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Effects of Transcutaneous Neuromuscular Electrical Stimulation on Swallowing Disorders

A Systematic Review and Meta-Analysis

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Objective: The aim of the study was to evaluate the efficacy of transcutaneous neuromuscular electrical stimulation on swallowing disorders. **Design:** MEDLINE/PubMed, Embase, CENTRAL, Web of science, and PEDro were searched from their earliest record to August 1, 2019. All randomized controlled trials and quasi-randomized controlled trial were identified, which compared the efficacy of neuromuscular electrical stimulation plus traditional therapy with traditional therapy in swallowing function. The Grading of Recommendations Assessment, Development and Evaluation approach was applied to evaluate the quality of evidence. **Results:** Eight randomized controlled trials and three quasi-randomized controlled trials were included. These studies demonstrated a significant, moderate pooled effect size (standard mean difference = 0.62; 95% confidence interval = 0.06 to 1.17). Studies stimulating suprahyoid muscle groups revealed a negative standard mean difference of 0.17 (95% confidence interval = −0.42, 0.08), whereas large effect size was observed in studies stimulating the infrahyoid muscle groups (standard mean difference = 0.89; 95% confidence interval = 0.47 to 1.30) and stimulating the suprahyoid and infrahyoid muscle groups (standard mean difference = 1.4; 95% confidence interval = 1.07 to 1.74). Stimulation lasting 45 mins or less showed a large, significant pooled effect size (standard mean difference = 0.89; 95% confidence interval = 0.58 to 1.20). The quality of evidences was rated as low to very low. **Conclusions:** There is no firm evidence to conclude on the efficacy of neuromuscular electrical stimulation on swallowing disorders. Larger-scale and well-designed randomized controlled trials are needed to reach robust conclusions.

What Is Known

- Transcutaneous neuromuscular electrical stimulation (NMES) is a new therapeutic method for dysphagia; its clinical effectiveness remains unclear. In addition, several studies with stimulating different muscle groups for improving swallowing function have been published and remain controversial.

What Is New

- This meta-analysis is the first to identify the effectiveness of NMES according to the stimulation muscle groups and stimulation duration. However, the quality of evidence according to Grading of Recommendations Assessment, Development and Evaluation approach ranged from low to very low. Therefore, there is no firm evidence to conclude on the efficacy of NMES on swallowing disorders. High-quality studies are needed to reach robust conclusions.

Key Words: Electric Stimulation, Deglutition, Rehabilitation, Meta-analysis

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Dysphagia is a clinical manifestation that interferes with the process of delivering food material from oral cavity to stomach because of neurologic or structural disorders.[1] Deglutition has a high prevalence, which is reported in 38%–65% of traumatic brain injury patients.[2,3] The prevalence of dysphagia After Parkinson is estimated to vary from 11% to 87%.[4,5] Between 31% and 79% of head and neck cancer patients experience dysphagia followed radiotherapy,[6,7] and 8%–80% of patients with stroke experience swallowing disorders.[8] Dysphagia is a major cause of mortality and morbidity due to life-threatening complications, including dehydration, malnutrition, and aspiration pneumonia.[9]

Currently, traditional therapies (TTs) include compensation strategies, such as posture adjustment or dietary modifications, heightening weak oropharyngeal musculature through oral motor exercises, swallowing exercises for the improvement impaired aspects of oropharyngeal swallowing, and strengthening sensory input through thermal tactile stimulation.[10] Transcutaneous neuromuscular electrical stimulation (NMES) is a new therapeutic method for dysphagia, involving the delivering of electrical current across the skin to stimulate the nerve or muscle

fibers during a functional task.[11] Although it has been hypothesized that transcutaneous NMES might increase swallowing muscle strength and sensory awareness to initiate or re-establish swallowing function,[12] its clinical effectiveness needs to be further verified because of the small number of studies.[11,13]

The different electrode placements will stimulate the different muscle groups and change the swallowing physiology in different ways.[14] As is known to all, suprahyoid muscle groups including the digastric muscle, mylohyoid muscle, and geniohyoid muscle pull the hyoid bone upward and toward the mandible, whereas most of the infrahyoid muscle groups, such as sternohyoid muscle, omohyoid muscle, and sternothyroid muscle, pull down the hyolaryngeal complex toward the sternum. When the infrahyoid muscle groups are stimulated during swallowing, it may cause penetration/aspiration.[15] In recent years, several studies with stimulating different muscle groups for improving swallowing function have been published and remain controversial.[16–18] The purpose of this study is to perform a meta-analysis of randomized controlled trials (RCTs) and quasi-RCTs to evaluate the efficacy of transcutaneous neuromuscular electrical stimulation (NMES) targeting the specific muscle groups on swallowing disorders.

METHODS

This systematic review and meta-analysis was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines[19] (see Supplemental Checklist, Supplemental Digital Content 1, http://links.lww.com/PHM/A959).

Eligibility Criteria

Studies were considered eligible and included into this systematic review that met the following participants, interventions, comparisons, outcomes and studies criteria: (*a*) *types of participants*: adults (aged ≥18 yrs) with dysphagia, diagnosed clinically (water swallow tests, oral intake of different food consistencies, and volumes) by a full bedside evaluation, or by videofluoroscopy or fiberoptic endoscopic evaluation of swallowing, or by valid reliable measures, such as the

Penetration-Aspiration Scale.[20] Participants suffered any stage and severity of dysphagia. (*b*) *Types of interventions*: intervention transcutaneous NMES targeting the specific muscle groups combined with TT. The schematic drawing that showing the electrode placements to the suprahyoid and infrahyoid muscles was shown in Figure 1. There was no restriction for the protocol of transcutaneous NMES. Comparison TT (including posture adjustment, dietary modifications, oral motor exercises, swallowing exercises, Mendelson maneuver, and thermal tactile stimulation) or TT combined with sham stimulation. (*c*) *Intervention efficacy evaluation and outcome measures*: intervention efficacy was rated with swallowing function. All validated quantitative scores that measured swallowing function in patients with dysphagia were acceptable, such as the Dysphagia Outcome and Severity Scale,[21] the Functional Dysphagia Scale,[22] and the Functional Oral Intake Scale.[23] (*d*) *Types of studies*: RCTs and quasi-RCTs examining the effectiveness of NMES plus TT on swallowing disorders were included. Quasi-RCTs are studies in which the method of allocation is not considered strictly random, such as case record number or date of admission. All studies were published in English.

