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Review Article

Expiratory Muscle Strength Training for Dysphagia in Chronic Obstructive Pulmonary Disease: A Meta-analysis and Systematic Review

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Abstract

Background: Chronic obstructive pulmonary disorder (COPD) negatively impacts respiratory function which may lead to breathing disorders (dyspnea) and swallow disorders (dysphagia). Device driven expiratory muscle strength training (EMST) programs improves these disorders in patients with a variety of diseases.

Purpose: A systematic and meta-analytic review was conducted to determine the feasibility of EMST as a treatment of dysphagia for COPD patients. The following three areas of research were reviewed: (1) Studies comparing swallow function in patients with COPD compared to healthy controls. (2) Studies examining the efficacy of EMST with a device as a treatment for dyspnea in patients with COPD. (3) Studies examining the efficacy of EMST with a device as a dysphagia treatment in patients with peripheral and central nervous system disorders.

Method(s): Literature searches of electronic databases were conducted between August 2015 to February 2016. Two independent investigators assessed the studies based on inclusion criteria and study quality.

Result(s): A moderate effect size revealed that patients with COPD have impaired swallow function compared to the healthy controls. A moderate effect size revealed that patients with COPD using EMST with a device had greater improvement in lung function compared to patients with COPD in a control group. An effect size of 1.39 revealed that the participants using an EMST device showed greater improvement in swallow function compared to a control group.

Conclusion: The results support EMST as a dysphagia treatment for patients with COPD. Higher levels of evidence-based research within this area is needed.

Abbreviations: COPD: Chronic Obstructive Pulmonary Disorder; **EMST:** Expiratory Muscle Strength Training; **IMST:** Inspiratory Muscle Strength Training; **RCT:** Randomized Control Trials

INTRODUCTION

The Centers for Disease Control reported that at least 15 million Americans have chronic obstructive pulmonary disorder (COPD), a leading cause of respiratory illness [1]. COPD negatively impacts lung function, which commonly leads to dysphagia and dyspnea. Dysphagia occurs in COPD because of the incoordination of breathing and swallowing caused by weakened respiratory function. This weakening may lead to exacerbations, increased risk of aspirations, pneumonia, and hospitalizations [2-4].

Because of the dysphagia associated with COPD, researchers have investigated treatments to improve respiratory function. A systematic review by Neves, et al (2014), found that expiratory muscle strength training (EMST) improves respiratory function in patients with COPD [5]. Because of the effectiveness of EMST for improving respiratory function in patients with COPD, cross-over benefits for improved airway protection and dysphagia treatment to be found.

EMST also improves voluntary cough reflex and dysphagia in central nervous system disorders, which are disorders resulting in muscle weakness and may cause reduced respiratory airflow similar to COPD [6]. Examples of central nervous system disorders include Parkinson's disease, ALS, and multiple sclerosis. Given the benefits of EMST as a dysphagia treatment in other disorders, it is plausible that EMST may be a viable dysphagia treatment for patients with COPD.

An electronic database search conducted in August 2015 revealed no literature existed on the efficacy of EMST as a dysphagia treatment with COPD patients. Thus, a need exists to examine the feasibility of this treatment before experimental studies are undertaken. The purpose of the study was to conduct a systematic and meta-analytic review to determine the feasibility of EMST as a dysphagia treatment for patients with COPD. To

accomplish this purpose, the following three research areas were reviewed:

(a) Studies examining swallow function in patients with COPD to determine the presence and severity of dysphagia in COPD patients. It is hypothesized that patients with COPD will have greater dysphagia compared to healthy controls and thus, highlight the need for treatments to reduce dysphagia in patients with COPD.

(b) Studies examining the efficacy of EMST as a treatment for dyspnea in patients with COPD. It is hypothesized that EMST with a device would improve dyspnea in patients with COPD. This finding will highlight the potential for an alternative dyspnea treatment that may result in a higher quality of life for those with COPD.

(c) Studies examining the efficacy of EMST as a dysphagia treatment in patients with neurological disorders. It is hypothesized that EMST treatments will be an effective intervention for dysphagia in patients with disorders affecting lung function in a manner similar to COPD.

A systematic and meta-analytic review of the aforementioned research areas will provide objective reasoning for examining the feasibility and clinical application of EMST as a dysphagia treatment for patients with COPD.

MATERIALS AND METHODS

Sample of Studies

To accomplish the study purpose, research in the following three areas was retrieved:

1. Studies comparing swallow function in patients with COPD versus healthy controls.
2. Studies examining the efficacy of EMST with a device as a dyspnea treatment in patients with COPD compared to control groups.
3. Studies examining the efficacy of EMST with a device as a dysphagia treatment in patients with neurological disorders.

