 0.7).³⁷ Baseline subjective perception of physical endurance in the morning after bathing and dressing, as rated on the RPE scale, did not differ between the training group (median, 13; range, 9–16) and the control group (median, 14; range, 9–17). There was no correlation between EDSS and FSS scores.

Posttraining

Respiratory muscle function, as evaluated by the P_{imax}, improved after 10 weeks for the patients in the training group ($P < .008$) (fig 1), but it remained unchanged in the control group. P_{Emax} was also improved for patients in the training group ($P < .02$), but did not change in the control group (table 2). The improvement in P_{imax} after 10 weeks was significantly higher than the improvement in the control group ($P < .01$), but the improvement in P_{Emax} failed to reach statistical significance between the groups. Figure 2 shows the median P_{imax} percentage of predicted normal values in both groups over time. The improvement in P_{imax} percentage of predicted normal values remained unchanged in the training group after 1 month, compared with the posttraining values (fig 2).

Respiratory function values remained unchanged in the training group after 10 weeks and did not differ between the groups.

The mean FSS scores were 4.7 ± 1.4 in the training group and 5.6 ± 1.4 in the control group. No significant differences could be found between the groups. The score of subjective perception of physical endurance in the morning after bathing and dressing did not change after training compared with baseline scores in both groups. There was no evidence of enhanced activities during the week that were not related to the patients' ordinary ADLs, as perceived by the patients. No complications were reported or observed during the 10 weeks.

DISCUSSION

In this study, specific inspiratory threshold loading training, twice every other day, by 3 sets of 10 loaded inspirations

(40%–60% of P_{imax}) over a 10-week period, improved the P_{imax} and P_{Emax} ($P < .008$, $P < .02$, respectively) in the training group. The improvement in P_{imax} was higher than that in the control group ($P < .01$), and the benefits of the 10 weeks of supervised training were still seen 1 month later. Inspiratory muscle training did not affect respiratory parameters, such as FEV₁, FVC, VC, PEF, and FEV%, nor were its benefits reflected in the FSS questionnaires or the patients' subjective perception of physical endurance after bathing and dressing in the morning. No correlation could be found between EDSS and FSS scores.

Respiratory Muscle Function

Baseline P_{Emax} ($48\% \pm 17\%$) was more affected than was baseline P_{imax} ($59\% \pm 25\%$), and both these values were significantly lower than predicted normal values. This finding has previously been described by Smeltzer et al.⁸ Paralysis in advanced MS is disposed toward ascending slowly from the lower extremities to the upper extremities.⁸ As a result, the muscles primarily affected are the expiratory muscles, followed by the abdominal and intercostal muscles, and, finally, the inspiratory muscles, including accessory inspiratory muscles in patients with quadriplegia and who are bedridden.⁸

In this study, patients showed a restrictive respiratory pattern. Their immobility, fatigue, reduced respiratory function, tobacco use, dysphagia, aspiration, and use of medication reinforced their primary restrictive respiratory patterns. Therefore, sustained treatment that combines physical and respiratory muscle training should be initiated early to preserve respiratory function and to avoid aspiration pneumonia. The importance of combined physical training and respiratory muscle training has been confirmed in several studies of patients with asthma and COPD.^{19,20}

Previous studies^{39–41} have shown the effect of respiratory muscle training and/or expiratory muscle training to improve respiratory muscle strength and coughing ability in patients with MS. To our knowledge, no other studies have been published concerning inspiratory muscle training in patients with MS. To obtain an effective cough, a deep inspiration, elastic recoil, abdominal muscle pressure, and glottis closure are needed.¹³ In this study, the patients had paralysis or weakness in the expiratory muscles, as indicated by the reduced P_{Emax}. Most of the patients also showed laryngeal and pharyngeal dysfunction and, thus, an impaired glottis function and difficulty in breathing as deeply as needed to produce an effective

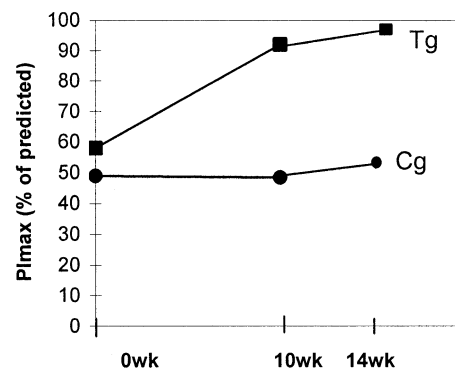


Fig 2. P_{imax} percentage (median) of predicted normal values, measured by mouth pressure meter, from baseline to after training (10wk) and 4 weeks after training (14wk) in the training group (Tg) and the control group (Cg).

cough. The coughing effectiveness might have been improved by the IMT, just as the P_{imax} and P_{Emax} improved. Interestingly, our patients showed a strong coughing reflex, which may have been caused by retention in the trachea. Unfortunately, this reflex may be impaired in the later stages of MS and in patients who are unconscious. Gosselink et al⁴¹ studied the effect of expiratory muscle training in patients with MS with approximately the same level of neurologic deficit as in our study (median EDSS score, 8.5; range, 6.5–9.5), using a resistive respiratory device. They showed improvement in both the P_{imax} and coughing in the training group, which reinforces the fact that effective inspiration is an important part of the ability to cough.