Search Strategy

A comprehensive electronic search strategy of MEDLINE/PubMed, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, and PEDro was performed from their earliest record to August 1, 2019. In addition, studies were identified from the reference lists of relevant systematic reviews and included articles. Citation tracking of all included articles was also performed. The highly sensitive filter was used to exclude animal trials and non-English trials. The search strategies can be seen in Appendix 1 (Supplemental Digital Content 2, http://links.lww.com/PHM/A960).

Selection Criteria

Two authors independently scanned the titles and abstracts, excluding obviously irrelevant studies. The full text of relevant
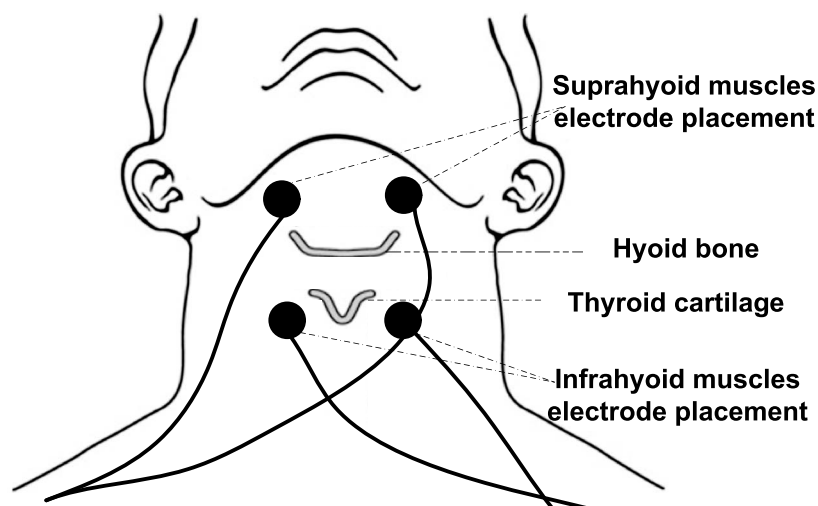

FIGURE 1. A schematic drawing that showing the electrode placements to the suprahyoid and infrahyoid muscles.

articles was evaluated according to prespecified eligibility criteria. Disagreements were resolved through discussion with the corresponding author.

Data Extraction

Two reviewers independently extracted data using a predefined data recording form, and discussed disagreements with the corresponding author by consensus. Specifically, the following data were extracted: details of the study design, patient characteristics (etiology, the number of patients, age, sex), intervention protocol (frequency, intensity, duration, and stimulation muscle groups), as well as swallowing function outcomes and assessment timing. The means and SDs of change scores (change from baseline) were extracted. When data were not reported, the posttreatment mean and SD were extracted. When articles only provided the median and quartiles, the mean and SD were estimated as described by Wan et al.[24] If important data were not available, attempts were made to contact the author by e-mail. When the authors did not respond to requests, the study was excluded.

Risk of Bias Assessment

Two reviewers independently assessed the risk of bias, using the Cochrane Risk of Bias Tool in the Cochrane Handbook for Systematic Reviews of Interventions.[25] This tool addressed seven domains, including random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases.[25] The risk of bias was assessed in each domain as "low risk," "unclear," or "high risk." Discrepancies between two reviewers were resolved through discussion until an agreement was reached.

Statistical Analysis

The standard mean difference (SMD) and corresponding 95% confidence intervals (CIs) were used to quantify the differences in the treatment effects for continuous variables. More specifically, the SMDs less than 0.4, 0.40–0.70, and greater than 0.70 represents small, moderate, and large, respectively.[25] To evaluated heterogeneity among different studies, both I^2 test and Q test were conducted. If I^2 of greater than 50%, or $P < 0.05$, it indicated that there was significant heterogeneity and the meta-analysis were carried out using the random effects model; otherwise, a fixed effects model was performed. Subgroup analysis was conducted based on etiology, stimulation muscle groups, and stimulation duration. Sensitivity analysis was performed to evaluate the stability of the results by removing individual studies. Funnel plots and Egger tests were used to assess publication bias. A threshold of $P < 0.05$ was considered statistically significant. All meta-analysis and funnel plots were performed using Review Manager Software 5.3. Egger tests were conducted using STATA Version 11.0.

Quality Assessment

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach[26] was applied to evaluate the quality of the evidence for each outcome by two reviewers, using GRADEPro software Version 3.6. Evidence level was classified as high, moderate, low, and very low. Randomized

controlled trials were initially considered high-quality. However, it is possible to downgrade this level of evidence according to five factors (study limitation, inconsistency, imprecision, indirectness, and publication bias).

RESULTS

Study Selection

A total of 976 studies were yielded. Using the EndNote X7 exact duplicate finder, 630 studies remained after de-duplication. Six hundred nine studies were excluded after title and abstract screening. Upon further full-text review of the 21 articles, 10 articles were excluded because surface electrodes were not targeting the specific muscle groups, outcomes were not swallowing function, data could not be available, or data were duplicated in another included article. No additional articles were included by the manual research of reference lists and citation tracking. At last, 11 studies involving 585 patients were considered eligible for this meta-analysis,[16–18,27–34] and the searching progress was presented in Figure 2.

Risk of Bias Assessment

The risk of bias for included studies was evaluated with the Cochrane Risk of Bias Tool, and the results are presented in Figures 3A and B. Seven studies were assessed as a low risk of bias in random sequence.[16,17,29,30,32–34] Only two studies had a low risk of bias in allocation concealment using sealed envelope or independent data coordinating center.[16,33] Three studies used sham stimulation as a control, which were classified at low risk of performance bias.[31–33] Three studies implemented blinding of the assessors, which were judged as at low risk of detection bias.[30,31,33] Seven studies with an adequate description for incomplete outcome data were evaluated as low risk.[16–18,29,30,32,34] All included studies were free of selective outcome reporting.[16–18,27–34] Eight studies had small sample sizes, ranging from 18 to 57 (high risk of bias).[17,18,28–32,34] Langmore et al.[33] stated that patients in their control group finished the treatment at home, which could have an effect on patient compliance (high risk of bias).

