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REVIEW ARTICLE

Effects of electromyographic biofeedback as an adjunctive therapy in the treatment of swallowing disorders: a systematic review of the literature

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Abstract

Purpose To describe the primary effects of electromyographic biofeedback therapy on swallowing via a systematic review.

Methods A blind search was carried out by two researchers in the PubMed and Bireme platforms and in the Medline, Lilacs, SciELO, PsycINFO, CINAHL, and Web of Science databases, and the journal articles identified therein were evaluated for inclusion in the study. Original articles associated with the theme were selected with no population-, region-, or language-associated limits. A protocol was created for this study with the following points: author, year, place, number and characteristics of participants, activities evaluated, instruments used, and main results. The PEDro scale was used to analyze the quality of the studies.

Results Among the 686 articles identified in the combined searches, 566 were duplicates. A total of 65 articles were discarded after the title and abstract were read, and a further 29 articles were discarded after the full text was read, yielding a total of six articles for inclusion. In summary, the results lead us to believe that positive effects on the laryngeal lifting capacity, improved swallowing functions, and increased excursion and maximal elevation of the hyoid bone, may be directly related to this method of therapy.

Conclusions Adjunctive therapeutic protocols with biofeedback electromyography exert positive effects on swallowing function.

Keywords Biofeedback treatment · Electromyography · Deglutition · Deglutition disorders

Introduction

Oropharyngeal dysphagia is a common condition and may be related to various neurological, muscular, metabolic, and age-related diseases [1]. Studies have reported oropharyngeal dysphagia rates of 30–50% among patients who have experienced strokes and approximately 80% among patients with neurodegenerative diseases, including Parkinson's disease and Alzheimer's disease, and even in populations without debilitative or chronic diseases, such as elderly individuals [1–3]. Other common causes of dysphagia are structural changes such as cancer, surgical removal of the head and neck structures, chemotherapy, inflammatory changes or infections in the esophagus, acid reflux, tumors within the esophagus, and compression of the esophagus from growths in the chest [4–6]. Although the severity of dysphagia varies among individuals, it can affect the quality of life even if managed properly [4]. Previous studies have demonstrated that dysphagia is closely associated with an increased risk of malnutrition, longer hospital stay, and pulmonary complications such as aspiration pneumonia [2–6].

The management of dysphagia is crucial, since a lack of treatment can negatively impact the quality of life and significantly influence the duration of hospitalization, and thereby

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affect the allocation of resources [7–9]. The objective of treatment for dysphagia is to ensure the safety of food and medication intake, adequate nutritional intake and hydration, and improvement in the patient's quality of life. The traditional approaches for the treatment and management of dysphagia include compensatory postural maneuvers; adjustments in the consistency, texture, and volume of foods and tactile, thermal, and gustatory stimuli [6]; exercises to strengthen the swallowing muscles; and transcutaneous neuromuscular stimulation and electromyographic biofeedback as an adjunct to regular therapy [7]. Although clinicians use these strategies in daily clinical practice, there is currently no well-established evidence to support the use of any of the available treatment options [10, 11].

The use of the electromyographic biofeedback tool as an adjunctive therapeutic technique for dysphagia is a relatively novel approach for speech therapists. Although other health professionals, such as physiotherapists, have used this biofeedback tool for several decades, the first application of electromyography (EMG) for biofeedback in speech therapy was performed in the 1990s after Crary's first publication in 1995 [8]. An adjunctive biofeedback technique is a self-monitoring technique that aims to reveal the internal physiological events to the patient in the form of visual and/or auditory signals. The goals of this technique are to manipulate these otherwise involuntary or unconscious events. Thus, by feeling and visualizing their muscular performance, individuals can better control these functions [8–10]. To perform this technique, it is necessary to use equipment capable of capturing and transcribing the electrical signals generated by the muscular contractions, typically with an electromyograph. By positioning electrodes on the suprahyoid muscles during swallowing, it is possible to activate the electromyographic tool and quantitatively capture the peaks and troughs corresponding to muscle activation and relaxation, respectively [8].

