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Breathing-enhanced upper extremity exercises for patients with multiple sclerosis

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Objective: To explore the effectiveness of breathing-enhanced upper extremity exercises on the respiratory function of patients with multiple sclerosis.
Design: Randomized controlled study of six-week duration.
Subjects: Forty patients with multiple sclerosis (age 39.2 ± 7 years; Kurtzke Expanded Disability Status Scale scores: 4.51 ± 1.55) randomly divided into two groups.
Methods: The training group followed a six-week home training programme designed to strengthen accessory respiratory muscles. Controls performed no exercises. All subjects submitted to baseline and post-training tests of spirometry, respiratory muscle strength and 6-minute walking. They were also assessed with pulmonary dysfunction and exertion fatigue indices.
Results: Spirometry revealed clear improvement in forced expiratory volume in 1 second (FEV_1) (+13%, $P = 0.003$) resulting in higher FEV_1/FVC (forced vital capacity) (+8.5%, $P = 0.03$). Maximal inspiratory pressure (P_{Imax}) increased by +7.1% but not significantly. Maximal expiratory pressure (P_{Emax}) and FVC were significantly higher (by +7.1%, $P = 0.0066$ and +4.8%, $P = 0.036$ respectively) with respect to baseline measures. Pulmonary dysfunction was reduced (−9%, $P = 0.002$) while 6-minute walking distance was longer (+16%, $P = 0.029$) at equal exertion fatigue level.
Conclusions: The programme improved most pulmonary performance measures and had clinical significance. Its sustained application may prevent respiratory complications frequently observed in the later stages of multiple sclerosis.

Introduction

Multiple sclerosis is a chronic, progressive disease caused by the demyelination of the central nervous system.[1,2] Depending on the localization of the lesions, respiratory impairments such as respiratory muscle weakness, bulbar function impairment and breathing control abnormalities are commonly seen.[3] Respiratory failure secondary to demyelination of respiratory centres is rarely observed in multiple sclerosis. However, in the terminal stages of the disease, pulmonary complications such as aspiration pneumonia, atelectasis or acute respiratory deficiency significantly contribute to mortality.[3,4]

Previous studies confirmed the impairment of pulmonary functions even during the early stages of

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multiple sclerosis[5,6] and point to manifest expiratory muscle weakness in more impaired patients with multiple sclerosis.[7–9] Remarkable success with supervised threshold training specifically targeting the main respiratory muscles has been reported.[7,10–12]

The present study explores a different approach that involves attempting to replicate for multiple sclerosis patients the reported improvements of pulmonary function in cases with chronic obstructive pulmonary disease (COPD) as a consequence of respiratory exercises performed.[13–15] An unsupervised home training programme using breathing-enhanced upper extremity exercises principally targeted to strengthening the accessory respiratory muscles[16] was applied and its effectiveness on improving the pulmonary functions of patients with multiple sclerosis evaluated.

Patients and methods

Sixty-two patients clinically diagnosed with definite multiple sclerosis according to Poser criteria[17] were invited to the study from the outpatient clinic of a neurology department. Fifty patients agreed to participate. Cases diagnosed with any pulmonary disease such as COPD, tuberculosis or chronic bronchitis were excluded. No patient in a period of multiple sclerosis relapse or with bulbar dysfunction known to cause respiratory impairment was admitted to the study after clinical evaluation which also included magnetic resonance imaging (MRI) findings.[3] After exclusions, decided by the same neurologist, the remaining 40 patients and their families were briefed on the study aims and protocols; their informed consent were taken.

Study design

Recruits were stratified by gender only and randomly divided into two equal-sized training and control groups by the study supervisor using a random number table. Each recruit's registration number was sealed in an opaque envelope; after shuffling the set, a random number in sequence from the table was assigned to each envelope, the parity of which was used for group selection (even: training, odd: control). All patients underwent a series of neurological (by the same neurologist), non-invasive pulmonary (spirometry and mouth pressure tests, each performed by separate cardiopulmonary physiotherapists) and endurance tests (by the evaluating physiotherapist) for baseline evaluation.

The training group followed a six-week home training programme assisted by an illustrated brochure (which can be obtained from the corresponding author) and was monitored weekly by the trainer physiotherapist by recalls to hospital for checking compliance with the assigned exercise schedule. The control group members had no such exercises assigned. The tests were repeated for all patients six weeks after initial evaluation with the same data collectors who were all blinded to both groups; only the study supervisor had knowledge of the patients' group assignments. The flowchart of the study is given in Figure 1.

