

Effects of expiratory muscle strength training on maximal respiratory pressure and swallow-related quality of life in individuals with multiple sclerosis

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Abstract

Background: Weakening and dyscoordination of expiratory muscles in multiple sclerosis (MS) can impair respiratory and swallow function.

Objective: The objective of this paper is to test a novel expiratory muscle strength training (EMST) device on expiratory pressure, swallow function, and swallow-related quality-of-life (SWAL-QOL) in individuals with MS.

Methods: Participants with MS were randomized to a five-week breathing practice of either positive pressure load (EMST) or near-zero pressure (sham). We compared baseline to post-treatment data according to maximum expiratory pressure (MEP), abnormal airway penetration and aspiration (PAS), and SWAL-QOL.

Results: Both groups improved in MEP ($p < 0.001$). Forty percent of the EMST group improved on PAS, and 15% worsened; conversely, 21.4% of the sham group worsened and 14.3% improved. There was no group difference in overall SWAL-QOL; but the EMST group had significantly greater gain versus sham on the Burden ($p = 0.014$) and Pharyngeal Swallow ($p = 0.022$) domains. Both groups improved in SWAL-QOL domains of Fear, Burden Mental Health, but only the EMST group improved in the SWAL-QOL and domains of Pharyngeal Swallow function, and Saliva management.

Conclusion: Results suggest that strengthening of expiratory muscles can occur with repetition of focused breathing practice in the absence of high resistance. Conversely, results from the PAS and SWAL-QOL domains suggest that the high resistance of the EMST was required in order to improve the functional safety (reduced penetration/aspiration) and coordination of swallowing, specifically pharyngeal function and saliva management.

Keywords: Respiration, quality of life, rehabilitation, MS, swallow

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Introduction

Multiple sclerosis (MS) is associated with impaired respiratory and swallowing function, fatigue, and degradation of sensory and motor function.¹ The respiratory and swallowing problems may escalate as the disease progresses, and patients become more affected by fatigue and physical inactivity.^{2–4}

MS and respiration

Although recognizable respiratory muscle impairment has historically been associated with the later

stage of MS,^{5,6} individuals with mild MS also exhibit respiratory deficit even in the absence of obvious respiratory symptoms.^{3,4} Expiratory muscle strength under the control of the abdominal and internal intercostal musculature deteriorates earlier during the disease progression than does inspiratory muscle strength controlled by the diaphragm and external intercostals.⁶ Abnormally reduced respiratory muscle strength affects cough production and increases the risk of respiratory failure, which is a leading cause of disability or death.^{3–6} Sufficient

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expiratory muscle strength is critical for generating the pressure necessary for cough production and normal airway clearance.⁷ Exercising the respiratory muscles via imposition of mechanical load may augment the capacity for normal airway clearance and cough.⁷ Previous investigations have examined expiratory and inspiratory muscle strength training in MS patients regarding expiratory muscle strength training (EMST) benefits for maximum expiratory pressure (MEP) and speech, and the results were mixed.^{4–10} One notable reason for different results could be that some studies used a device that featured progressive increase in resistance associated with practice performance, while others did not. Therefore, our first purpose was to use an EMST training device that could modulate training difficulty, according to practice performance, to evaluate effects of the EMST on respiratory function in individuals with MS.

MS and swallowing

Swallow dysfunction or *dysphagia* may not be properly recognized during early or mid-stage MS, though many individuals are actually affected.^{11,12} Swallow coordination can be disrupted by demyelination of the corticobulbar tracts, cerebellar and/or brainstem involvement, and weakness or paresis of the muscles important for swallowing function.¹² Dysphagia can in turn cause malnutrition, dehydration, and lung infection, and potentially contribute to greater mortality.^{13,14} Dysphagia worsens with disease progression and can become life threatening.^{15,16} Estimates of the prevalence of dysphagia among those with MS vary widely based on the diagnostic procedure used.^{15,17} A recent, large-scale meta-analysis of existing data concluded that the prevalence was approximately 36% according to subjective screening tests for dysphagia, but objective tests of swallow function yielded an estimate of 81% of the population for those with MS.¹⁵ It is, therefore, important to develop methods to preserve or improve swallow function for those with MS.