In summary, electromyographic biofeedback therapy is a tool capable of providing real-time information regarding muscle activity, improving the attention and motivation of the patient, and providing the patient and therapist with quantitative muscular electrical activity data, with the possibility of storing the information for later comparison and evaluation [11, 12]. Although reports on the application of electromyographic biofeedback as a therapy for deglutition disorders remain scarce in the scientific literature [11], this strategy is a valid option in the treatment of swallowing disorders as an adjunct to swallowing therapy exercises. Thus, previous studies have demonstrated that electromyographic biofeedback is a valid option in the improvement of oropharyngeal dysphagia [8, 9]. Research has evidenced that this tool can allow patients to control muscular behavior and therapists to personalize the treatment, thereby benefiting both groups [8, 9, 13]. Considering these findings, this systematic review aimed to evaluate the effects of electromyographic biofeedback as a therapeutic tool for the treatment of deglutition disorders.

Search strategy

A systematic review was performed following a pre-defined protocol [14] from November 2017 to April 2018, using questions that follow the PICO strategy, in which the following methodological elements must be answered: P = population, I = Intervention, C = control group, and O = outcome that corresponded to the treated condition (Table 1).

For the literature survey, electronic searches were conducted of the Scopus, Cochrane, Bireme, PubMed, and via Periódicos Capes platforms and the following databases: Literatura Latino-Americana e do Caribe em Ciências da Saúde (LILACS), Medical Literature Analysis and Retrieval System Online (Medline), Scientific Electronic Library Online

Table 1 Eligibility criteria for studies considered for this review

Guiding: "What are the effects of electromyographic biofeedback treatment on dysphagia or conscious swallowing control?		
Selection criteria	Inclusion criteria	Exclusion criteria
Population	Humans, healthy or not, without limits of age, gender, race	Experimental studies and animal studies
Intervention	Treatment of swallowing disorders, self-monitoring and voluntary control of swallowing	Non-therapeutic tools or use of tools that did not include electromyographic biofeedback
Control	Patients treated with other tools, associated or not with electromyographic biofeedback	No therapy performed for the treatment of swallowing
Results	Modifications to the results of evaluation and monitoring protocols with quantitative or qualitative investigations of the mechanisms involved in the swallowing process or in the swallowing function	Default of results in evaluation and monitoring protocols, quantitative or qualitative assessments, of evaluations of the mechanisms involved in the swallowing process or in swallowing function
Types of studies	Population-based studies. Original descriptive and/or analytical articles in which the methodological design examined the effects and capacity of electromyographic biofeedback in therapy and swallowing control	Review articles, editorials, opinions and annals of scientific events, theses, case studies, and studies that did not approach electromyographic biofeedback as a therapeutic tool

(SciELO), the American Psychological Association (PsycINFO), and the Cumulative Index to Nursing and Allied Health Literature (CINAHL). Reviews of the references, internet searches, and conference of abstracts were included to ensure the inclusion of ongoing studies or unpublished articles. Thus, using previously defined search strategies, two primary evaluators searched the title and abstracts of the studies and excluded those that were not relevant, using several combinations of both keywords and words (Table 2). Once the full text was obtained, the same reviewers selected the relevant studies for a descriptive analysis of the application of electromyographic biofeedback used in dysphagia therapy.

Study selection was guided by the following question: "What are the effects of electromyographic biofeedback treatment on dysphagia or conscious swallowing control?"

For searching the articles, we used free terms (FTs) that are terms not found in the MESH but are relevant for research, and Medical Subject Headings (MESH), which are obtained from an international data search platform. The following crosses were used: "deglutition" (MESH) OR "swallow" (MESH) OR "Deglutition disorders" (MESH) AND "Biofeedback" (MESH) OR "Biofeedback treatment" (FT) OR "neurofeedback" (FT) and their possible combinations in Portuguese, English, and Spanish.

The assessments were performed by two researchers independently and blindly. In cases involving disagreements, a third researcher was consulted to reach a consensus. The researchers followed a search protocol developed before the study. All articles selected by the researchers in a subsequent consensus and according to the inclusion and exclusion criteria were included in this review.

Selection criteria

The inclusion criterion defined for the selection of articles was as follows: articles addressing the treatment of swallowing with electromyographic biofeedback. In this review, we excluded theses, editorials, comments and opinions, articles of reflection, experimental studies using animal models, projects, reports and technical reports, articles of revision, as well as articles addressing other changes that were not related to swallowing. For reliable sampling, no search filter was used.