Study Characteristics

The 11 studies involving 585 patients were included.[16–18,27–34] Studies were undertaken across five countries, and six were conducted in Korea, two in China, one in the United States, one in the Netherlands, and one in Spain. Of the 11 studies, eight of the studies were RCTs[16,17,29–34] and the three other studies used a clinical controlled trial (CCT) design.[18,27,28] The characteristics of included studies were summarized in Table 1. All studies included variable etiologies, including stroke, traumatic brain injury, head and neck cancer, and Parkinson disease. The age of the participants varied from 46[30] to 68.5[18] yrs. Nevertheless, the demographic information of included patients was not reported in two studies.[27,33]

Interventions

The electrode placement was targeted the specific muscle groups among studies. Five studies stimulated the suprahyoid and infrahyoid muscle groups,[16,28–30,34] four studies stimulated the suprahyoid muscle groups,[18,27,33,34] and three other studies
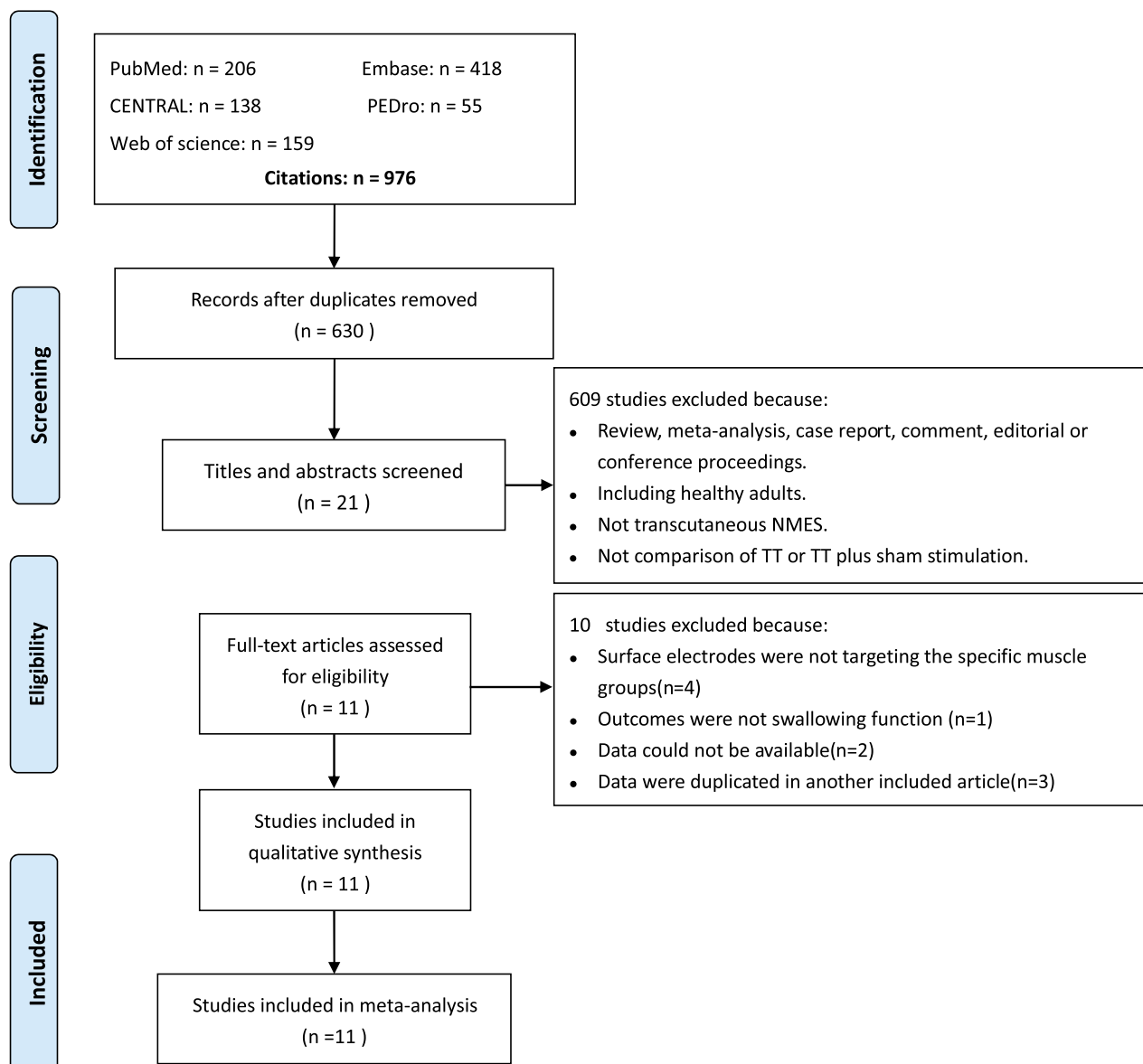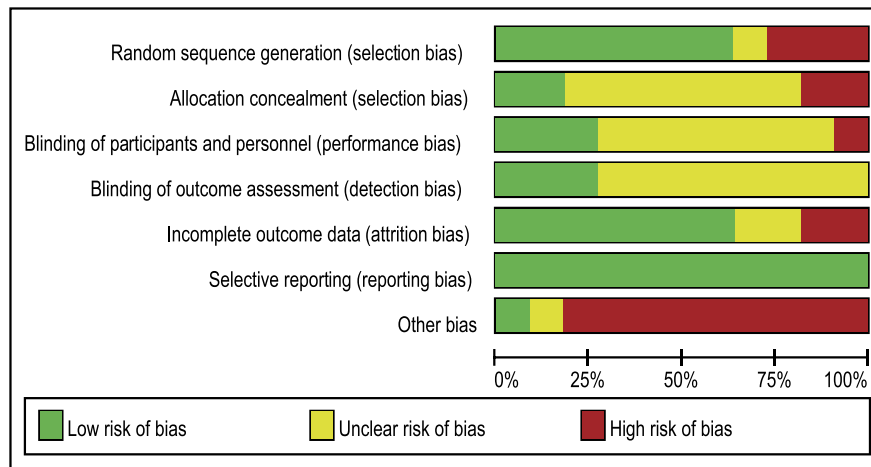
FIGURE 2. Flow chart of study selection.

stimulated the infrahyoid muscle groups.[17,31,32] The study by Meng et al.[34] used the three treatment arms, including TT plus stimulating the suprahyoid and infrahyoid muscle groups, TT plus stimulating the suprahyoid muscle groups alone, and TT. The included studies reported the frequency of NMES, ranged from 60 Hz to 80 Hz. The intensity varied across all studies. Conducting daily treatment during weekdays, two studies used a 1-hour session,[16,28] seven studies followed a similar treatment duration for 30 mins per day,[17,18,27,29,31,32,34] and the stimulation of two other studies lasted for 16–20 and 45 mins per time,[30,33] respectively. The treatment sessions were ranged from 10 to 72 mins across the studies.