The physiological mechanisms underpinning dysphagia involve the weakening of pharyngeal constrictors (crucial for complete transfer of the oral bolus from the mouth and into the esophagus), decreased duration of laryngeal excursion (meaning that the airway is exposed and vulnerable to penetration or aspiration of foreign materials for a longer-than-normal duration of time), and prolonged time (impaired coordination) of vocal fold closure and upper esophageal sphincter opening.^{18,19} Disrupted neuromuscular sequencing of pharyngeal and laryngeal events during swallow has been observed in up to 90% of individuals with MS.¹⁷ When the

corticobulbar tracts, cerebellum and brainstem areas are affected as the disease advances, swallowing dyscoordination produces further safety risks.¹² Given the importance of preserving swallow function in MS, our second purpose was to test the effects of EMST on swallow function and swallow-related quality of life (SWAL-QOL).

Methods

Participants

Inclusion and exclusion criteria were as follows: males and females diagnosed with MS by a neurologist; age 20–75 years; non-smoking or no smoking within the previous five years; no MS symptom exacerbation within the three months prior to entrance into the study; sufficient facial strength for lip closure around a circular mouthpiece; cognition sufficient to participate in an MS support group, outside the home; no neurological (other than MS) condition affecting respiratory muscles or gas exchange; reduced MEPs compared to published normative values for age and sex; and participant report of difficulty in swallowing (either isolated or consistent). The participants were randomly assigned to either the EMST or sham group. The University of Florida Institutional Review Board approved and provided oversight of this investigation.

Intervention

EMST group. The EMST group used an experimental pressure threshold trainer, the EMST 150 (Aspire LLC; Atlanta, GA)^{20,21} consisting of a breathing tube with a modified AMBU PEEP valve. This is a handheld device with a one-way valve affixed to a metal spring that can be customized to a pressure threshold (the amount of air pressure required to open the one-way valve) from approximately 20 to 150 cmH₂O.

The EMST group was instructed to use the device at home according to a five-week training protocol.^{21–23} The EMST requires the participant to forcibly blow into the device with sufficient pressure to open the one-way valve. Each “blow” was one repetition. The participants were instructed to complete five sets of five repetitions (total of 25 times and approximately 20 minutes per day), any five days per week, for five weeks. In-home caregivers were provided with instructions regarding how to assist the participant with daily practice, if needed.

Weekly service, monitoring and adjustment. In order to monitor and adjust the EMST 150 strictly for treatment purposes, we obtained MEP (cmH₂O) on a weekly basis using a calibrated pressure gauge

(Micro Mouth Pressure Meter, MP01, Micro Direct Inc). The three highest MEP values (within 5% variation of one another) were obtained in the home once weekly during the five-week home training program; the EMST device was then adjusted for the upcoming week, for training, to a pressure threshold equal to 75% of maximum MEP. These were not outcome measures; rather, these values were used strictly to progress treatment.

Sham treatment. Those assigned to the sham group underwent an identical training protocol using an EMST 150 that did not contain an internal pressure threshold spring. This modification enabled the one-way valve to open at an air pressure of 2–5 cmH₂O, lowering the pressure threshold load to a negligible level (pressure used in quiet talking).

Primary outcome measures

Measures for both groups were obtained at baseline and at the end of five weeks of treatment. For both MEP and penetration and aspiration scale (PAS) measures for both groups, the data were obtained at baseline and at the end of five weeks of treatment by a study team member who was blinded to participant group assignment. During a given data acquisition for MEP for a given participant, the study team member did not have access to prior data acquisition values for that individual. For the PAS, the study team member scoring the data was also blinded as to the time point of the data acquisition.

MEP

The MEP was a primary outcome measure in addition to its use for setting the EMST 150 pressure load levels as described above. The MEP was measured repeatedly with approximately one- to two-minute rest periods between each trial until three measures obtained were within 5% variation of each other; these were averaged and standard deviation of the MEPs were automatically calculated.