The following four procedures were used to avoid bias retrieval of searching only major journals and to obtain fugitive studies [7]. First, computer based searches of the electronic databases PubMed, ComDisDome, and Google Scholar were conducted using the relevant key words (i.e., "COPD," "EMST," "swallow function," "dysphagia," "chronic obstructive pulmonary disease expiratory muscle training," "chronic obstructive pulmonary disease breathing exercises," "chronic obstructive pulmonary disease dysphagia," and "expiratory muscle training swallow function"). Second, ancestry searches were conducted using the reference lists of all retrieved studies. Third, active researchers in the field were contacted to retrieve current research. Fourth, computerized searches were conducted on all authors of retrieved studies meeting the inclusion criteria [8-9]. Our searches resulted in 14 studies meeting our inclusion criteria (see Figure 1, 2, and 3) [10-23].

Inclusion Criteria

Only English language articles published through February 2016 were reviewed. Below is the inclusion criteria by study purpose:

Purpose 1: Included studies were experimental designs that reported data on swallow function in patients with COPD compared to healthy controls while in a seated position. A preliminary study investigating if two screening tools effectively detected dysphagia in those with COPD rather than investigating the swallow function of the participants was excluded [24]. Studies were excluded if participants had the presence of a tracheostomy tube or mechanical ventilation.

Purposes 2 and 3: Included studies were randomized control trials (RCTs) that had at least one group using an EMST device. If the efficacy studies had pre-, mid and post-intervention data, only the pre- and post-intervention data were used to compute effect sizes. Thus, the focus was on studies that tested whether the change in the outcomes over time were greater in the intervention group versus the control group. Our work focused on assessing outcomes associated with physiological functions.

Included in the results for purpose 2 was a systematic and meta-analytic review published by Neves, et al [5]. This article included research published February 18, 2013, and earlier. The articles included RCTs that compared EMST versus a control group or EMST plus inspiratory muscle strength training (IMST) versus a control group in persons with COPD. Thus, only articles published February 19, 2013, and later were included to provide an updated version of the aforementioned publication.

Studies returned during a database search for purpose 2 were excluded for only examining IMST without the addition of EMST. One study was excluded because it investigated EMST through a retraining of breathing patterns. Studies examining EMST with a device as a dysphagia treatment for patients with non-COPD diagnoses were excluded because they compared patients with healthy subjects, were not randomized, or were case studies.

Coding the Studies

A coding framework was developed and pilot tested, revised, and then applied to the included studies. Coding was performed by the first author. Reliability was ensured through additional searches conducted by an independent investigator. Disagreements were resolved by discussion and by further examining the studies until 100% agreement was reached by the authors [9]. All the coded characteristics were used as descriptions of the studies retrieved and as potential moderator variables [7-9].

Effect Size Estimation Procedures

Using random effects modeling procedures effect sizes were calculated by:

Purpose 1: Mean and standard deviation data for healthy

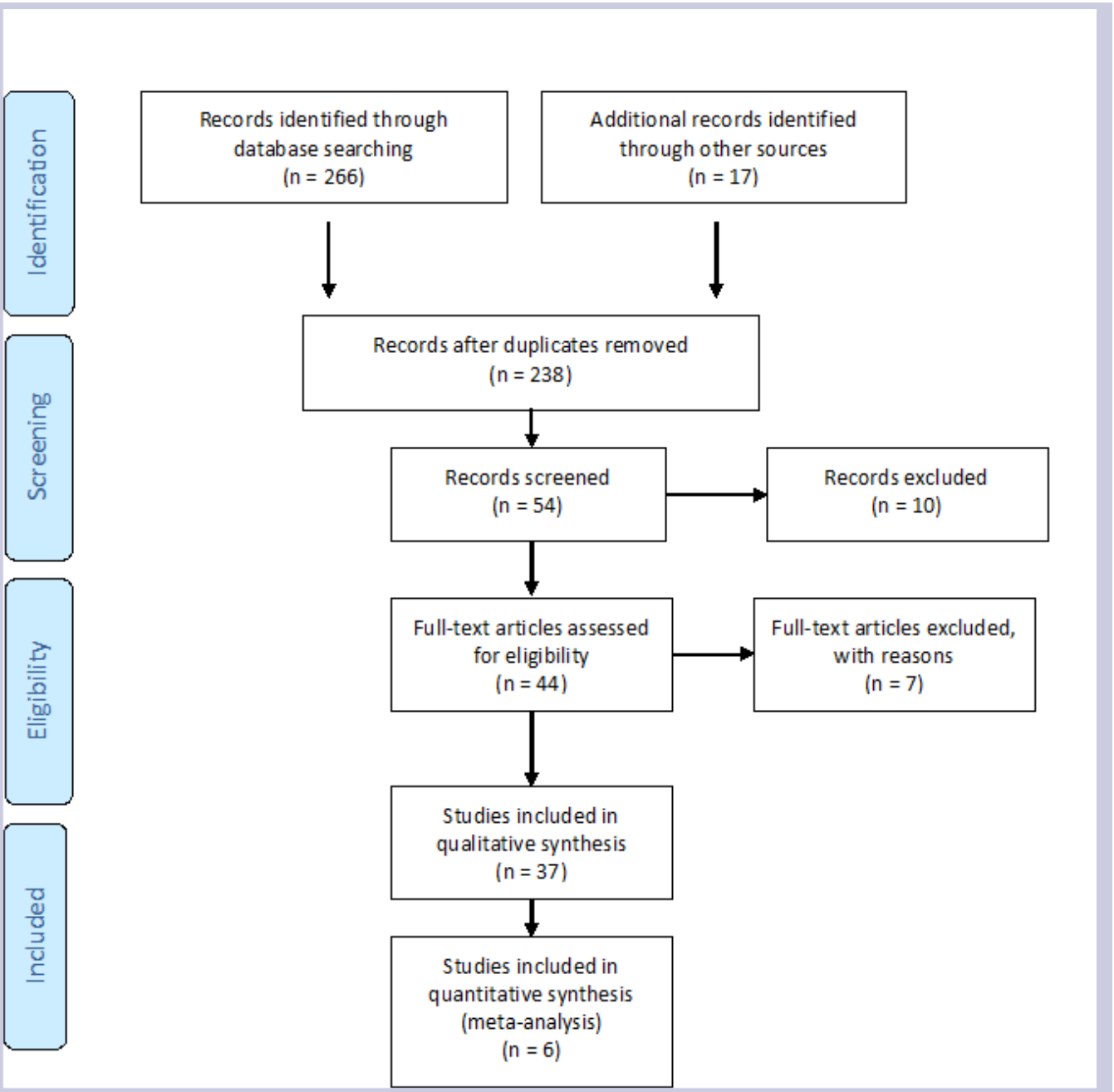

Figure 1: PRISMA 2009 Flow Diagram: Swallow Impairments in COPD Patients Compared to Healthy Controls

controls vs patients with COPD for swallow function.

Purpose 2 and 3: Subtracting the mean change for a control group from the mean change for an experimental group and divided this difference by the pooled standard deviation of the pre-test score. If a study included more than one type of treatment, each treatment was entered as an individual effect and then grouped by study to control for dependence. The measurements included physiological aspects, timing, amplitude, or respiratory functions. Measurements for each bolus size and type were entered as an individual effect. Baseline and immediate post treatment data, including standard deviations, of a treatment group and control were used to compute effect sizes. When the *N* at the pre-test differed from the *N* at the post-test, the smaller *N* was used.

For all study purposes when mean and standard deviation data were not reported, effect sizes were estimated from *F* tests, *t* tests, *p*-values, or figures. Along with the weighted average effect sizes, 95% confidence intervals were computed. To determine heterogeneity of the effect sizes, the dispersion on the forest plot was examined and both the Q-statistic and I^2 were calculated. To assess publication bias, the following graphical and statistical methods were used: forest plots (available upon request from the first author) and Fail-Safe *N* (Nfs) using Rosenthal's procedures [7]. Data were analyzed using Comprehensive Meta-analysis-2 (BioStat, Englewood, New Jersey).