Physical endurance results in our study were dissimilar to those in a study by Klefbeck et al²⁴ of patients with polio, who showed improvement in the performance of ADLs after inspiratory muscle endurance training with an IMT device. This difference may be because patients in our study were more affected by neurologic disorders (with 70% of patients wheelchair bound and 30% bedridden) and the appearance of fatigue. The patients with prior polio were also users of part-time assisted ventilation and used the assisted ventilation before and after the training program; also, the designs of the 2 studies differed. In our study, no patient experienced dyspnea while performing this kind of activity, because all patients reached the level of fatigue before dyspnea set in, an observation also seen by Smeltzer et al.⁸

The improvement in inspiratory and enhanced expiratory muscle strength in the training group was apparent after 6 weeks, and significant changes were found after 10 weeks of training. The improvements continued after 10 weeks for 4 patients who continued the training protocol, but it did not change in the other patients. The other 3 patients in the training group continued their IMT periodically after 10 weeks, which was not difficult because of its training design (it was short and did not require much time). The subjective outcome of interest in this study was that the patients in the training group reported that after 10 weeks of IMT, deep inspiration was easier to perform. They thought that the training was most effective and was a good way to resist the symptoms of MS; furthermore, they were more confident and more motivated to do additional activities. All patients in the training group knew that training with the IMT device was complementary to other physical training. Most of the patients were restricted to a wheelchair or to bed much of the time and were limited in their physical activities because of weakness, an increased body temperature as a result of such activities, and a worsening of the fatigue symptom. This has also been reported in previous studies.^{10,14} In this regard, our patients were not able to reach optimal effects of the physical activities; therefore, additional respiratory training could be beneficial for them. To ensure proper training load and no adverse effects, careful assessment of patients is recommended.

A limitation of this study was our assessment of baseline values by spirometry and mouth pressure measurements, because both methods are effort and motivation dependent. Although the maneuvers were repeated at least 3 times until no further enhancement was observed, careful instruction was given, and patients were well motivated. However, it was sometimes difficult to achieve full cooperation and coordination from all the patients. Consequently, the observed P_{imax}, P_{Emax}, and respiratory function values may have been underestimated.

To determine the number of maximal mouth pressure maneuvers and obtain a reproducible value of P_{imax} and P_{Emax} in patients with COPD who are untrained and inexperienced in

such maneuvers, Fiz et al²⁹ recommend that a minimum of 9 technically acceptable maneuvers should be performed. Smeltzer and Lavietes³⁰ assessed the reliability of P_{imax} and P_{Emax} in a group of healthy controls and patients with MS and concluded that 3 maneuvers were needed to obtain a reproducible value in the former group and more than 3 maneuvers were necessary for patients with MS. Previous studies^{9,14} have stated that performing a respiratory function test can be laborious and stressful for patients with MS and that, in fact, such patients show a poor activity tolerance and often complain of fatigue. Therefore, respiratory function tests should be singly performed in these patients because of the rapid onset of fatigue. The patients in our study had a manifest and more severe neurologic deficit than did those in the study by Smeltzer.³⁰ Our patients performed the maneuvers at least 3 times and mentioned fatigue often during or after the test. The patients were, however, probably highly motivated, because they were self-enrolled in the respiratory training study. This high level of motivation may be the most apparent explanation for the high reliability in this study. Variation resulting from daytime fatigue was avoided by testing each patient at the same time each day.

The questions remain whether the threshold inspiratory training load and the training intensity were too low or too high and whether the training period needs to be extended to achieve improvement in the level of physical activity and fatigue severity. This study's purpose was to strengthen inspiratory muscles; however, the variables of physical activity and fatigue severity might be associated with endurance rather than strength training of inspiratory muscles. The number of patients in the training group was small, which can be explained because the number of MS survivors at such a high level of disability is not large (approximately 20% of the total MS patients in the selected region). A multicenter trial would be necessary to obtain a larger number of participants.

CONCLUSION

The MS patients in this study, with its randomized, controlled trial, showed a significant improvement of inspiratory muscle strength after 10 weeks of supervised training. The improvements were evident 1 month after the study ended.

It would be of interest to do a 1-year follow-up to establish whether the positive outcomes are still present. Furthermore, the optimal training stimulus needed to elicit a clinical benefit in physical activity and fatigue severity is not known in patients with MS. However, this study should provide a better understanding of respiratory muscle weakness and patients' limited capability resulting from severe handicap and fatigue and should, therefore, enable therapists to design more effective physical and respiratory muscle training protocols.

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Suppliers

- a. Micro Medical Ltd, 6 Ambley Green, Gillingham Business Park, Kent ME8 0NJ, UK.
- b. Health Scan Products Inc, 908 Pompton Ave, Unit B2, Cedar Grove, NJ 07009-1292.