Swallowing Function Outcomes

The swallowing function outcomes measures differed across trials. When multiple outcomes were used in a study, the outcome that was an ordinal scale was chosen as an attempt to maintain uniformity.[35] Specifically, the Functional Oral Intake Scale[23] was used by Terre et al.[30] and Lee et al.,[17] which is a 7-point ordinal scale describing the dietary intake of patients experienced dysphagia. Another outcome measure, used by two studies,[18,31] was the American Speech Language-Hearing Association National Outcome Measurement System Swallowing Level Scale (NOMS).[36] The American Speech Language-Hearing Association level is measured based on the supervision level required and diet level, decreasing severity from 1 to 7. The Penetration Aspiration Scale (PAS)[20] was used by Park et al.[32] and Langmore et al.,[33] a scale of increasing severity from 1 to 8. The Standardized Swallowing Assessment,[37] a scale of increasing severity from 17 to 46, was used as an outcome measure for Li et al.[16] The Functional Dysphagia Scale,[22] a scale of increasing severity from 1 to 100 representing different characteristics of the oral and pharyngeal stages was used by Lim et al.[29] The

FIGURE 3. Assessment of the risk of bias (A) and risk of bias summary (B).

Dysphagia Outcome and Severity Scale[21] was used by Meng et al.,[34] which is a scale of decreasing severity from 1 to 7 rating the diet level, independence level, and type of nutrition. In addition, the Dysphagia Severity Scale was used by Heijnen et al.,[27] whose patients self-report their dysphagia with a score presented as 0 to 100 points. Finally, the swallow function scoring system,[38] used by Lim et al.,[28] was validated as a 7-point scale that describes the severity of swallowing function from 0 to 6. Furthermore, a minus sign was added to the extracted value of PAS, Functional Dysphagia Scale, and Standardized Swallowing Assessment to match direction of other scales with greater scores indicating improvement.

Meta-Analysis

Overall Summary Effect

Compared with control groups, NMES plus TT significantly improved swallowing function by a SMD of 0.62 (95% CI = 0.06 to 1.17; $I^2 = 89\%$; Fig. 4A), which would be considered a moderate effect size. Sensitivity analysis was performed by removing 3 CCT.[18,27,28] The SMD from the remaining eight studies was 0.92 (95% CI = 0.19 to 1.64; $I^2 = 90\%$; Fig. 4B). It seems that the finding was relatively stable.

Etiology of Dysphagia

In the subgroup analyses based on the etiology of dysphagia, acquired brain injury (stroke and traumatic brain injury) group exhibited statistically significant improvement between the two interventions, and the pooled SMD was 0.95 (95% CI = 0.22 to 1.68; $I^2 = 87\%$; Fig. 4C). Head and neck cancer group (SMD = 0.07; 95% CI = −0.46 to 0.60; $I^2 = 40\%$; Fig. 4C) and Parkinson group (SMD = 0.02; 95% CI = −0.75 to 0.79; $I^2 = 76\%$; Fig. 4C) produced an uncertain effect.

Stimulation Muscle Groups

Studies stimulating suprahyoid muscle groups showed a negative SMD value of 0.17 (95% CI = −0.42 to 0.08; Fig. 4D)

TABLE 1. The characteristics of included studies

Study	Country	Study Design	Etiology	Comparison	No. Participants (Exp/Ctr)	Age, yr	Sex (M/F)	Stimulation Muscle Groups	Reported Stimulation Parameters	Swallowing Function Outcomes	Assessment Timing
Li et al.[16] (2015)	China	RCT	Stroke	NMES + TT vs. NMES vs. TT	135 (45/45/45)	66.7 ± 14.6; 65.8 ± 13.2; 66.1 ± 13.1	24/21; 22/23; 23/22	Suprahyoid and infrahyoid muscle groups	Intensity: inducing tingling sensations, at approximately 7 mA Duration: 1 h/d, 5 times/wk, 20 sessions.	SSA	0 and 4 wks
Lim et al.[29] (2014)	Korea	RCT	Stroke	NMES + TT vs. rTMS + TT vs. TT	60 (20/20/20)	65.4 ± 15.5; 61.8 ± 10.4; 60.6 ± 7.7	12/8; 9/11; 13/7	Suprahyoid and infrahyoid muscle groups	Frequency: 80 Hz Intensity: 7–9 mA Duration: 30 mins/d, 5 times/wk, 10 sessions.	FDS	0, 2, and 4 wks
Lim et al.[28] (2009)	Korea	CCT	Stroke	NMES + TT vs. TT	28 (16/12)	67.8 ± 8.1; 60.8 ± 12.3	14/2; 10/2	Suprahyoid and infrahyoid muscle groups	Intensity: inducing tingling sensations, at approximately 7 mA Duration: 1 h/d, 5 times/wk, 20 sessions.	Swallow function scores	0 and 4 wks
Terre et al.[30] (2015)	Spain	RCT	Stroke and traumatic brain injury	NMES + TT vs. TT	20 (10/10)	46.0; 51.0	6/4; 6/4	Suprahyoid and infrahyoid muscle groups	Frequency: 80 Hz Intensity: 7–12 mA, average 9.5 mA Duration: 45 mins/d, 5 times/wk, 20 sessions.	FOIS	0, 1, and 3 mos
Lee et al.[17] (2014)	Korea	RCT	Stroke	NMES + TT vs. TT	57 (31/26)	63.4 ± 11.4; 66.7 ± 9.5	22/9; 20/6	Infrahyoid muscle groups	Frequency: 80 Hz Intensity: maximal tolerable intensity Duration: 30 mins/d, 5 times/wk, 15 sessions.	FOIS	0, 3, 6, and 12 wks
Ryu et al.[31] (2009)	Korea	RCT	Head and neck cancer	NMES + TT vs. TT	26 (14/12)	63.4 ± 7.3; 60.8 ± 12.0	14/0; 11/1	Infrahyoid muscle groups	Frequency: 80 Hz Intensity: inducing a grabbing sensation Duration: 30 mins/d, 5 times/wk, 10 sessions.	ASHA NOMS	0 and 2 wks