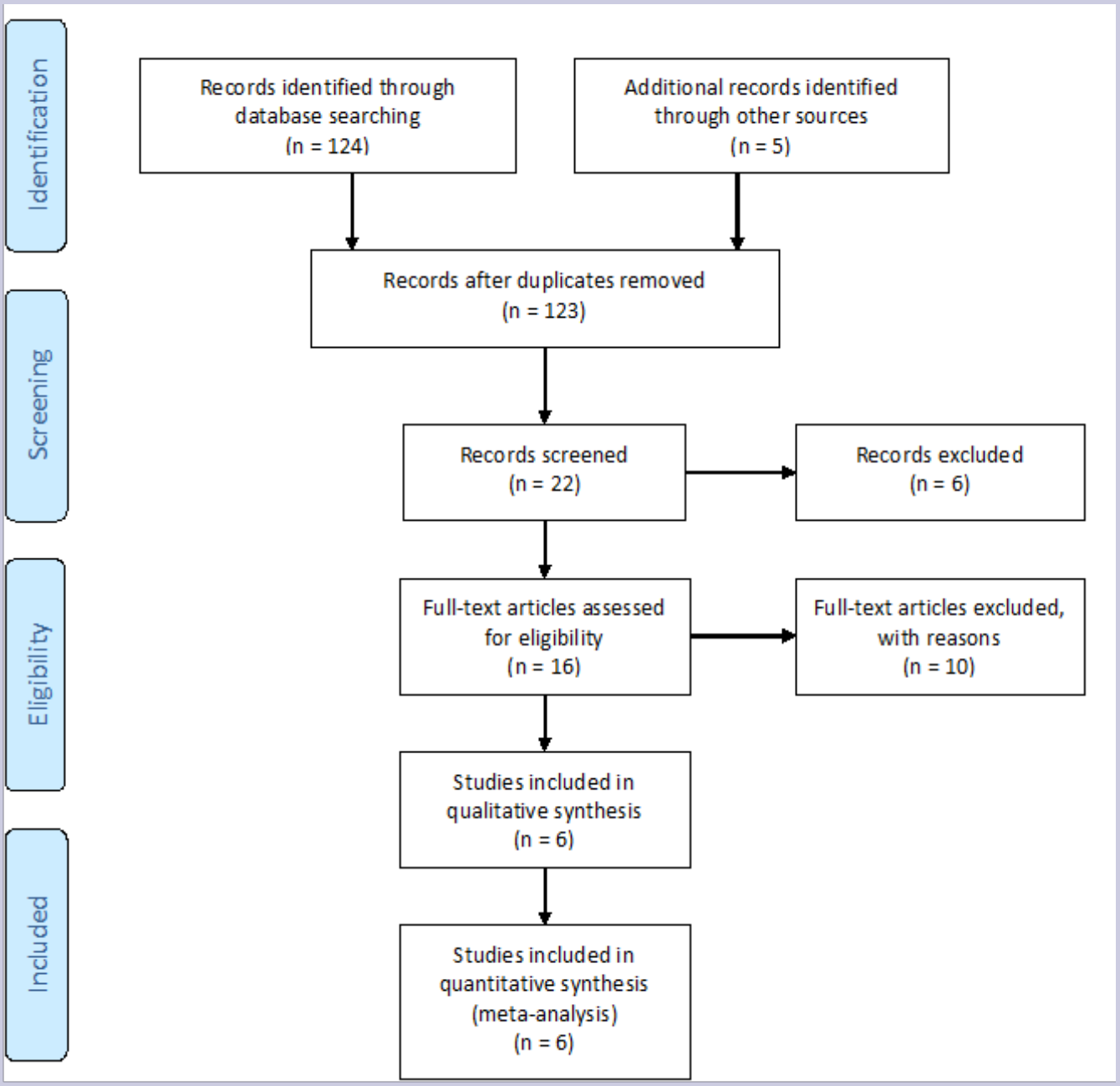

Figure 2: PRISMA Flow Diagram: Expiratory Muscle Strength Training with a Device as a Treatment for Dyspnea

RESULTS

Purpose 1: Presence of Dysphagia

Six studies met inclusion criteria (see Table 1) [10–15]. Each study used multiple measures and none of the studies used the same measure. This is reflected in the fact that a total of 199 different measures were used to assess swallow function in the 6 studies. For example, one study measured 9 physiological aspects per consistency trial (e.g., 9 for 5 mL paste, 9 for 10 mL paste) [12] and another study had 18 physiological/timing aspects per consistency trial [11]. The measures were classified in the table by a singular category. When the effect sizes were combined per study to control for dependency, a moderate effect size of -0.67 revealed that patients with COPD have impaired swallow function compared to the healthy controls, $SE = 0.28$, $p = 0.02$, 95% CI = $\pm$ 0.56, $Q(5) = 28.24$; $I^2 = 82.29$; Fail Safe $N = 34$.

Purpose 2: EMST for Dyspnea

Six studies met the inclusion criteria (see Table 2) [16–22]. When the effect sizes were combined per study, a significant moderate effect size was found revealing that the COPD patients using EMST with a device had greater improvement in lung function compared to patients with COPD in a control group, $M ES = 0.58$, $SE = 0.25$, $p < .001$, 95% CI = $\pm$ .48, $Q(5) = 50.95$, $I^2 =$