Data analysis

For pre-selection of the studies, the titles and abstracts of all of the publications located by the search strategy were rigorously read to verify their adherence to the inclusion criterion. In cases where the title and the abstract were not sufficient to determine whether the article met the inclusion criterion, the publication was searched in its entirety, after which each pre-selected study was read in full. At this stage, meetings of the authors of the survey were organized to clarify doubts regarding inclusion or exclusion of the studies. This procedure aimed to reduce bias in the selection of studies, thus providing greater security.

The articles that fit all of the above-mentioned selection criteria were selected and allowed to answer the guiding questions of this review. The data of the selected articles were analyzed systematically through a protocol. The author, year, country, place of study, type of study, population/sample, type of intervention, age of patients, methods of evaluation of swallowing, treatment duration, and main results related to swallowing were considered.

Study quality analysis and data extraction

Two reviewers independently selected the studies according to the inclusion and exclusion criteria mentioned above. The methodological quality of the selected studies was evaluated using the PEDro scale [15]. The literature suggests that this scale provides a more detailed and comprehensive measure

Table 2 Search strategy for identifying relevant studies

Database Search strategy and Descriptors	Portuguese, English, and Spanish
Medline/PubMed Ovid MEDLINE(R) 1946 to Present with Daily Updates	("Biofeedback therapy" [MeSH]) OR "Neurofeedback" [Publication Type]) AND "Dysphagia" [Mesh]) OR "Deglutition Disorders" [Mesh]
Scopus	Key ("Biofeedback therapy") or ("Neurofeedback") or ("Biofeedback") and (dysphagia) or ("swallowing disorders") or ("deglutition disorders")
Cochrane Library MeSH descriptor	[Biofeedback therapy] explores all trees and MeSH descriptor: [neurofeedback] and MeSH descriptor: [deglutition disorders] explores all trees
CINAHL	(MH "+") and (MH "Dysphagia") or (MH "Deglutition Disorders")
Web of Science	Terms of search = (dysphagia near/10 neurofeedback)
PsycINFO (APA)	Index terms: biofeedback therapy or Index terms: neurofeedback and Index Terms: dysphagia or Index terms: deglutition disorders
Lilacs	"BIOFEEDBACK THERAPY" [words] AND "DYSPHAGIA" [words]
SciELO	(Biofeedback therapy) AND (dysphagia)

of the methodological quality of rehabilitation research. The scale consists of ten scores of quality, and the maximum score is 10. Higher scores on this scale represent better study quality (high quality: 6–10, reasonable quality: 4–5, poor quality: ≤3).

Results

Summary of study characteristics and interventions

Among the 686 articles identified from the combined searches, 566 were duplicates. No articles were found in the gray literature. Among the remaining articles, 65 were discarded after the title and abstract were read and 49 were discarded after the full text was read, yielding a total of six articles [13, 16–20] that reported on interventions and were eligible for review (Table 3). No additional studies were included following the manual search of reference lists (Fig. 1).

The six included studies were conducted in four countries (USA [13, 17, 20], Netherlands [18], Australia [19], and China [16]). Three studies were carried out at universities [12, 16, 19] and three at medical centers/hospitals [16, 18, 19]. All studies sought to evaluate the impact of swallowing exercises with electromyographic biofeedback support. Two were non-randomized, paired clinical trials [16, 17], and four were non-randomized clinical trials [13, 17–19].

One study used a control group that received treatment without adjunctive electromyographic biofeedback [16]. The other studies used one or more treatment methods with various types of biofeedback [17–20] or compared the effects of the same treatment with electromyographic biofeedback in different pathologies [13].

In the study with the control group, the treatment for the control group was described as exercises for the tongue, pharynx, and larynx without electromyographic biofeedback support [16], whereas the treatment for the case group was supported by the electromyographic biofeedback tool.

The comparison groups for the remaining studies used the same exercises but had different patient populations of interest, such as patients with head and neck cancer [13], post-stroke patients [18, 20], or patients with Parkinson's disease and Alzheimer's disease [19], or different types of biofeedback, including electromyographic biofeedback [17].

The monitoring time ranged from 1 to 76 days. The measurements used for the basal swallowing state varied greatly, with three studies [17, 19, 20] not employing protocols frequently used for evaluation of swallowing. A minimum of 15 different outcome measures related to swallowing were reported in all studies.