Study	Country	Design	Population	Intervention	N	Age	M/F	Muscle groups	Parameters	Outcome	Timepoints
Park et al.[32] (2018)	Korea	RCT	Parkinson	NMES + TT vs. sham NMES + TT	18 (9/9)	63.4 ± 13.6; 54.7 ± 13.8	5/4; 3/6	Infrahyoid muscle groups	Frequency: 80 Hz. Intensity: inducing a strong muscle contraction. Duration: 30 mins/d, 5 times/wk, 20 sessions.	PAS	0 and 4 wks
Beom et al.[18] (2011)	Korea	CCT	Stroke and traumatic brain injury	NMES + TT vs. TT	28 (7/21)	66.1 ± 19.5; 68.5 ± 12.5	3/4; 9/12	Suprahyoid muscle groups	Frequency: 60 Hz. Intensity: Maximal tolerable intensity. Duration: 30 mins/d, 5 times/wk, 20 sessions.	ASHA NOMS	0 and 4 wks
Heijnen et al.[27] (2012)	The Netherlands	CCT	Parkinson	NMES (motor) + TT vs. NMES (sensory) + TT vs. TT	88 (29/29/30)	NR	NR	Suprahyoid muscle groups	Frequency: 80 Hz. NMES (motor) intensity: average 9.5 mA. NMES (sensory) intensity: average 3.25 mA. Duration: 30 mins/d, 5 times/wk, 13–15 sessions.	DSS	0, 3–5 wks
Langmore et al.[33] (2016)	America	RCT	Head and neck cancer	NMES + TT vs. sham NMES + TT	125 (90/35)	NR	NR	Suprahyoid muscle groups	Frequency: 70 Hz. Intensity: inducing a comfortable contraction. Duration: 16–20 mins/times, 2 times/d, 6 d/wk for 12 wks, 72 sessions.	PAS	0 and 13 wks
Meng et al.[34] (2018)	China	RCT	Stroke	NMES (A) + TT vs. NMES (B) + TT vs. TT	30 (10/10/10)	65.2 ± 10.7; 67.2 ± 15.8; 64.4 ± 9.0	7/3; 6/4; 7/3	A: Suprahyoid and infrahyoid muscle groups; B: Suprahyoid muscle groups	Frequency: 80 Hz. Intensity: 0–25 mA. Duration: 30 mins/d, 5 times/wk, 10 sessions.	DOSS	0 and 2 wks

ASHA NOMS, American Speech Language-Hearing Association National Outcome Measurement System Swallowing Level Scale; Ctr, control group; DOSS, Dysphagia Outcome and Severity Scale; DSS, Dysphagia Severity Scale; Exp, experimental group; FDS, Functional Dysphagia Scale; FOIS, Functional Oral Intake Scale; M/F, male/female; NR, not reported; RCT, randomized controlled trial; rTMS, repetitive transcranial magnetic stimulation; SSA, standardized swallowing assessment.
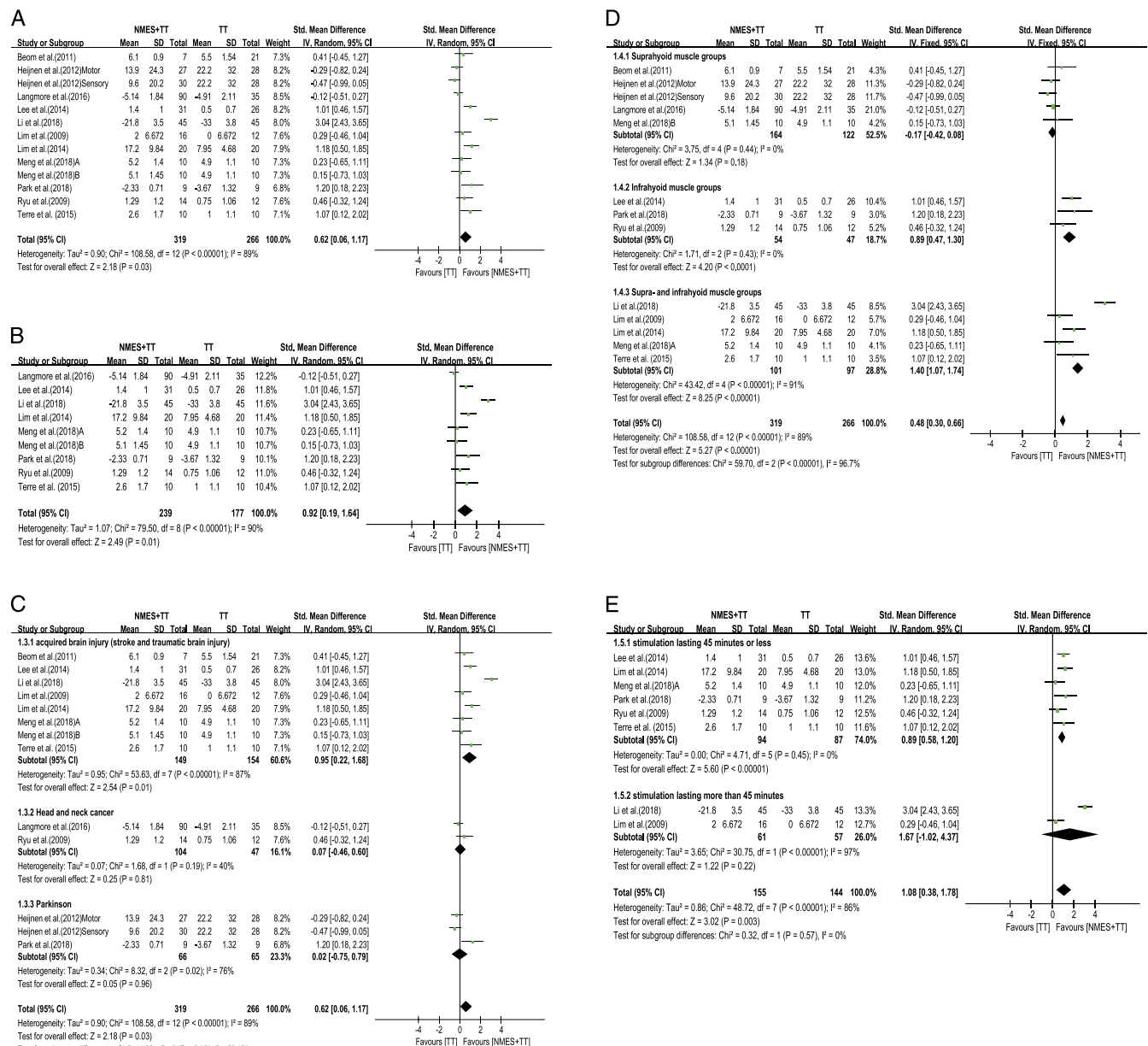
FIGURE 4. Forest plot: effects of NMES on swallowing function (A), sensitivity analysis by excluding 3 CCT (B), subgroup analysis based on etiology (C), stimulation muscle groups (D), and stimulation duration (E).