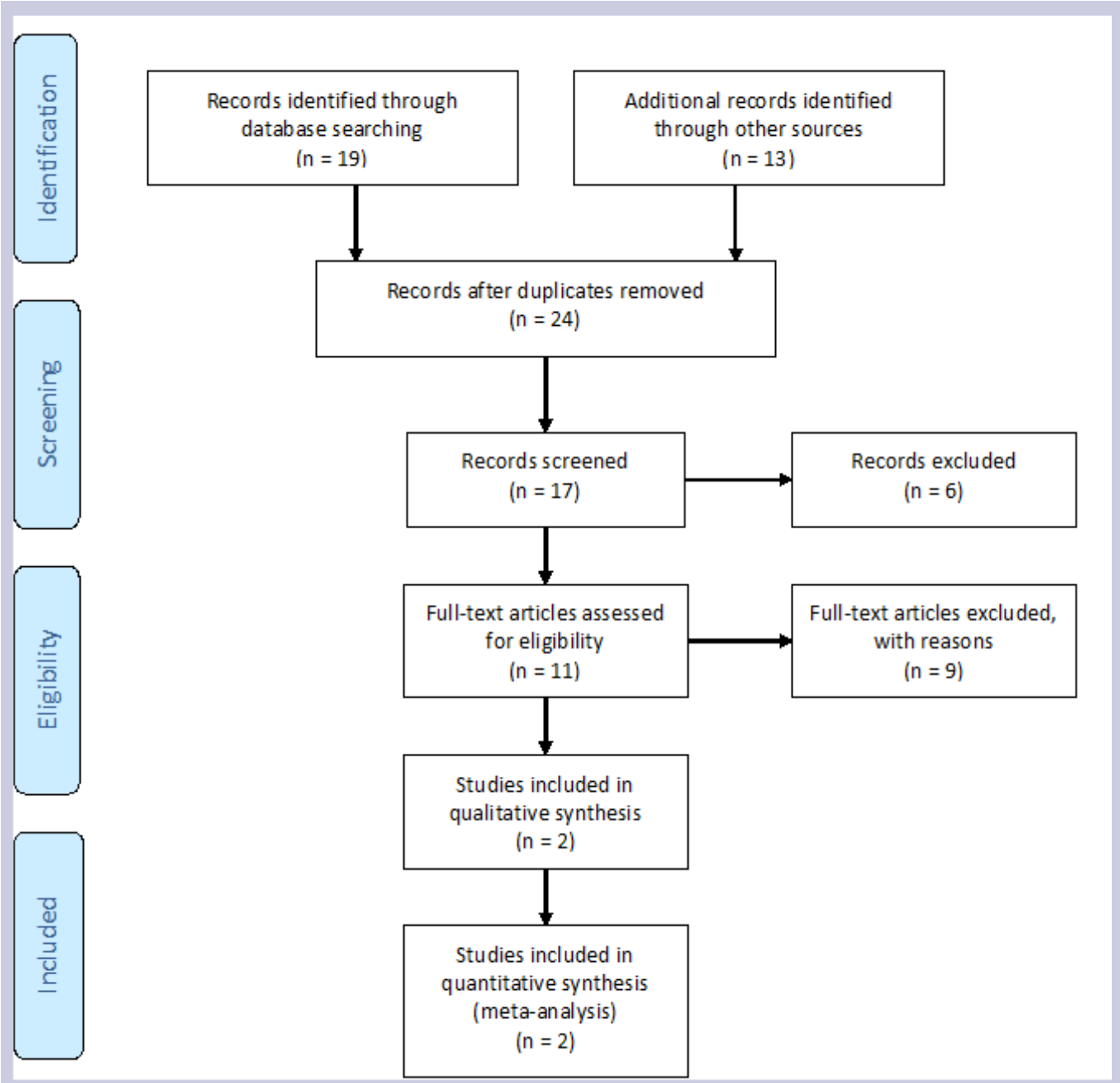

Figure 3: PRISMA Flow Diagram: EMST with a Device as Dysphagia Treatment in Other Disorders

90.18, Fail Safe $N = 54$.

Purpose 3: EMST for Dysphagia

Two studies met inclusion criteria (see Table 3) [23,24]. When the effect sizes were combined per study, a significant effect size of 1.39 was evidenced revealing that the participants with multiple sclerosis and Parkinson's disease using EMST with a device showed greater improvement in swallow function compared to a control group, $SE = 0.09$. $p < 0.001$, 95% CI = $\pm$.18, $Q(1) = 0.16$; $I^2 = 0$.

DISCUSSION

This study conducted a systematic and meta-analytic review to determine the feasibility of EMST as a dysphagia treatment for patients with COPD. The findings support the feasibility of EMST as a dysphagia treatment for patients with COPD. More specific study outcomes and future research directions are outlined below.