PAS

The PAS is a quantitative measure of swallow function and swallow safety.²⁴ The significance of the PAS is that it indicates whether and how well the swallow function prevents material from abnormally entering the airway. We recorded images of the dynamic swallow function by videofluoroscopy (Phillips radiographic/fluoroscopic unit; 63 kv, 1.2 mA output, full field view mode²³). Using PAS, an experienced rater scored the presence and degree of abnormal airway penetration and aspiration from review of video fluorographic exams in real time and after the fact. Participants were provided with the spoon or cup and instructed by the

staff to place the food in the mouth and swallow when ready. Participants performed swallows of an array of bolus consistencies including 10 5-cc boluses of pudding-consistency barium, six 5-cc boluses of thin liquid barium, and one 3-ounce bolus of thin liquid barium. Premixed Varibar barium was used for all of the trials, in the specified volumes. The PAS consists of an eight-point ordinal scale that is commonly used in clinical practice to quantify specific aspects of penetration and aspiration.²⁴ The PAS scores the depth to which material abnormally enters the airway as well as whether the material is expelled following penetration or aspiration. PAS scores are rated according to the following: “normal to mild” (1–2), “moderate” (3–5) and “severe” (6–8, indicating that material has passed into the lower airway).²⁴

SWAL-QOL instrument

The SWAL-QOL²⁵ is a validated and standardized 44-question tool that includes 13 domains: burden, eating desire, eating duration, pharyngeal symptom status (PSS), oral symptom status, saliva management, food selection, communication, fear, mental health, social functioning, fatigue, and sleep. Responses were determined according to an ordinal scale (1 = severe problem; 5 = normal). The SWAL-QOL provides an overall score as well as domain scores. Participants rated quality of life as follows: little to no impact (81%–100%), mild impact (61%–80%), moderate impact (41%–60%), severe impact (21%–40%), and profound impact (0%–20%). Standard published methods were used for administration and scoring.²⁵

Data analysis

For the MEP measure, baseline group comparison was performed using the Mann-Whitney Rank Sum test; group comparison of treatment responses were performed using the Plum Ordinal Regression test; and within-group pre-/post-comparisons were made using paired *t*-test after confirming the data were normally distributed (Shapiro-Wilk Normality test). For the SWAL-QOL, baseline group comparison was performed using the Mann-Whitney Rank Sum test; group comparison of treatment responses were performed using the Plum Ordinal Regression test; and within-group pre-/post-comparisons (SWAL-QOL overall score and sub-domains) were performed using the Wilcoxon signed ranks test or paired *t*-test. Descriptive statistics were generated for the PAS measure according to accepted ratings of Mild, Moderate and Severe categories.²⁴ Additionally, we generated more detailed PAS descriptive statistics by designating “improvement”

as a decrease of one or more points in the worst PAS score observed over all swallows of all food material consistencies for a given participant; “Worsening” was identified as an increase of one or more points.

Results

A total of 42 individuals (11 males and 31 females) with MS were enrolled. Six participants withdrew following the baseline testing, citing travel or loss of interest. Therefore, a total of 36 participants completed the MEP test ($n = 16$, sham; $n = 20$, EMST). Eight participants failed to complete the PAS examination either at baseline or post-training testing (total completing the test, $n = 34$ ($n = 14$, sham; $n = 20$, EMST)). Ten participants were either “no shows” for the SWAL-QOL or only partially answered the swallow questionnaire (total completing the test, $n = 32$ ($n = 13$, sham; $n = 19$, EMST)). At baseline, there was no group difference in MEP ($p = 0.899$) or SWAL-QOL total score or domains ($p > 0.05$). There was no significant difference between the groups with regard to age, gender, and disease severity ((a) Expanded Disability Status Scale (EDSS) score for EMST group: (mean (STD) and range): 5.5 (± 1.5), 2.5–8.0); and (b) EDSS score for sham group: (mean (STD) and range): 5.48 (± 1.7), 2.0–8.5).