without significant heterogeneity ($I^2 = 0\%$). However, large effect size was observed in studies stimulating the infrahyoid muscle groups (SMD = 0.89; 95% CI = 0.47 to 1.30; $I^2 = 0\%$; Fig. 4D) and studies stimulating the suprahyoid and infrahyoid muscle groups (SMD = 1.40; 95% CI = 1.07 to 1.74; $I^2 = 91\%$; Fig. 4D).

Stimulation Duration

When the analysis only included studies stimulating the infrahyoid muscle groups and stimulating the suprahyoid and infrahyoid muscle groups, stimulation lasting 45 mins or less demonstrated a large, significant pooled effect size (SMD = 0.89; 95% CI = 0.58 to 1.20; Fig. 4E) without significant heterogeneity ($I^2 = 0\%$). Studies stimulating lasting more than 45 mins produced an uncertain effect (SMD = 1.67; 95% CI = −1.02 to 4.37; $I^2 = 97\%$; Fig. 4E).

Adverse Effects

No serious adverse events associated with NMES were reported in all included studies. Only two studies mentioned that subjects complained of pain.[18,29] One study[18] reported transient pain, which disappeared immediately after cessation of NMES. Lim et al.[29] reported that two participants complained of mild pain, but it was resolved after the adjustment of the stimulation intensity.

Publication Bias

Funnel plot and Egger test were used to assess the publication bias. The funnel plot was symmetrical on visual inspection (Appendix 2, Supplemental Digital Content 2, http://links.lww.com/PHM/A960). Egger tests indicated that no significant publication bias was observed ($P = 0.303$).

Quality of Evidence

Quality of evidence contributing to this meta-analysis was rated as low to very low. The reasons for this decision were documented. The "Summary of findings" table is shown in Table 2.

DISCUSSION

This systematic review showed that NMES, targeting the specific muscle groups, plus TT could significantly improve the swallowing function. Subgroup analysis showed a beneficial effect in the acquired brain injury group that was not observed in the head and neck cancer group and Parkinson group. Swallowing function could be improved by stimulating the suprahyoid and infrahyoid muscle groups or single stimulating infrahyoid muscle groups, especially for stimulating 45 mins or less. The quality of evidence according to GRADE approach ranged from low to very low.

Further analysis of articles included in this meta-analysis found that two studies using the same outcome measurement showed the different result.[32,33] Langmore et al.[33] reported that the NMES plus TT had significantly worse PAS scores than the sham NMES plus TT, whereas Park et al.[32] reported that the NMES plus TT revealed significant improvement in PAS. By analyzing the characteristics of these two studies,[32,33] etiology

TABLE 2. Summary of findings table

"NMES + TT" Compared With "TT or TT + Sham Stimulation" for Swallowing Disorders

Patient or population: patients with swallowing disorders
Settings: in hospital
Intervention: NMES + TT
Comparison: TT or TT + sham stimulation

Outcomes	Illustrative Comparative Risks* (95% CI)		Relative Effect (95% CI)	No. Participants (Studies)	Quality of the Evidence (GRADE)
	Assumed Risk TT or TT + Sham Stimulation	Corresponding Risk NMES + TT			
Swallowing function		SMD 0.62 higher (0.06 higher to 1.17 higher)		585 (13 studies)	⊕⊕⊖⊖ low[a–d]
Etiology-acquired brain injury		SMD 0.95 higher (0.22 higher to 1.68 higher)		303 (8 studies)	⊕⊖⊖⊖ very low[a–e]
Etiology-head and neck cancer		SMD 0.07 higher (0.46 lower to 0.6 higher)		151 (2 studies)	⊕⊕⊖⊖ low[e,f]
Etiology-Parkinson		SMD 0.02 higher (0.75 lower to 0.79 higher)		131 (3 studies)	⊕⊖⊖⊖ very low[c–e,g,h]
Stimulation muscle groups-stimulating suprahyoid muscle groups		SMD 0.17 lower (0.42 lower to 0.08 higher)		286 (5 studies)	⊕⊕⊖⊖ low[e–h]
Stimulation muscle groups-stimulating infrahyoid muscle groups		SMD 0.89 higher (0.47 higher to 1.3 higher)		101 (3 studies)	⊕⊕⊖⊖ low[a,e,f]
Stimulation muscle groups-stimulating suprahyoid and infrahyoid muscle groups		SMD 1.4 higher (1.07 higher to 1.74 higher)		198 (5 studies)	⊕⊖⊖⊖ very low[a–e]
Stimulation duration-stimulation lasting 45 mins or less		SMD 0.89 higher (0.58 higher to 1.2 higher)		181 (6 studies)	⊕⊕⊖⊖ low[a–c,e]
Stimulation duration-stimulation lasting more than 45 mins		SMD 1.67 higher (1.02 lower to 4.37 higher)		118 (2 studies)	⊕⊖⊖⊖ very low[b–e,h]

*The basis for the assumed risk (eg, the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

GRADE Working Group grades of evidence.

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

[a] No clear description of allocation concealment.

[b] No clear description of blinding of participants and personnel.

[c] No clear description of blinding of outcome assessment.

[d] Significant heterogeneity.

[e] Less than 400 subjects.

[f] Incomplete outcome data.

[g] No allocation concealment.