Consistent with the hypothesis for purpose 1, a moderate effect size revealed that patients with COPD have impaired swallow function compared to the healthy controls, though the severity varied based on comorbidities and severity of COPD. This

Table 1: Swallow Impairments in COPD Patients Compared to Healthy Controls

Mean Age (SD)	Clayton NA, Carnaby-Mann GD, Peters MJ, Ing AJ. (2012)		Cassiani RA, Manfredi Santos C, Baddini-Martinez J, Oliveira Dantas R. (2015)		Gross RD, Atwood CW, Ross SB, Olszewski JW, Eichhorn KA. (2009)		Mokhlesi B, Logemann J, Rademaker AW, Stangl CA, Corbridge TC. (2002)		Chaves RD, de Carvalh CRF, Cukier A, Stelmach R, de Andrade CRF. (2011)		Cvejic L, Harding R, Churchward T, et al. (2011)	
	COPD	Control	COPD	Control	COPD	Control	COPD	Control	COPD	Control	COPD	Control
Number of Participants	16m/4f	7m/4f	15m/1f	12m/3f	25m	12m/13f	19m/1f	20	17m/18f	17m/18f	10m/6f	8m/7f
Mean Age	71.7(6.8)	70.4(11.6)	68	65	69	64	69	N/A	58(4)	58(4)	70.7(5.2)	70.1(7.1)
COPD Severity	Stage 2-4		Stage 2-3		Stage 2-3		Stage 2		Stage 1-4		Stage 2	
Phase of Swallow Investigated	Pharyngeal		Oral, Pharyngeal		Pharyngeal		Oral, Pharyngeal		Oral, Pharyngeal, Esophageal		Pharyngeal	
Type of Bolus	Air Pulse		5mL Liquid, 10mL Liquid, 5mL Paste, 10mL Paste, Solid		2.5g Solid, 5mL Pudding		3mL Liquid, 5mL Liquid, 1c Liquid, 3mL Paste		N/A		5mL Liquid, 10mL Liquid, 20mL Liquid, 100mL Liquid	
Type of Measurements	Sensation		Timing		Timing/Freq of High vs Low Lung Volume		Timing/Amplitude/ Coordination		Symptoms		Timing/Coordination	
Withdrawals	2 Total		None Noted		None Noted		None Noted		None Noted		None Noted	
COPD severity determined by GOLD classifications: Stage 1 (Mild) FEV1 ≥ 80% predicted, stage 2 (Moderate) 50%≤FEV1<80% predicted, stage 3 (Severe) 0%≤FEV1<50% predicted, stage 4 (Very Severe) FEV1 < 30% predicted or FEV1 < 50% predicted plus chronic respiratory failure (NHLBI/WHO. GOLD COPD Guidelines; 2006 Revised)												

Table 2: Expiratory Muscle Strength Training with a Device as a Treatment for Dyspnea

Mean Age (SD)	Mota S, Guell R, Barreiro E, et al. (2007)		Weiner P, Magadle R, Beckerman M, Weiner M, Berar-Yanay N. (Oct, 2003)		Nield MA, Soo Hoo GW, Roper JM, Santiago S. (2007)		Battaglia E, Fulgenzi A, Ferrero ME. (2009)		Weiner P, Magadle R, Beckerman M, Weiner M, Berar-Yanay N. (Aug, 2003)		Tout R, Tayara L, Halimi M. (2013)	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control		
Number of Participants	10	8	SEMT - 7m/1f SIMT - 6m/2f SEMT/SIMT - 6m/2f	7m/1f	PLB - 13m/1f EMST- 13m/0f	12m/1f	10m/6f	9m/7f	9m/3f	10m/1f	All groups of 10. Total of 40 participants (19m/21f)	
Mean Age	62(2)	66(3)	SEMT - 65.4(3.3) SIMT - 63.1(3.1) SIMT/SEMT - 62.7(3)	61.8 (3.2)	PLB - 62(12) EMT – 63(5)	69(8)	66	69	63.3(2.9)	61.1(2.8)	IMST – 61(9.32) EMST – 63.1(5.29) IMST/EMST – 59.1(9.3)	58.1 (8.72)
COPD Severity	Stage 3-4		Stage 3		Stage 3		Stage 1-4		Stage 3		Stage 1-2	
Types of Treatment Tested	EMST vs. Sham		SEMT vs. SIMT vs. SEMT/SIMT vs. Sham		Pursed Lip Breathing vs. EMST vs. Sham		IMST/EMST vs. Sham		SEMT vs. Sham		IMST vs. EMST vs. IMST/ EMST vs. Sham	
Length of Study	5 wks.		3 mos.		3 mos.		12 mos.		3 mos.		2 mos.	
Training Protocol	30min/d, 3x wk		30min/d, 6x wk		1st wk – 10min/d 2nd wk – 15min/d 3rd wk – 20min/d 4th wk – 25min/d		15min/2xd, 7x wk		30min/d, 6x wk		8-10 2-min cycles, 4-5 2-min cycles 2x wk	
Device, Final Resistance Load	Device N/A 50%		Threshold IMT 60%		Threshold PEP 10%		Respilift, Respivol		Threshold IMT 60%		Threshold IMT, Threshold PEP 60%	
Withdrawals	2 Total		None Noted		14 Total		None Noted		3 Total		None Noted	
Key: SEMT – Specific Expiratory Muscle Training; SIMT – Specific Inspiratory Muscle Training; PLB – Pursed Lip Breathing; EMST – Expiratory Muscle Strength Training												
COPD severity determined by GOLD classifications: Stage 1 (Mild) FEV1 ≥ 80% predicted, stage 2 (Moderate) 50%≤FEV1<80% predicted, stage 3 (Severe) 30%≤FEV1<50% predicted, stage 4 (Very Severe) FEV1 < 30% predicted or FEV1 < 50% predicted plus chronic respiratory failure (NHLBI/WHO. GOLD COPD Guidelines; 2006 Revised)												