MEP

There was no group difference in MEP in response to treatment ($p = 0.946$). For the EMST group, MEP increased by 20.4% ($p = 0.00042$) after training. For the sham group, MEP increased by 23.81% ($p = 0.0019$). Mean pre-/post-treatment values were as follows: EMST, 78.60 ± 30.72 cmH₂O,

99.00 ± 32.97 cmH₂O; sham, 75.56 ± 27.68 cmH₂O, and 99.38 ± 37.59 cmH₂O, respectively.

Penetration/aspiration during swallowing

For the PAS, there was a greater trend toward improved swallow function for the EMST group compared to the sham group. Table 1 presents information according to standard clinical categories of symptom severity.²⁴ In the EMST group, two individuals with severe impairment (Table 1, row 3, panel (b)) improved to either moderate or mild status (Table 1, rows 1 and 2, panel (b)), and two moderately impaired individuals (Table 1, row 2, panel (b)) improved to mild (Table 1, row 1, panel (b)). In the sham group, however, two individuals worsened from normal or mild to moderate impairment, and one individual improved from moderate to normal status.

Table 2 presents a more fine-grained accounting based on PAS score change of one point or more (improving or worsening). Overall, 40% in the EMST group (Table 2, row 1, column (a)) demonstrated an improvement in PAS from pre- to post-treatment; and 15% worsened (Table 2, row 1, column (c)). In comparison, 21.4% in the sham group worsened (row 2, column (c)), and only 14.3% improved (Table 2, row 2, column (a)).

SWAL-QOL

Group comparisons

For the total SWAL-QOL score, there was no significant difference between groups ($p = 0.072$).

Table 1. PAS status according to three clinical categories of severity of impaired swallow function before and after treatment.

(a) PAS measure	(b) EMST group ($n = 20$) Number of participants in each of the three categories		(c) Sham group ($n = 14$) Number of participants in each of the three categories	
	Pre-EMST	Post-EMST	Pre-sham	Post-sham
1. Normal to mild (PAS 1–2)	14	18	12	11
2. Moderate (PAS 3–5)	3	1	2	3
3. Severe PAS (PAS 6–8)	3	1	0	0

PAS: penetration, aspiration scale; EMST: expiratory muscle strength training.

Table 1 shows the CATEGORICAL changes of PAS with treatment. For the EMST group, four participants improved from Moderate (row 2) and from Severe (row 3) to Normal/Mild (row 1) category following EMST treatment. For the sham group, two participants worsened from Normal/Mild (row 1) to Moderate (row 2) while one improved from Moderate (row 2) to Normal/Mild (row 1) following sham treatment.

But there was a significant group difference in two domains, with the EMST group performing significantly better than the sham group on Burden ($p=0.014$) and Pharyngeal Swallow Symptom Status ($p=0.022$).

Within-group pre-/post-treatment comparisons

There was an improvement in response to treatment in the SWAL-QOL overall score in the EMST group

($p=0.016$), but no change in the sham group ($p=0.072$; Table 3). For the domains, the EMST group improved significantly in the following: Burden ($p=0.027$), Pharyngeal Swallow Symptom Status ($p=0.007$), Saliva ($p=0.036$), Fear ($p=0.004$), and Mental Health ($p=0.016$). The sham group exhibited a significant post-training improvement only in Burden ($p=0.038$) and Mental Health ($p=0.031$; Table 3).

Table 2. Percentage of participants with changed PAS score of one point or more from pre- to post-treatment.

Group	(a) With improved PAS	(b) With unchanged PAS	(c) With worsened PAS
1. EMST	40.0% (8 ^a)	45.0% (9)	15.0% (3 ^b)
2. Sham	14.3% (2 ^c)	64.3% (9)	21.4% (3 ^d)

PAS: penetration, aspiration scale; EMST: expiratory muscle strength training
^aFour participants improved from Mild (score 2) to Normal (score 1), and another four participants improved from Moderate and Severe (scores 3–8) to Normal (score 1) or to Mild (score 2) following EMST treatment.
^bThree participants worsened from Normal (score 1) to Mild (score 2) following EMST treatment.
^cOne participant improved from Moderate (score 4) to Normal (score 1), and another improved from Mild (score 2) to Normal (score 1) following sham treatment.
^dTwo participants worsened from Normal/Mild (scores 1–2) to Moderate (score 3), and one participant worsened from Normal (score 1) to Mild (score 2) following sham treatment.