Following their post-study assessment, all control group members were fully informed on the programme applied to the training group. Sixteen of the waiting list patients requested and were supplied with the prepared exercise brochure and given necessary instructions for their own home training.

Training protocol

The home training programme consisted of breathing-enhanced upper extremity exercises performed once per day. These included all the relevant procedures involving arm, shoulder and trunk

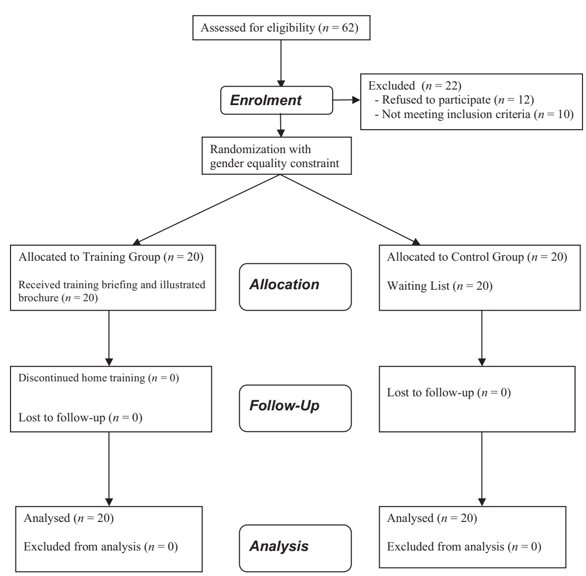

Figure 1 The flowchart of the study.

motions recommended by Watchie[16] and are detailed in Appendix 1.

Patients were instructed and trained to use deep nasal inspiration and forced oral expiration in the exercise sequence during an initial instruction session which lasted about 1 hour. This exercise sequence was initially estimated by the trainer physiotherapist to last 30 minutes for the average patient. Patients were warned to avoid exhaustion by resting temporarily at will between exercises, to demand assistance when necessary for safe execution of the motions and to record time spent exercising on a calendar chart included in the brochure.

Tests and parameters

Each patient's height and weight were measured and their body mass index calculated. Clinical history and demographic data were obtained from medical files. Table 1 shows no significant differences initially existed between the training and control group demographical, physical and neurological characteristics.

Neurological examination

The standard Kurtzke Expanded Disability Status Scale (EDSS) was used to describe neurological status.[18] The EDSS provides one score ranging from 0 (normal neurological findings) to 10 (death from multiple sclerosis). All EDSS scores were assessed with the same neurologist.

Pulmonary function tests

Spirometric tests using a dry spirometer (Vitalograph, Buckingham, UK) were repeated three times and best trial results reported. Parameters measured and converted into predicted value percentages[19] were the forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1), from which the FEV_1/FVC ratio was computed.

Respiratory muscle strength

Maximal inspiratory (P_{Imax}) and expiratory (P_{Emax}) pressures were measured (Micro-MPM; SensorMEDICS, Yorba Linda, CA, USA) four times with 2-minute intervals for each patient with the maximal readings retained and normalized to predicted values.[20]

All respiratory tests were performed with patients in sitting position by cardiopulmonary physiotherapists.

Pulmonary dysfunction index (PDI)

PDI, a predictor index of respiratory dysfunction for patients with multiple sclerosis,[21] comprises clinical

Table 1 Baseline characteristics of participants

Parameter	Training group	Control group	*P*-value[a]
Gender (male/female)	12/ 8	12 / 8	Identical
Age (years)	40.3 ± 6	38.1 ± 7	NS
Height (cm)	164 ± 7.2	166 ± 12	NS
Weight (kg)	67.9 ± 12	65.6 ± 11	NS
Body mass index (kg/m^2)	25.0 ± 3	24.0 ± 4	NS
Multiple sclerosis duration (years)	9.8 ± 5.6	9.0 ± 4.6	NS
Multiple sclerosis course (RR/PP/SP)	4/5/11	8/3/9	NS[b]
EDSS (0–10)	4.85 ± 1.3	4.18 ± 1.7	NS
Ambulation (full/assisted/wheelchair)	8/11/1	10/9/1	NS[b]
FVC (L) [% predicted]	3.65 ± 1.09 [91 ± 17]	3.83 ± 1.05 [93 ± 13]	NS
FEV_1 (L) [% predicted]	2.85 ± 0.98 [86 ± 18]	3.21 ± 0.82 [94 ± 11]	NS
FEV_1/FVC (%) [% predicted]	78 ± 11 [95 ± 13]	84 ± 9 [102 ± 9]	0.040
P_{Imax} (cmH_2O) [% predicted]	64.1 ± 25 [72 ± 26]	73.3 ± 19 [84 ± 17]	NS
P_{Emax} (cm H_2O) [% predicted]	69.7 ± 24 [56 ± 12]	74.8 ± 23 [62 ± 15]	NS
6MWT (m) [% predicted]	268 ± 126 [43 ± 21]	376 ± 159 [55 ± 23]	NS
Borg Scale (6–20)	15.0 ± 2.3	13.8 ± 1.9	NS
Pulmonary dysfunction index (4–11)	5.65 ± 0.76	5.55 ± 0.60	NS