finding highlights the need for treatments to reduce dysphagia in patients with COPD. Of importance is the need to investigate respiratory function simultaneously with swallow function [18,20]. Each study used multiple measures and no studies used the same measure. This is reflected in the fact that a total of 199 different measures were used to assess swallow function in the 6 studies (see Table 4). Forthcoming research is needed to provide consistency and objectivity in measurement [21].

Table 3: EMST with a Device as Dysphagia Treatment in Other Disorders

Mean Age (SD)	Troche MS, Okun MS, Rosenbek JC, et al. (2010)		Gosselink R, Kovacs L, Ketelaer P, Carton H, Decramer M. (2000)	
	Treatment	Control	Treatment	Control
Number of Participants	25m/5f	22m/8f	6m/3f	3m/6f
Mean Age	66.7	68.5	54(13)	59(14)
Disorder	Parkinson's Disease		Multiple Sclerosis	
Types of Treatment Tested	Expiratory Muscle Strength Training vs. Sham		Expiratory Muscle Strength Training vs. Breathing Exercises	
Types of Measurements	Timing/Amplitude		Strength	
Length of Study	4 wks.		6 mos.	
Training Protocol	20min/d, 5x wk		3 15x/d, 2x/d	
Device, Final Resistance Load	$EMST_{150}$ Aspire Products 75%		Threshold 60%	
Withdrawals	5 Total		3 Total	

Consistent with the prediction for purpose 2, EMST improved dyspnea in patients with COPD. This finding emphasizes the need for an alternative dyspnea treatment that may result in a higher quality of life for those with COPD. In the studies reviewed the most common device was threshold PEP and/or Threshold IMT [11,13-15]. Of interest, Battaglia, et al found that the training group utilizing a combination of EMST and IMST showed improvement after 6-12 months, although the findings varied on the severity of COPD [12].

Mota, et al found participants had an increase in lung volume and an effective cough, which provides crucial airway protection [10]. Nield, et al concluded that while an EMST training group showed reduced exertional dyspnea, pursed lip breathing was the most effective treatment [11]. However, their study trained participants to prolong their expiration rather than strengthen expiratory muscles [11]. All treatment groups in the Tout, et al study improved with the greatest benefit shown in the treatment group trained in respiratory physiotherapy combined with IMST and EMST [15]. In two studies conducted by Weiner, et al, improvement in dyspnea, strength and exercise performance was shown with EMST and EMST plus IMST training [13-14].

Insufficient pharyngeal transport may be due to reduced subglottal pressure and impaired respiratory-swallow coordination, which may be a result of obstructive airflow and low lung volume. Patients are at an increased risk of aspiration, particularly with larger bolus and subsequent sips of liquids. However, review of included studies also showed this risk and subglottal pressure may be improved with the EMST because expiratory muscles improve airway protection and lower airway and mouth pressure.

When generating high expiratory muscles, the supralaryngeal muscles of swallow co-contract with greater muscle activity. This has been shown to translate to decreased penetration/aspiration, increased hyolaryngeal elevation with swallowing and improvements in swallowing quality of life. All of these outcomes are in previously peer reviewed publications.

Of particular note, the studies investigating EMST as a treatment for patients with COPD including those primarily with GOLD [25] stage 3 COPD while the studies investigating the prevalence of dysphagia included patients primarily with GOLD stage 2 COPD. However, all studies included a variety of GOLD severity levels within the COPD participants.