Table 3. SWAL-QOL total and domain results in response to EMST and sham.

SWAL-QOL Domain	EMST group (<i>n</i> = 19)		% change (<i>p</i> value)	Sham group (<i>n</i> = 13)		% change (<i>p</i> value)
	Pre-training (%)	Post-training (%)		Pre-training (%)	Post-training (%)	
Burden	90.0 ± 20.0	97.4 ± 7.3	7.4^a (<i>p</i> = 0.027)	80.8 ± 25.0	86.2 ± 18.9	5.4^a (<i>p</i> = 0.038)
Symptom status: pharyngeal	73.5 ± 16.9	82.4 ± 16.6	8.9^a (<i>p</i> = 0.007)	75.4 ± 13.0	77.6 ± 11.6	2.2 (<i>p</i> = 0.240)
Symptom status: saliva	84.2 ± 16.2	92.3 ± 9.5	8.1^a (<i>p</i> = 0.036)	83.1 ± 13.5	83.6 ± 15.8	0.5 (<i>p</i> = 0.920)
Fear	80.5 ± 22.2	89.2 ± 20.4	8.7^a (<i>p</i> = 0.004)	79.2 ± 14.8	84.6 ± 11.3	5.4 (<i>p</i> = 0.056)
Mental Health	87.2 ± 21.5	94.1 ± 18.2	6.9^a (<i>p</i> = 0.016)	83.4 ± 16.5	90.2 ± 13.0	6.8^a (<i>p</i> = 0.031)
Total score	83.3 ± 11.5	88.1 ± 10.8	4.8^a (<i>p</i> = 0.016)	81.4 ± 10.9	84.4 ± 8.5	3.0 (<i>p</i> = 0.072)

SWAL-QOL: swallow-related quality-of-life; EMST: expiratory muscle strength training. Percent change denotes improvement with positive change indicating improvement toward more normal QOL.

Five out of 13 domains and the total SWAL-QOL for which the EMST and/or sham group participants showed significant improvement from pre- to post-treatment are listed here.

^aSignificance: $p \leq 0.05$.

Discussion

The results of the study contribute to the existing literature in a number of ways. Because this was a randomized, controlled trial (RCT), we were able to provide results of EMST in comparison to sham treatment. First, we found that the capacity to generate MEP improved significantly both for the EMST and sham groups. Notably, in effect, the sham group practiced simple expiratory breathing with the spring removed and negligible pressure of 2–5 cmH₂O. This result suggests that simple expiratory breathing practice alone can improve the MEP in those with MS. Second, the EMST intervention holds promise for reducing abnormal airway penetration during swallow. Third, according to within-group analyses, the EMST intervention produced significantly improved total SWAL-QOL score and sub-domains of pharyngeal function and saliva symptom status (SSS), whereas the sham group showed no change in these measures.

MEP

EMST has been shown to increase MEP-generating capacity (or MEP) in other populations⁷ such as in Parkinson disease, the sedentary elderly, and young healthy adults. Several RCT studies reported approximately 20%–30% increases in MEP after six to 12 weeks of EMST training in individuals with MS.^{9,10,19} We found a greater than 20% increase in MEP in our MS patients after five weeks of training, which is consistent with the published data.