The most commonly used evaluation protocol was the Functional Oral Intake Scale (FOIS), which was used in two studies [13, 18]. The water swallowing test (WST) was also used [16]. One study assessed the duration and accuracy of glottic closure in a conscious state; time and duration of swallowing; elevation, duration, and excursion of the hyoid bone; and opening of the upper esophageal sphincter [17]. Among the quantitative measures used to measure muscle performance, surface EMG was used in all studies.

Other markers such as the presence or absence of gastrostomy and alternative feeding routes, the findings of swallowing videoendoscopy (VED) and videofluoroscopy (VFSD) examinations, swallowing quality of life questionnaire (SWAL-QOL) assessments, the findings of chewing time and solid swallowing examinations, self-assessment tools for swallowing (the Eating Assessment Tool [EAT 10]), and albumin and serum hemoglobin concentrations were also used, although less frequently [19, 20].

Overall, five studies [16–20] used a combination of several instruments for evaluation (instrumental evaluation) or patient- and/or clinician-led evaluation (non-instrumental evaluation). One study [13] reported using FOIS exclusively.

Quality of studies

The mean PEDro score was 6. Four of the six studies were considered "good" (PEDro score: 6–8) [16, 17, 19, 20], and the other two studies were "reasonable" (PEDro score: 4–5) [13, 18]. The details of the quality assessment are described in Table 4. The randomized controlled trial studies reported adequate sequence generation. Only two studies [19, 20] reported details of allocation concealment. Two studies mentioned blinding of the evaluators [19, 20].

Incomplete results were adequately addressed in all studies. One study reported that the result was analyzed without following the intention-to-treat principle [17]. All studies were free of suggestions of selective reporting of results. None of the studies indicated a greater risk of bias.

Sample characteristics

Considering all of the selected studies, a total of 222 participants were reported at the beginning of the studies. A total of 113 men and 74 women participated in the studies, and one study with 35 patients did not report the patient sex [16]. The sample size ranged from 11 to 103 patients. The mean age of the patients was 64.78 years.

Treatment protocols

All selected studies used electromyographic biofeedback treatment in the intervention group. One study [17] used only visual biofeedback (electromyographic and videofluoroscopic), without adjunctive therapy, as the treatment. The other studies [13, 16, 18–20] used a combination of

Table 3 Summary of studies included for analysis

Authors/ country of origin	Year of publication	Type of study	Sample size, total (T), intervention group (I) or (I1-3), control group (C) and gender (M: F)	Sample characteristics	Type of intervention: intervention group (I) and control group (C)	Age for (I), (I1), (I2-3) and (C). (mean and standard deviation)	Main swallowing assessment protocol	Treatment intensity	Treatment frequency	Treatment duration	Follow-up	Main results
Tang et al. [16], China	2017	Non-randomized clinical trial paired	(T): 103 (I): 53 patients 26:27 (C): 50 patients 30:20	Patients with Alzheimer's disease and associated dysphagia	Control group (C): conventional therapy with exercises for tongue, pharynx and larynx repeated 15 times three times per day Intervention group (I): in addition to conventional therapy, electrostimulation was performed and electromyographic biofeedback therapy was performed for one hour, one time per day	(C) 76.2 ± 2.3 (I) 72.5 ± 2.5	(C): WST = 4.2 (I): WST = 4.1	60 min	Not reported	20 sessions	Not reported	The intervention group (I) showed better results in WST ($P < 0.05$)
Azola; Sunday; Humbert [17], US	2017	Non-randomized clinical trial, paired	(T): 35 (I1): 10 (I2): 12 (I3): 13 The sexes were not informed	Healthy adults without dysphagia	Intervention group (I1): electromyographic biofeedback Intervention group (I2): biofeedback with videofluoroscopy Intervention group (I3): biofeedback with videofluoroscopy and electromyographic biofeedback	(I1-I3) 35 ± 1,4	Duration and conscious control of laryngeal vestibule closure	30 min	Not reported	1 session		Group I2 showed a significant improvement in the accuracy and duration of laryngeal vestibule closure ($P < 0.05$)

Table 3 (continued)