Finally, consistent with the hypothesis for purpose 3, EMST treatments were an effective intervention for dysphagia in patients with multiple sclerosis and Parkinson's disease affecting lung function in a manner similar to COPD.

CONCLUSION

Hospital and skilled nursing facility clinicians, particularly speech language pathologists, may assess and/or treat patients with COPD for oropharyngeal dysphagia [2,3]. Previous results show swallow function is affected by respiratory function and respiratory function improves in patients with COPD after EMST. The current analysis supports the potential use of EMST for improving dysphagia in patients with COPD by using an EMST device because of the ease, convenience, and cost effectiveness of the device. It allows for low-mobility patients to improve lung function and dysphagia regardless of facility, severity, or overall physical abilities, which can be a factor for those with COPD.

The literature review provides support to the theory that EMST may improve dysphagia in patients with COPD. However, this review also revealed a deficit in the availability of higher levels of evidence-based research. Further research with randomized participant pools with control of COPD disease severity and comorbidities is needed to show the feasibility and potential benefits of using EMST for improving dysphagia in patients with COPD. Careful research design may aid in determining clinical applicability and long-term effectiveness. Research is required investigating the benefits of combined EMST and IMST as a combined modality treatment option for patients with COPD.

The review also indicated randomized research is needed to examine the effect of using EMST to improve dysphagia in other patient populations. The literature reviewed revealed improvement of swallow in patients with Parkinson's disease and improvement of voluntary cough reflex in patients with multiple sclerosis [23,24]. Literature available, but not meeting the inclusion criteria also showed improvement of dysphagia in patients with amyotrophic lateral sclerosis [26]. If other neurological diseases are examined, one may be able to determine further the cross-benefits of EMST, as well as long-

term effectiveness on swallow impairment, lung function, airway protection, and disease severity or exacerbation.

PRATICAL IMPLICATIONS

The implications in finding benefits to swallow function in patients with COPD through the use of a handheld EMST device may lay the framework for an alternative standardized treatment protocol. These devices are small, lightweight, and are provided with instructions for patients that are user-friendly. The devices may be used in homes and healthcare facilities. As discussed, a patient with COPD can improve lung function with a device. If benefit to dysphagia is also found, a patient with COPD may be equipped with a tool that could supplement their overall plan

Table 4: Measurements Included for Analysis

Expiratory Muscle Strength Training with a Device as a Treatment for Dyspnea	Swallow Impairments in Patients with COPD	EMST with a Device as Dysphagia Treatment in Other Disorders
BORG Scale	Laryngopharyngeal Sensitivity	Pulmonary Index
Modified Medical Research Council Scale	Oral Transit	PE_{max}
St. George's Respiratory Questionnaire	Maximal Glossopalatal Opening	Hyoid Displacement • Onset Bolus Transit • UES Opening • UES Widest • UES Closure • Laryngeal Closure • Maximum Laryngeal Closure • Laryngeal Opening
PE_{max}	Pharyngeal Transit	
PE_{mpeak}	Pharyngeal Clearance	
San Diego Shortness of Breath Questionnaire	UES Transit	
Human Activity Profile	Maximal Laryngeal Elevation	
Short Form 36-item Health Survey, Version 2.0	Duration of Hyoid Movement	
MEP	Laryngeal Vestibular Closure	
PEFR	Oral-Pharyngeal Transit	
FEV_1 (Liter)	Modified Medical Research Council Scale	
FVC (Liter)	Pharyngeal Symptoms	
TLC (Liter)	Esophageal Symptoms	
Modified BORG Scale	Nutritional Symptoms	
Mahler Focal	Oral Symptoms	
	Penetration-Aspiration Scale	
	Swallows Occurring at Tidal Volume (V_T)	
	Pharyngeal Response Time	
	Pharyngeal Delay Time	
	Oral Residue (%)	
	Pharyngeal Residue (%)	
	Oropharyngeal Swallow Efficiency (%)	
	Duration of Tongue Base Movement to Posterior Pharyngeal Wall	
	Duration of Tongue Base Contact with Posterior Pharyngeal Wall • Mid-C2 • Inferior-C2 • Superior-C3	
	Duration of Velopharyngeal Closure	
	Duration of Hyoid Elevation	
	Duration of Laryngeal Elevation	
	Duration of Laryngeal Entrance Closure	
	Duration of Cricopharyngeal Opening	
	Duration of Laryngeal Entrance Closure to First Opening	

of care in an effort to minimize further exacerbations from aspiration pneumonia.

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DISCLOSURE

No financial interest or conflict of interest exist for the authors.

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