[h] Lack of random sequence generation.

and stimulation muscle groups might be reasons for the different conclusions. Therefore, subgroup analysis was performed based on etiology and stimulation muscle groups.

This meta-analysis showed a moderate, significant pooled effect size of 0.62 in the acquired brain injury (stroke and traumatic brain injury) group, which is much smaller than what has been seen in the other meta-analysis.[13] Tan et al.[13] calculated effect sizes of 0.78. The author included studies comparing NMES versus TT and studies comparing NMES plus TT versus TT into a meta-analysis for "NMES versus TT." The inappropriately comparisons in their meta-analysis might have caused the difficulty in interpreting the results. Moreover, the present meta-analysis included patients with stroke or traumatic brain injury, whereas the meta-analysis conducted by Tan et al.[13] only enrolled patients with stroke. The differences in samples may have an impact on the effectiveness. Additionally, given the small number of studies included in the head and neck cancer group and Parkinson group, insufficient data were available to draw a reliable conclusion.

Another important factor is which muscle groups should be stimulated. Though large effects sizes observed in studies stimulating the suprahyoid and infrahyoid muscle groups (SMD = 1.40; 95% CI = 1.07 to 1.74) and single stimulating infrahyoid muscle groups (SMD = 0.89; 95% CI: 0.47 to 1.30), there was no evidence of effect in studies stimulating suprahyoid muscle groups (SMD = −0.17; 95% CI = −0.42 to 0.08). The possible reason is that infrahyoid muscle groups, including omohyoid muscle and sternohyoid muscle, are larger and closer to the surface than the suprahyoid muscle groups.[14] Thus, the infrahyoid muscle groups have greater muscular strength and are more easily to be stimulated when the surface electrodes are placed.[34] Of particular concern is the fact that most of the infrahyoid muscle groups lower the hyolaryngeal complex toward the sternum. Stimulating the infrahyoid muscle groups during swallowing may increase the risk of aspiration.[15]

For studies stimulating the suprahyoid and infrahyoid muscle groups and stimulating infrahyoid muscle groups, the duration of stimulation varied from 30 to 60 mins. Studies stimulation lasting 45 mins or less demonstrated a large, significant pooled effect size (SMD = 0.89; 95% CI = 0.58 to 1.20) without significant heterogeneity (I^2 = 0%). However, the SMD for the stimulating more than 45-min group (1.67) was greater than that of the stimulating 45 mins or less group (0.89). Given the significant heterogeneity and wide CIs in the stimulating more than 45-min group, caution should be taken before jumping to conclusions.

Three studies reported long-term outcomes for swallowing rehabilitation,[17,29,30] which were measured at different time points after interventions. Therefore, the follow-up data were not analyzed. Clinically, patients need to improve swallowing function not only immediately after the intervention but in the long term. The limited number of long-term follow-up studies provided limited evidence for long-term effectiveness and limit comparisons between short- and long-term intervention effects.

As for safety concerns, only pain occurred in two studies,[18,29] which disappeared after cessation of NMES or adjusting the stimulation intensity. However, possible adverse events of NMES including laryngospasm, arrhythmia, hypotension, glottic closure, and skin irritation have been reported previously.[38] Perhaps larger patient groups could reveal the safety of NMES.

The quality of evidence according to GRADE approach ranged from low to very low. The weakness in quality of evidences was mainly due to the high risks of bias, imprecision, and inconsistency. Lack of blinding and allocation concealment constituted the judgment of high risks of bias. Imprecision induced by the small sample sizes and inconsistency from diversities across the included studies led to downgrading the quality of evidence. The low quality of the evidence suggested that confidence in the effect estimate is limited and the true effect may differ substantially from the estimated effect.[39] Therefore, this study cannot draw firm conclusions on the efficacy of NMES. High-quality studies are needed to reach robust conclusions.

There were some limitations to this systematic review. First, the included studies differed considerably regarding the patient characteristics, stimulation parameters, and outcome measurements contributing to the evident heterogeneity. Second, the meta-analysis focused on short-term effectiveness immediately after the intervention, in which only three studies provide limited evidence for long-term effectiveness and remain controversial. Finally, this systematic review only searched for published studies in English, which might also cause potential bias.

CONCLUSIONS

There is no firm evidence to conclude on the efficacy of NMES on swallowing disorders. Larger-scale and well-designed RCTs are needed to reach robust conclusions. In addition, researchers should pay attention to the most optimal NMES protocol (eligible participants, stimulation muscle groups, duration) and long-term effects of NMES.

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REFERENCES

1. Sejdić E, Malandraki GA, Coyle JL: Computational deglutition: signal and image processing methods to understand swallowing and associated disorders. *IEEE Signal Process Mag* 2019;36:138–46
2. Terré R, Mearin F: Prospective evaluation of oro-pharyngeal dysphagia after severe traumatic brain injury. *Brain Inj* 2007;21(13–14):1411–7
3. Terré R, Mearin F: Evolution of tracheal aspiration in severe traumatic brain injury-related oropharyngeal dysphagia: 1-year longitudinal follow-up study. *Neurogastroenterol Motil* 2009;21:361–9
4. Barichella M, Cereda E, Madio C, et al: Nutritional risk and gastrointestinal dysautonomia symptoms in Parkinson's disease outpatients hospitalised on a scheduled basis. *Br J Nutr* 2013;110:347–53
5. Ding X, Gao J, Xie C, et al: Prevalence and clinical correlation of dysphagia in Parkinson disease: a study on Chinese patients. *Eur J Clin Nutr* 2018;72:82–6
6. Van den Steen L, Van Gestel D, Vanderveken O, et al: Evolution of self-perceived swallowing function, tongue strength and swallow-related quality of life during radiotherapy in head and neck cancer patients. *Head Neck* 2019;41:2197–207
7. Rinkel RN, Verdonck-de Leeuw IM, Doornaert P, et al: Prevalence of swallowing and speech problems in daily life after chemoradiation for head and neck cancer based on cut-off scores of the patient-reported outcome measures SWAL-QOL and SHI. *Eur Arch Otorhinolaryngol* 2016;273:1849–55
8. Takizawa C, Gemmell E, Kenworthy J, et al: A systematic review of the prevalence of oropharyngeal dysphagia in stroke, Parkinson's disease, Alzheimer's disease, head injury, and pneumonia. *Dysphagia* 2016;31:434–41
9. Kushner DS, Peters K, Eroglu ST, et al: Neuromuscular electrical stimulation efficacy in acute stroke feeding tube–dependent dysphagia during inpatient rehabilitation. *Am J Phys Med Rehabil* 2013;92:486–95
10. Tarameshlu M, Ghelichi L, Azimi AR, et al: The effect of traditional dysphagia therapy on the swallowing function in patients with multiple sclerosis: a pilot double-blinded randomized controlled trial. *J Bodyw Mov Ther* 2019;23:171–6
11. Carnaby-Mann GD, Crary MA: Examining the evidence on neuromuscular electrical stimulation for swallowing: a meta-analysis. *Arch Otolaryngol Head Neck Surg* 2007;133:564–71