Authors/ country of origin	Year of publication	Type of study	Sample size, total (T), intervention group (I) or (I1-3), control group (C) and gender (M: F)	Sample characteristics	Type of intervention: intervention group (I) and control group (C)	Age for (I), (I1), (I2-3) and (C). (mean and standard deviation)	Main swallowing assessment protocol	Treatment intensity	Treatment frequency	Treatment duration	Follow-up	Main results
Bogaardt; Grolman; Fokkens, [18],Países baixos	2009	Retrospective cohort study	(T): 11 (I): 11 10:1	Patients with post-stroke dysphagia	Intervention group: electromyographic biofeedback	(I) 61 ± 7.6	FOIS	20 min	1–2 x fortnight	6.4 sessions	Not reported	Group I showed significant improvement in FOIS ($P < 0.05$)
Athukorala et al. [19], Austrália	2014	Prospective interventional study	(T) 10 (I):10 7:3	Patients with Parkinson's disease and associated dysphagia	Intervention group: electromyographic biofeedback	(I) 67.4 ± 8.6	Time and duration of deglutition	60 min	5 d/wk	10 sessions	Not reported	Group I showed significant decrease in time and duration of swallowing ($P < 0.05$)
Crary et al. [13], US	2004	Prospective interventional study	(T) 45 (I1) 25 16:9 (I2) 20 13:7	(I1): Patients with post-stroke dysphagia (I2): Patients with dysphagia after cancer of the head and neck	Intervention group (I1): electromyographic biofeedback with 5 ml of thickened liquid Intervention group (I2): electromyographic biofeedback with 5 ml of non-thickened liquid	(I1) 69 ± not reported (I2) 67 ± not reported	FOIS	50 min	5 d/ wk	(I1) 12.23 sessions (I2) 9.33 sessions	Not reported	Groups I1 and I2 showed significant improvement in FOIS (I1): 55% released for oral diet (FOIS: 5.5). ($P < 0.05$) (I2): 25% released for oral use (FOIS: 4). ($P < 0.05$)

Table 3 (continued)

Authors/ country of origin	Year of publication	Type of study	Sample size, total (T), intervention group (I) or (I1-3), control group (C) and gender (M: F)	Sample characteristics	Type of intervention: intervention group (I) and control group (C)	Age for (I), (I1), (I2-3) and (C). (mean and standard deviation)	Main swallowing assessment protocol	Treatment intensity	Treatment frequency	Treatment duration	Follow-up	Main results
McCullough et al. [20], US	2012	Prospective intervention study	(T) 18 (I1) 18 11:7 (I2) 18 11:7	(I1 and I2): Patients with dysphagia post-stroke	Intervention group (I1): electromyographic biofeedback for 2 weeks, followed by 2 weeks without treatment Intervention group (I2): 2 weeks without treatment, followed by 2 weeks with electromyographic biofeedback therapy	(I1 e I2): 70.16 ± 13.75	Duration of maximal elevation and anterior excursion of hyoid and duration of upper esophageal sphincter opening	45–60 min	2 x d/ 2 wk	12 sessions	2 weeks	Groups I1 and I2 showed a significant improvement in the duration of the maximal elevation ($p < 0.05$) anterior hyoid excursion ($P < 0.05$)