All data are presented as mean ± SD.
RR, relapsing remitting; PP, primary progressive; SP, secondary progressive; EDSS, Expanded Disability Status Scale; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second; P_{Imax}, maximal inspiratory pressure; P_{Emax}, maximal expiratory pressure; NS, not significant.
[a]Smith-Satterthwaite corrected two-tailed Student's *t*-test was used unless indicated.
[b]Chi-squared test.

signs that include a weakened cough as rated by the examiner, the patient's ability to count on a single exhalation and patient's report of a weak cough and difficulty clearing pulmonary secretions. The summed PDI score is classified as low (4–5), medium (6–8) and high (9–11) with higher scores correlating with increasing respiratory difficulties.

Six-minute walk test (6MWT)

The distance covered by patients who were instructed to walk under supervision at their fastest pace twice for 6 minutes in a measured corridor was recorded. One 30-minute rest period was granted between the walks and the best result retained and normalized to predicted values.[22,23]

Rating of perceived exertion

The Borg Scale[24] ranging from 6 (no breathlessness nor fatigue) to 20 (exhaustion) describing the subjective feeling of the required effort intensity was used. Subjects were questioned immediately after the second 6MWT completion.

Statistical methods

Following baseline intergroup difference analysis that was carried out after final tests, the effectiveness of the applied programme was evaluated by statistically analysing post-training group changes. For quantitative data Smith-Satterthwaite corrected two-tailed Student's t was used; non-parametric data were subjected to chi-squared test. Outcome measures below 95% confidence level threshold were considered as not significant. Investigation of all possible intra- and inter-factor parameter dependencies used Pearson's linear correlation analysis with maximum $P = 0.01$ threshold decision level.

Results

The baseline and final outcome measures are shown in Table 2.

Clinical changes

The mean EDSS of all participants was 4.51 ± 1.55, indicating moderate disability level. Final assessment showed EDSS score changes were minor and not

Table 2 Post-training changes in multiple sclerosis patients

Parameter	Training group				Control group				*P*-value[a]
	Base line	Final	Change	% change	Baseline	Final	Change	% change	
EDSS (0–10)	4.85 ± 1.3	4.63 ± 1.3	−0.23 ± 0.44	−4.0%	4.18 ± 1.7	4.25 ± 1.8	+0.08 ± 0.37	+1.1%	NS
FVC	91 ± 17	95 ± 16	+4.3 ± 8.4*	+4.8%	93 ± 13	92 ± 14	−0.4 ± 8.5	−0.3%	0.112[b]
FEV_1	86 ± 18	96 ± 13	+10.6 ± 11	+13%	94 ± 11	94 ± 13	+0.3 ± 11	+0.3%	0.003
FEV_1/FVC	95 ± 13	102 ± 7	+8.0 ± 11	+8.5%	102 ± 9	103 ± 8	+0.8 ± 10	+0.4%	0.030
P_{Imax}	72 ± 26	77 ± 29	+5.1 ± 12	+7.1%	84 ± 17	85 ± 19	+1.0 ± 10	+1.2%	NS
P_{Emax}	56 ± 12	62 ± 18	+6.9 ± 9.5**	+13%	62 ± 15	64 ± 17	+2.3 ± 7.9	+3.7%	0.111[b]
6MWT	43 ± 21	47 ± 22	+4.9 ± 5.3	+13%	55 ± 23	51 ± 21	−3.1 ± 6.8	−4.6%	0.029
Borg(6–20)	15.0 ± 2.3	14.5 ± 2.3	−0.50 ± 1.3	−3.2%	13.8 ± 1.9	13.9 ± 2.0	+0.14 ± 1.2	+1.0%	NS
PDI (4–11)	5.68 ± 0.83	5.15 ± 0.75	−0.53 ± 0.39	−9.0%	5.55 ± 0.60	5.45 ± 0.60	−0.10 ± 0.38	−1.8%	0.002