The observation of the significantly but similarly improved MEP both in EMST and sham groups in the current study is new and somewhat surprising. Commonalities in study procedures across the two groups offer a potential explanation. First, both groups participated in the MEP testing for seven consecutive weeks (week 1: baseline testing; weeks 2–6, during the five weeks of home training; week 7, post-treatment testing). The MEP test is a maximum effort task, which was repeated multiple times at any given single test session until the threshold 5% variability was obtained in three trials. Typically, this required no more than three to five repetitions but in isolated cases, more repetitions were necessary. In every case the participant was offered ample recovery time between repetitions, as it is a maximum effort task. This same procedure was used at baseline and post-treatment data acquisition for the MEP outcome measure, resulting in a total of seven MEP test sessions (five for treatment decision making and two for MEP outcome measurement). Since muscle weakness is common in MS, it is

possible that a strength-training effect could have manifested as a result of the weekly MEP testing, which required repetition and likely strengthening of the respiratory muscles. Second, the sham group was assigned the same frequency and duration of home exercise program as was the EMST group albeit in the absence of a positive pressure load. This underscores the commonality that both groups consequently practiced expiratory breathing for the same duration and frequency, further engaging muscle activations. Two other studies support this reasoning. First, Westerdahl et al. used a moderate positive pressure threshold (10–15 cmH₂O), intermediate between the current study groups (2–5 cmH₂O, control group; minimum of 36 cmH₂O EMST group). They reported improved lung function with respect to vital and forced vital capacities in patients with mild to moderate MS.²⁶ Second, recent work by Ishida et al. (2017) revealed significantly improved inspiratory and expiratory pressures in a cohort of elderly participants trained *without a pressure threshold* to complete “fast expiratory” exercises into a peak flow meter, suggesting that maximum effort tasks alone may be sufficient to achieve respiratory strengthening.²⁷ A third commonality is that motor imagery could have played a similar role in both groups. Motor imaging is the process of mental conceptualization of motor movements and can be associated with specific kinesthetic sensations.^{28,29} Significant strength and motor performance gains have been reported following mental training and imagery, and in some cases occurred without overloading the targeted muscles.^{30–32} In the current study, the participants in both groups engaged in focused expiration practice, which may have engaged motor imagery.

PAS

According to the descriptive statistics, the two groups showed different swallow coordination and airway maintenance (PAS). Forty percent of the EMST group improved (Table 2, row 1, column (a)) compared to 14% in the sham group (Table 2, row 2, column (a)) after the training period (score improvement; Table 2). Specifically, with respect to categorical changes, two individuals with severe PAS impairment in the EMST group improved to the normal/mild status (Table 1, row 1, column (b)/(c)), and another two moderately impaired individuals improved to normal (Table 1, row 2 at pre-treatment, moving to row 1 at post-treatment). However, in the sham group, two individuals worsened from normal/mild to moderate impairment (Table 1, column (c), moving from row 1 at pre-treatment to row 2 at post-treatment), and one improved from the moderate

to normal/mild category (Table 1, column (c), moving from row 2 at pre-treatment to row 1 at post-treatment). These findings suggest that the EMST produced greater improvement in PAS. Consistent with our findings, other groups have demonstrated improved swallow physiology (i.e. reduced PAS scores) following EMST.^{7,19,22}

There is strong clinical relevance of improved PAS score because it indicates a safer swallow in that oral contents are more effectively diverted away from the airway, which is desirable, and as occurs during a normally coordinated swallow. The EMST protocol could potentially have provided two aspects of training: (1) improving hyolaryngeal elevation during swallowing, thereby lessening the risk of aspiration; and (2) improving cough strength to assist airway clearance should aspiration occur. It is likely that the training did produce the effect of improved PAS scores, since swallowing is an automatically controlled precision movement and therefore the PAS measure is not subject to the factors of “greater effort” or “test-retest” aspects of other types of measures that can be biased through effortful learning. The clinical significance in improved PAS and swallow function is that it lessens the probability of pneumonia and costly hospitalizations, in addition to supporting better quality of life for the clients for whom we care. These are strong justifications for billing and insurance payment of this simple clinical treatment, which could be accomplished for the most part in the home. Additionally, given the relatively simple treatment protocol, many different professionals could administer and supervise the treatment in other care scenarios both during inpatient and outpatient visits. This could include professionals in fields such as physical therapy, respiratory therapy, and nursing.