WST Water swallowing test, *FOIS* Functional Oral Intake Scale

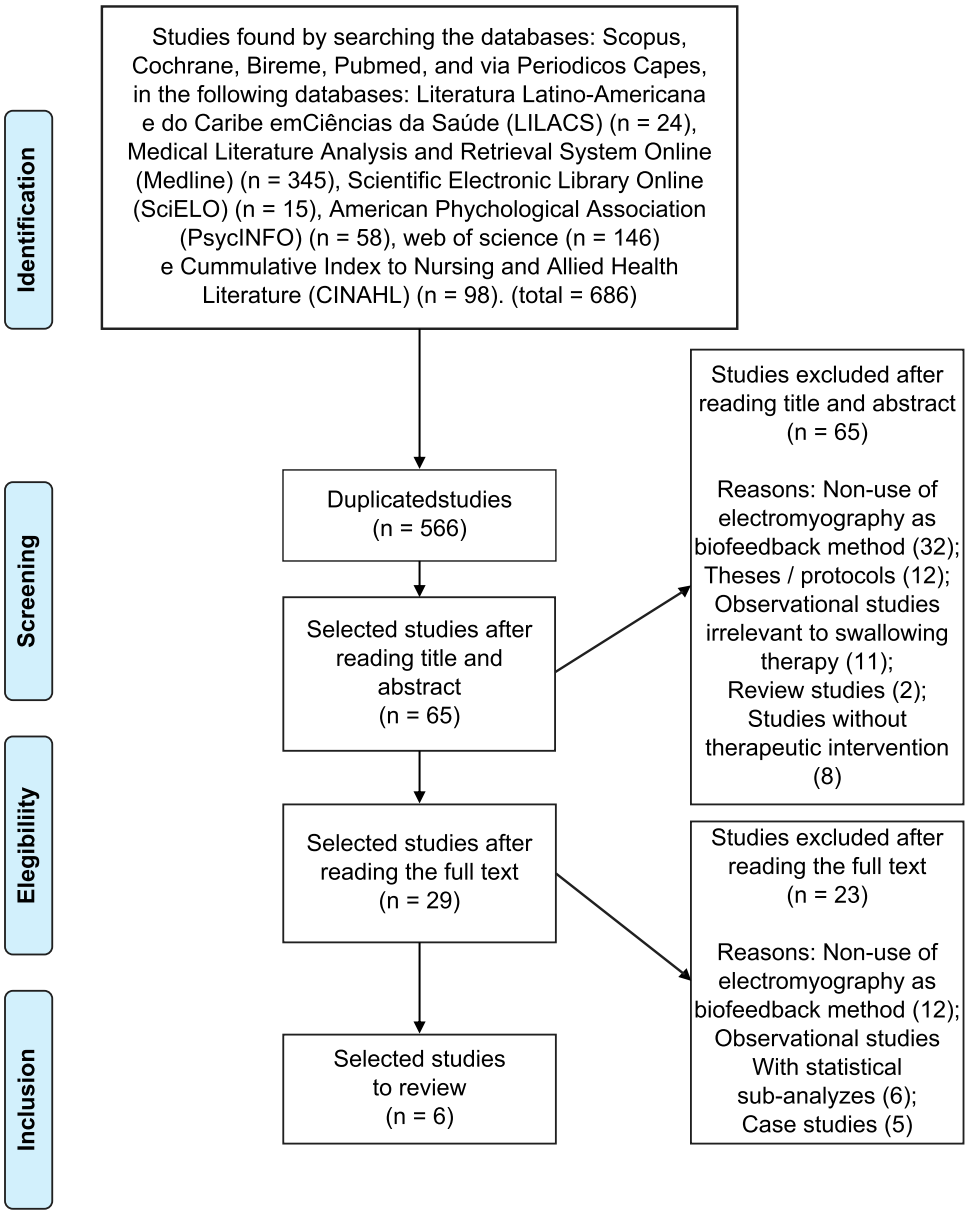

Fig. 1 Flow-chart of studies selection

therapies with electromyographic biofeedback and conventional deglutition rehabilitation in the experimental group.

All studies [13, 16–20] used the Mendelsohn maneuver with or without adaptations. For example, maintenance of laryngeal elevation was maintained for 2–4 s in the majority of the studies [13, 16, 17, 19, 20] and 8–10 s in the Bogaardt study [18]. The number of repetitions also varied from 11 to 100 [11, 17], and the number of sessions ranged from 1 [17] to 20 [16].

In all studies, electromyographic biofeedback therapy was performed along with two-channel surface EMG, a screen that provided real-time visual information, and electrode positioning in a standardized order, with the electrodes being positioned between the mandible and the upper border of the hyoid bone.

The studies used visual biofeedback with slight variations in the shape and position of the electromyographic tracing. The variations occurred according to the therapy regimen used, thereby increasing the size of the trails to be followed [18] or the peak that should be reached with the progress of the therapies [13, 16, 17, 19, 20].

Treatment results

The outcome measures used in the studies included the FOIS [13, 17, 18], WST [16], VFSD [16, 17, 20], range of movement of the hyoid bone (G)-related quality of life (SWAL-QOL) [19], and swallowing time. Swallowing tests were the most common outcome measures employed in all studies. Other measured outcomes such as aspiration pneumonia,