12. Park JS, Oh DH, Hwang NK, et al: Effects of neuromuscular electrical stimulation combined with effortful swallowing on post-stroke oropharyngeal dysphagia: a randomised controlled trial. *J Oral Rehabil* 2016;43:426–34

13. Tan C, Liu Y, Li W, et al: Transcutaneous neuromuscular electrical stimulation can improve swallowing function in patients with dysphagia caused by non-stroke diseases: a meta-analysis. *J Oral Rehabil* 2013;40:472–80

14. Poorjavad M, Talebian Moghadam S, Nakhostin Ansari N, et al: Surface electrical stimulation for treating swallowing disorders after stroke: a review of the stimulation intensity levels and the electrode placements. *Stroke Res Treat* 2014;2014:918057

15. Ludlow CL, Humbert I, Saxon K, et al: Effects of surface electrical stimulation both at rest and during swallowing in chronic pharyngeal dysphagia. *Dysphagia* 2007;22:1–10

16. Li L, Li Y, Wu XH, et al: The value of adding transcutaneous neuromuscular electrical stimulation (VitalStim) to traditional therapy for Poststroke dysphagia a randomized controlled trial. *Top Geriatr Rehabil* 2018;34:200–6

17. Lee KW, Kim SB, Lee JH, et al: The effect of early neuromuscular electrical stimulation therapy in acute/subacute ischemic stroke patients with dysphagia. *Ann Rehabil Med* 2014;38:153–9

18. Beom J, Kim SJ, Han TR: Electrical stimulation of the suprahyoid muscles in brain-injured patients with dysphagia: a pilot study. *Ann Rehabil Med* 2011;35:322–7

19. Moher D, Liberati A, Tetzlaff J, et al: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009;151:264–9, W64

20. Rosenbek J, Robbins J, Roecker E, et al: A penetration-aspiration scale. *Dysphagia* 1996;11:93–8

21. O'Neil KH, Purdy M, Falk J, et al: The Dysphagia Outcome and Severity Scale. *Dysphagia* 1999;14:139–45

22. Han TR, Paik NJ, Park JW: Quantifying swallowing function after stroke: a functional dysphagia scale based on videofluoroscopic studies. *Arch Phys Med Rehabil* 2001;82:677–82

23. Crary MA, Mann GD, Groher ME: Initial psychometric assessment of a functional oral intake scale for dysphagia in stroke patients. *Arch Phys Med Rehabil* 2005;86:1516–20

24. Wan X, Wang W, Liu J, et al: Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Methodol* 2014;14:135

25. The Cochrane Collaboration: Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0. Available at: http://handbook-5-1.cochrane.org. Accessed March 1, 2011

26. Atkins D, Best D, Briss PA, et al: Grading quality of evidence and strength of recommendations. *BMJ* 2004;328:1490

27. Heijnen BJ, Speyer R, Baijens LW, et al: Neuromuscular electrical stimulation versus traditional therapy in patients with Parkinson's disease and oropharyngeal dysphagia: effects on quality of life. *Dysphagia* 2012;27:336–45

28. Lim KB, Lee HJ, Lim SS, et al: Neuromuscular electrical and thermal-tactile stimulation for dysphagia caused by stroke: a randomized controlled trial. *J Rehabil Med* 2009;41:174–8

29. Lim KB, Lee HJ, Yoo J, et al: Effect of low-frequency rTMS and NMES on subacute unilateral hemispheric stroke with dysphagia. *Ann Rehabil Med* 2014;38:592–602

30. Terre R, Mearin F: A randomized controlled study of neuromuscular electrical stimulation in oropharyngeal dysphagia secondary to acquired brain injury. *Eur J Neurol* 2015;22:687–e44

31. Ryu JS, Kang JY, Park JY, et al: The effect of electrical stimulation therapy on dysphagia following treatment for head and neck cancer. *Oral Oncol* 2009;45:665–8

32. Park JS, Oh DH, Hwang NK, et al: Effects of neuromuscular electrical stimulation in patients with Parkinson's disease and dysphagia: a randomized, single-blind, placebo-controlled trial. *NeuroRehabilitation* 2018;42:457–63

33. Langmore SE, McCulloch TM, Krisciunas GP, et al: Efficacy of electrical stimulation and exercise for dysphagia in patients with head and neck cancer: a randomized clinical trial. *Head Neck* 2016;38(Suppl 1):E1221–31

34. Meng P, Zhang S, Wang Q, et al: The effect of surface neuromuscular electrical stimulation on patients with post-stroke dysphagia. *J Back Musculoskelet Rehabil* 2018;31:363–70

35. Pisegna JM, Kaneoka A, Pearson WG Jr., et al: Effects of non-invasive brain stimulation on post-stroke dysphagia: a systematic review and meta-analysis of randomized controlled trials. *Clin Neurophysiol* 2016;127:956–68

36. Wesling M, Brady S, Jensen M, et al: Dysphagia outcomes in patients with brain tumors undergoing inpatient rehabilitation. *Dysphagia* 2003;18:203–10

37. Perry L: Screening swallowing function of patients with acute stroke. Part one: identification, implementation and initial evaluation of a screening tool for use by nurses. *J Clin Nurs* 2001;10:463–73

38. Freed ML, Freed L, Chatburn RL, et al: Electrical stimulation for swallowing disorders caused by stroke. *Respir Care* 2001;46:466–74

39. Balshem H, Helfand M, Schünemann HJ, et al: GRADE guidelines: 3. Rating the quality of evidence. *J Clin Epidemiol* 2011;64:401–6