Activity-based brain plasticity for motor coordination change requires daily and weekly practice sessions of breathing with certain intensity and high repetitions.^{30,32} Although our findings are preliminary, it is reasonable to consider that five weeks of breathing practice with the positive pressure threshold set at 75% of the maximal MEP helps improve or preserve swallow coordination and maintenance of a clear airway.

SWAL-QOL

In within-group, pre-/post-treatment comparisons, for the overall SWAL-QOL measure, there was a significant improvement of the total quality (score) for the EMST group, but not for the sham group. The results from exploratory analyses of the separate

SWAL-QOL domains may provide explanatory information underlying these results. Many MS disease-related issues such as fatigue and motor dysfunction could potentially have a general effect on certain SWAL-QOL domains. Our data showed no training effect for either group in the following: Eating Desire, Eating Duration, Oral Symptom Status (moving food inside the mouth), Communication, Social Functioning, Fatigue Level, Food Selection, and Sleep.

In contrast, the Burden domain did exhibit a training effect for both groups. The Fear domain also displayed a significant improvement for EMST and showed a similar trend for sham ($p = 0.056$). These results altogether indicate a reduction of emotional distress over swallowing. This is reasonable for both groups, considering that they had the opportunity to rehearse expiratory muscle function for the same frequency and duration and improved MEP similarly. Consistent with a reduction of fear, the Mental Health domain was improved for both groups as well. It is likely that the improved MEP scores reflected improved strength, which would presumably promote coordination needed to improve the PAS swallow score. With improvement in these two impairment measures, we could expect a more safe swallow with concomitant reduction of fear of swallowing (improved swallow function) and mitigation of the depression, discouragement and frustration (Mental Health domain) that would accompany a more impaired swallow.

The Burden and Mental Health domains of the SWAL-QOL measure feelings of anxiety, frustration, fear of dysphasia and pneumonia, and depression; the SWAL-QOL social domains assess the ability to engage in social activities. Amyotrophic lateral sclerosis (ALS) patients with swallowing impairment showed increased fear, burden, mental stress and social withdrawal and isolation.³³ With oculopharyngeal-muscular-dystrophy (OPMD), SWAL-QOL score for burden, eating duration, and fatigue were decreased.³⁴ Participants with MS in our study had abnormally low scores on the SWAL-QOL. These results are consistent with those reported for ALS and OPMD. Further, when both groups in our study performed breathing exercises, Burden and Mental Health scores improved. The clinical implication is that even simple breathing exercises may help promote positive feelings and reduce burden in patients with MS.

The two SWAL-QOL domains most specific to pharyngeal function are PSS and SSS. Both significantly

improved in response to EMST, but not sham. These findings are reasonable given that EMST directly provided two types of exercise. The EMST resistance breathing provided strengthening exercise. Practice and repetition of complex movements (coordination) is known to improve coordination. These two types of exercises could have improved function of the pharyngeal muscles that control swallow and saliva management.

Study limitations

This was an initial study of the effects of EMST for those with MS, with any interested individuals with MS enrolled if they were participating in an MS support group. A limitation of the study is that there was no information acquired regarding the following: history of depression, disease modification treatment, or MS duration or type. A future study would be valuable in which these variables are included.

The current study had begun prior to the publication of the psychometrics study of the modified barium swallowing tool (MBSImp) measure.³⁵ In future work, it would be advisable to consider using the MBSImp, given its fine-grained approach to identifying any impairment in the separate oral and pharyngeal movements that are precisely coordinated during swallows.

Conclusions

The MEP improved significantly from pre- to post-treatment both for the EMST and sham participants, suggesting that strengthening of the expiratory muscles can occur with repetition of focused breathing practice in the absence of high resistance. On the other hand, results from the PAS and from the SWAL-QOL domains suggest that the high resistance of the EMST was required in order to improve the functional safety (reduced penetration/aspiration according to PAS), as well as coordination of the complex function of coordinated swallowing, specifically pharyngeal function and saliva management (according to SWAL-QOL subscales).

Conflicts of interest

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