Table 4 Result quality on the PEDro scale

	Study					
	Crary et al. [13]	Tang et al. [16]	Azola et al. [17]	Athukorala et al. [19]	Gary et al. [20]	Bogaardt et al. [18]
1. Eligibility criteria were specified	1	1	1	1	1	1
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated in the order in which the treatments were received)	0	0	0	0	0	0
3. Allocation was concealed	0	0	0	0	0	0
4. The groups were similar at baseline with respect to the most important prognostic indicators	0	1	1	1	0	0
5. All subjects were blinded	0	?	0	?	0	0
6. All therapists who administered the therapies were blinded	0	0	0	0	1	0
7. All assessors who measured at least one key outcome were blinded	0	0	0	1	1	0
8. Measures of at least one key outcome were obtained from > 85% of the subjects initially allocated to groups	1	1	1	1	1	1
9. All subjects to whom the outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention-to-treat"	1	1	1	1	1	1
10. The results of between-group statistical comparisons were reported for at least one key outcome	1	1	1	1	1	1
11. The study provides both point measures and measures of variability for at least one key outcome	1	1	1	1	1	1
Total	5	6	6	7	7	5

duration of hospitalization, removal or modification of the alternate feeding pathway, and nutritional measures were mentioned in some of the selected studies [13, 16, 18, 19].

Three studies [16, 18, 20] used the incidence of aspiration pneumonia, hospitalization time, etc., as measures of the efficacy of electromyographic biofeedback in participants with post-stroke dysphagia [18, 20] or associated Alzheimer's disease [16].

Short-term effects of electromyographic biofeedback therapy

Most of the studies included in this systematic review yielded positive results for the use of electromyographic biofeedback as an adjunctive therapy for improving dysphagia [13, 16, 18–20]. In all studies, the experimental group underwent a significant improvement in relation to the control group or intervention group without electromyographic biofeedback ($P < 0.01$ and $P < 0.05$, respectively) in all outcome measures. The results suggest that a combination of conventional rehabilitation with adjunctive electromyographic biofeedback was more effective in improving dysphagia than exclusive conventional rehabilitation. No adverse effects were reported. Only one study [18] mentioned reasons for abandonment, such as death or surgery for dysphagia.

Discussion

In this systematic review, most studies were conducted in the USA [13, 17, 20], followed by China [16], the Netherlands [18], and Australia [19], and, regardless of quality scores, the findings indicated that electromyographic biofeedback, independent or not of conventional therapy, had a significant therapeutic effect on several aspects of dysphagia. The results of this review suggest that electromyographic biofeedback plays an important role in the treatment of dysphagia. However, the current review does not clarify whether electromyographic biofeedback is recommended for routine use in the treatment of dysphagia, although all of the studies covered in this review yielded positive results [16, 17].

The methodological quality of the studies should be interpreted with caution. Most reports did not offer an adequate and detailed description of the randomization procedure that could ensure the validity of the results for clinical application. The methodological quality of these studies classified by the PEDro scale ranged only from reasonable to good. Blinding of evaluators was reported in only two studies [19, 20], and only one study mentioned blinding of the therapists [20]. Furthermore, details of the participants' characteristics such as age, post-stroke stage, history of recurrent stroke, amount of medication, and use of validated assessment protocols were not adequately provided in these studies [19, 20].

In addition, none of the randomized controlled trials included herein reported details of concealment of allocation. All studies also had a high risk of bias in intervention allocation. These are limitations that could affect the interpretation of the results. This could be primarily attributed to the heterogeneity and restricted use of outcome measures in these reports. There was only one study [19], for example, that used the SWAL-QOL, a validated measure of quality of life and swallowing. Evaluations of swallowing capacity mainly included bedside evaluation and instrumental assessment. Surface EMG, VFSD, and VED were the three instrumental evaluations used for the evaluation and monitoring of dysphagia. However, only three studies [16, 17, 20] used VFSD, a tool historically considered the "gold standard" in swallowing assessment, to report participants' swallowing performance, while most studies used bedside swallowing evaluation, including EMG, the EAT 10, the FOIS, and the SWAL-QOL expressed in scales. These factors decreased the validity of the results.

All studies included in this review reported only the short- and med-term effects of EMG biofeedback on dysphagia. Participants were assessed before and immediately or 2 weeks after treatment [20]. None of the remaining selected studies included follow-up evaluations of the subjects. This limitation makes it difficult to identify the long-term effects of electromyographic biofeedback on dysphagia, such as the risk of aspiration pneumonia, mortality, disability, and quality of life, thus indicating the need for studies that address the effect of detraining on the gain in muscular and functional performance.