All data presented as mean ± SD and are expressed as percentage of predicted except where units or scores are explicitly indicated.
EDSS, Expanded Disability Status Scale; FVC, Forced Vital Capacity; FEV_1, forced expiratory volume in 1 second; P_{Imax}, maximal inspiratory pressure; P_{Emax}, maximal expiratory pressure; PDI, Pulmonary Dysfunction Index; NS, not significant.
[a]Smith-Satterthwaite corrected two-tailed Student's t-test was used.
[b]Borderline significance (trend): $*P = 0.0358$ when compared with training group baseline FVC; $**P = 0.0066$ when compared with training group baseline P_{Emax}.

significant in both groups. No multiple sclerosis relapses have been observed nor any other diseases reported by the subjects during the study period.

Spirometry

Spirometric data means were around 10% below normal values, which are clearly not at pathological levels. FEV_1/FVC ratios were near normal, negating any suspicion of airflow obstruction.[25] Training group post-training improvements were observed for all spirometric parameters. Control group values were unchanged.

Respiratory muscle strength

Baseline mean P_{Imax} and P_{Emax} values of the participants show moderate loss (−23% and −41% respectively, $P < 0.001$) of inspiratory and expiratory muscle strength. Post-training increases in P_{Imax} and P_{Emax} mean values for the training group are not significant when tested against those found for the control group. However, when compared with the training group baseline data, the improvement in P_{Emax} is statistically significant ($P = 0.0066$).

Pulmonary dysfunction

Subjects had low to medium level initial pulmonary dysfunction (average PDI 5.58 ± 0.69). Final evaluation indicated $-9.0\% \pm 7\%$ significant decrease of PDI for the training group while the control group PDI scores remained stationary.

Endurance and perceived exertion

After training, significant progression of 6MWT results was measured in the training group while the control group performance regressed. Borg scores for both groups were unchanged. Post-training FVC changes in the training group were correlated with 6MWT differences ($r = +0.57$, $P < 0.005$).

Exercise compliance

Returns of the patient-annotated daily exercise calender charts indicate that most patients (85%) affirmed full compliance with the programme, with a 94% ± 10% scheduled exercise completion rate. Mean time spent for the completion of the full exercise sequence, as recorded by the patients and including resting time, was 31 ± 10 minutes. Only one wheelchair-bound patient, who also omitted movement 10 described in Appendix 1, reported need for assistance during exercising.

Discussion

This study shows that a simple and unsupervised home training programme can effectively enhance the pulmonary functions of patients with multiple sclerosis. Although the disability status (EDSS scores) remained unchanged, very significant improvements in 6-minute walking and spirometric tests were achieved while success in increasing mouth pressures was more limited.

Respiratory muscle weakness, especially in expiratory muscles, is frequently observed in patients with multiple sclerosis with higher level of functional disability levels[7,9,26] (average EDSS scores 8.5, 6.5 and 7.0 respectively) and is perceptible even in patients with less disability[5,6] (average EDSS scores 5.3 and 4.3 respectively). Closely supervised threshold training programmes have achieved significant improvement of P_{Emax} (+19% to +36%) and P_{Imax} (+36% to +39%) for severely disabled patients (with average EDSS scores 6.0 to 9.5)[7,10,11] with notable retention rates observed 1–3 months after their cessation.[7,11]

The present work tests a different approach. It is known that respiratory exercises improve tidal volume, inspiratory capacity and coughing effectiveness; their benefit on respiratory muscle weakness caused by neurological disorders is widely recognized.[27] Meanwhile, upper extremity exercises have been shown to be effective in respiratory rehabilitation especially for patients with COPD.[13,14] Patients with multiple sclerosis are more commonly affected in their lower extremities[2] and can easily perform respiratory and upper extremity exercises. Based on these findings, the home training programme design was based on breathing-enhanced upper extremity exercises for strengthening shoulder girdle, sternocleidomastoid, intercostal and abdominal muscles which assist respiration.[16]

Baseline spirometric test results of our patients were below but close to normal values as reported in previous studies.[8,9,26] After training, these measurements still significantly increased, almost reaching normal expected values from a healthy population. Our method seems to be more effective for improving pulmonary functions than respiratory muscle training programmes which did not report increases in spirometric tests.[7,11] In addition, the significant decrease in the PDI scores of the training patients shows clinical effectiveness for our programme which matches similar PDI improvements reported by threshold training method for more disabled patients.[7]

We found baseline P_{Imax} and P_{Emax} were moderately reduced in concordance with previous reports.[5,6] Progress achieved in maximal mouth pressures by training was not as strong as that obtained by threshold training programmes.[7,10,11] This should not be surprising for P_{Imax} since the training design did not include threshold training. The increase obtained for P_{Emax} was stronger, indicating some training effectiveness for the expiratory muscle strength. This may have been caused by the abdominal muscles strengthening and expiration enhanced with forward and sideway trunk motion.

Besides improving respiratory functions, the programme effects were also noticeable in the endurance level of the subjects, which is commonly measured in clinical practice and pulmonary rehabilitation research by 6MWT. Similar improvements in 6MWT were also obtained in patients with COPD by pulmonary rehabilitation.[28,29] The interrelated changes observed in FVC and 6MWT suggest that part of the increase in endurance may be attributed to FVC improvement noted in the training group. Also, it has been suggested that improved upper limb and accessory respiratory muscle functions are responsible for the increased ventilatory capacity observed in COPD patients during the 6MWT.[30] Our training exercises specifically targeted these muscles and the same mechanism may have positively affected the 6MWT results of our patients with multiple sclerosis.

The exertion level induced by 6MWT as measured by Borg scores did not significantly improve in the study group patients; but their perceived fatigue was still slightly less despite the significantly longer average distance covered during the final 6MWT.

In the present study, the retention success at term of the improvements achieved and the influence of longer periods of training could not be tracked due to operational and patient constraints; however the successful retention rates recorded in previous threshold training studies[7,11] may be expected with the present method as well. Gender distribution was not typical of multiple sclerosis which has a male/female = ½ incidence ratio,[1] but no gender-related variance or correlations were detected in baseline parameters nor in post-training variations.

The apparent success of an unsupervised home training programme in significantly improving most pulmonary performance criteria is encouraging. This programme may be complemented, whenever needed, by supplemental supervised threshold training in more severe cases. Conversely, this programme may be recommended to patients who underwent threshold training to further enhance respiratory functions and improve their retention. The continuous, albeit at a reduced rate, practice of such exercises in the framework of inexpensive and easily applicable home training or group exercise programmes may, in the longer term, help to reduce the risk of serious respiratory complications frequently observed during the later stages of multiple sclerosis. This potential longer term benefit is under investigation by the authors.

Clinical messages

- Unsupervised breathing-enhanced upper extremity exercises improve respiratory functions of patients with multiple sclerosis.
- Further follow-up study is necessary to evaluate the longer term potential benefit of continued exercising on reducing respiratory complications in multiple sclerosis.

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Appendix 1 – Training sequence for the breathing-enhanced upper extremity exercises

	Starting position	Starting movement	Return movement	Repeat/follow
1.a	Sitting on a chair	Inspiration while flexing both arms up and over the head	Expiration while returning the arms to the sides	
1.b		Inspiration while abducting both arms	Expiration while returning arms to the sides	
2	Sitting on a chair	Inspiration while body extending backwards with hands behind the head	Expiration while bending maximally forward with elbows touching each other in final position	
3.a	Sitting on a chair	Inspiration while one arm is abducted out and over the head	Expiration while continuing previous motion into a side bend	Follow with 3.b
3.b	End of movement 3.a	Inspiration while returning to upright position	Expiration while returning the arm to the side	Repeat with other side from 3.a
4	Sitting on a chair	Expiration while bending forward to touch the floor with arms crossed at the feet	Inspiration while extending outup and lifting arms up and out into a 'V' above the head	
5	Sitting on a chair, right hand holding left elbow	Expiration while bending and rotating to touch the floor lateral to the right ankle with left hand	Inspiration while extending upward and rotating left arm and hand over the head and away from the left side	Repeat 5 with other side
6.a	Lying in supine position (hips and knees flexed)	Expiration while reaching the knees with both hands with head lift	Inspiration while returning to supine position	
6.b		Inspiration while stretching both arms over head	Expiration while reaching past the knees	
7	Lying in supine position (hips and knees flexed)	Inspiration while stretching right hand up and over the head	Expiration while bringing the extended arm over and across the body reaching past the left hip	Repeat 7 with other side
8	On hands and knees	Inspiration while rocking forward	Expiration while heel-sitting backward with chin tucked	
9.a	On hands and knees	Inspiration while rocking forward	Expiration while drop ping one elbow to the floor	Follow with 9.b
9.b	End of movement 9.a.	Inspiration while pushing onto hands and knees	Expiration while rocking back to heel-sitting position	Repeat with other side from 9.a
10	Standing with hands on a wall at shoulder height	Expiration while bending the elbows	Inspiration while pushing away from the wall	