Concerning the therapeutic regimens, the treatment protocols appeared to be standardized with respect to the number of channels used, positions of the electrodes on the suprahyoid musculature, and the maneuvers used, in accordance with the guidance in the literature [21] that establishes a good correlation between EMG measurements for the suprahyoid muscles and swallowing [21]. The Mendelsohn maneuver, which was used in all of the studies, was conceived as a compensatory swallowing technique to clear the pharyngeal lumen but was also effective as a rehabilitation exercise to restore swallowing function. As a rehabilitation exercise, this maneuver can result in improved laryngeal elevation and coordination during swallowing and is also considered to contribute to improved pharyngeal contraction [21].

The greatest variation found in the therapeutic regimens was with respect to the number of repetitions. The studies do not explain the reason for the adjustments. However, the literature established that muscle contractions for tonic function varied from 4 to 10 s of support, with 8–12 repetitions of high intensity and rest periods of 6–10 s between each contraction. With regard to the work of the phasic fibers, series of up to five rapid contractions should be performed, with 3–6 s of rest between each series. Regarding the number of series and contractions, a minimum of 24–36 contractions were observed—a series of 8–12 contractions, three times per day—with a maximum of 200, with 20–50 contractions being performed four times per day [22, 23].

On the basis of the conclusions of the studies, it is believed that electromyographic biofeedback will yield different physiological effects on the body, depending on the form of use. The study by Crary et al. [13] that evaluated the submental muscles clarified that patients change their control of muscular behavior and therapists can personalize the treatment, thereby benefiting both groups. Our analysis of the results suggests that self-monitoring, instead of performing monotonous tasks, can be motivational, challenging, rewarding, and interesting, resulting in the reformulation and adaptation of the swallowing process, helping the patient to succeed in what was originally considered to be impossible [24]. Since 1991, studies [24, 25] showed that visual and auditory biofeedback improved swallowing training [26] and inspired the patient [27]. Through real-time verbal positive feedback cues, patients are motivated to perform better and to try harder. Increased awareness and motivation may allow the patients to modify the responses psycho-physiological and to achieve better physiologic functions.

It is also possible that the efficacy of treatment varied as electromyographic biofeedback was applied in conjunction with different treatments such as rehabilitation therapy and drugs. Thus, on the basis of this analysis, it is difficult to design a standard protocol for the treatment of dysphagia with electromyographic biofeedback, although this type of adjunctive therapy seems to play an important role in this treatment.

In the current review, we have attempted to identify all relevant and updated tests. As a result, the findings differed from those of previous studies, in which the use of electromyographic biofeedback in several muscular and neurological pathologies was conclusive [28]. This review identified six studies conducted in different countries, with different populations, pathologies, medications, monitoring times, evaluation methods, and therapies. None of the studies aimed to purely identify the possible effects of electromyographic biofeedback therapy in healthy populations. As a result, it was difficult to conduct a publication bias analysis, and the effects were linked only to biofeedback. Furthermore, we did not exclude the possibility that other studies with different findings may have remained unpublished.

Considering the methodological concerns associated with the studies included in this systematic review, a conclusive observation on the use of electromyographic biofeedback with conventional rehabilitation therapy in the treatment of dysphagia cannot be made at present, although this approach appears to be promising. Therefore, a larger, multi-center, well-blinded randomized controlled trial with homogeneity

of outcome measures needs to be carried out before electromyographic biofeedback may be recommended as an evidence-based treatment to patients with structural or neurological dysphagia.

Conclusions

In conclusion, electromyographic biofeedback, as an adjunctive therapy, elicited positive effects on the laryngeal lifting capacity, increased the oral transit time, improved swallowing functions, and increased the excursion and maximal elevation of the hyoid bone. However, for electromyographic biofeedback to be recommended as an adjunctive evidence-based treatment, further studies with larger, multicenter, well-controlled, blinded, randomized samples with homogeneity of outcome measures are required.

Novelty of the study

During the course of this review, we did not find other systematic reviews or studies that addressed the subjective, primary effects of electromyographic biofeedback as an adjunctive therapy for the treatment of dysphagia; thus, this study appears to be novel. In addition, we can conclude that electromyographic biofeedback, as an adjunctive therapy, can be easily used by rehabilitation professionals, and that it exerts positive effects and is associated with few contraindications.

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Data availability Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Compliance with ethical standards

Conflict of interest The authors report no conflicts of interest.

Ethical approval and informed consent This article does not contain any studies with human participants or animals performed by any of the authors.

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