

Original Research

Received 03 June 2026

Revised 22 July 2026

Accepted 04 August 2026

Natural Resources for Human
Health 2026, Vol. 6 (14s): 944–953

KEYWORDS:

Surface Electromyography
Biofeedback, Dysphagia, Post-
Stroke

Effects of Surface Electromyography Biofeedback to Conventional Swallowing Therapy in Post-Stroke Dysphagia: A Systematic Review

Rania Namira Roem¹, Rumaisah Hasan¹, Nilla Mayasari¹,
Nuralam Sam¹, Husnul Mubarak¹

¹ Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Hasanuddin University, Makassar, Indonesia

ABSTRACT: Dysphagia is common in post-stroke patients. Various rehabilitation techniques can aid the swallowing disorder in post-stroke dysphagia. Surface electromyography (sEMG) biofeedback is thought to improve clinical outcomes in patients with post-stroke dysphagia. This systematic review aims to determine the effect of providing sEMG intervention on swallowing disorders in post-stroke dysphagia patients. Systematic review, which used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach, included patients aged 18 and older with post-stroke dysphagia who received sEMG biofeedback intervention compared to a control group or no control group (comparing before and after intervention only). The risk of bias was assessed using the Cochrane Risk of Bias Tool (RoB 1) for RCTs and the Agency for Healthcare Research and Quality (AHRQ) evaluation for non-RCTs. Three articles demonstrated clinical improvement after sEMG biofeedback compared to a control group. One article demonstrated clinical improvement after sEMG biofeedback compared to before the intervention. However, two articles demonstrated no significant difference in the severity and clinical outcomes of post-stroke dysphagia patients after sEMG biofeedback compared to a control group. Four studies showed that sEMG biofeedback can improved several parameters of post-stroke dysphagia; however, two studies did not show any significant difference in improvement effects between the intervention and control groups.

1. INTRODUCTION

Stroke is one of the neurological pathological disorders most often connected with dysphagia, or difficulty swallowing liquids and/or food [1] Dysphagia is extremely common among stroke patients, with estimates ranging from 50% to 80%, particularly during the acute and subacute periods. Post-stroke dysphagia affects 21.1% of patients, with 15.1% suffering both dysphagia and hemiparesis and 6.0% experiencing just dysphagia [2]. Post-stroke dysphagia affects approximately 40% of patients with acute ischemic stroke, however the prevalence figures vary greatly between studies, ranging from 8% to 80%. Six months after the stroke, approximately half of individuals with post-stroke dysphagia continue to be impacted [3]

Many different brain areas may be involved in post-stroke dysphagia. Post-stroke dysphagia is caused by damage of the sensorimotor cortex, insula, cerebellum, cingulate gyrus, thalamus, basal ganglia (such as the lentiform nucleus), and related white matter connections, or the brainstem, according to structural and functional MRI studies [3]. Swallowing recovers as a result of cortical remodeling. Dysphagia following a unilateral hemispheric stroke may be caused by stroke lesions affecting the "dominant swallowing hemisphere" [4], [5]

The goal of swallowing exercises is to strengthen the motor muscles and restore normal neurological function in order to enhance the physiology of swallowing [6]. Numerous swallowing rehabilitation methods have been developed in recent years due to developments in neurology and rehabilitation medicine. One of the rehabilitation methods called surface electromyography (sEMG) biofeedback therapy has drawn more interest and demonstrated encouraging promise in the management of dysphagia following a stroke. sEMG biofeedback therapy improves the efficiency of pharyngeal transit and bolus clearance while strengthening airway protection mechanisms during swallowing by increasing the amplitude of electromyography signals in swallowing-related muscles, improving muscle contraction capacity, and encouraging upper esophageal sphincter opening and epiglottis elevation. Additionally, patients' self-awareness and control over swallowing movements can be improved by sEMG biofeedback therapy, which promotes active therapy involvement and further improves treatment results [7], [8]. The purpose of this systematic review is to evaluate the efficacy of sEMG biofeedback as a swallowing therapy for individuals with dysphagia following a stroke.

2. MATERIALS AND METHODS

2.1 Data Collection

The methodological guideline of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is employed to collect data in this study, resulting in a more comprehensive and transparent systematic review. Five reviewers (R.N.R, R.H, N.M, N.S, H.M) selected studies from a variety of highly reputable online search engine databases, such as PubMed, ScienceDirect, and Cochrane Library. The literature search was conducted using the following keywords: "Surface Electromyography Biofeedback", "sEMG", "Electromyography", "Bioelectrical activity", "Swallowing Therapy", "Conventional Swallowing Therapy", "Swallowing Disorder", "Swallowing Difficulty", "Feeding Difficulty", and "Post-Stroke."

2.2 Eligibility Criteria

Focusing exclusively on completed randomized controlled trials (RCTs) and non-RCTs published in peer-reviewed publications, this systematic review included studies that met specific eligibility criteria. **(P)** Adult participants aged 18 years or older with post-stroke dysphagia; **(I)** Surface electromyography biofeedback; **(C)** Conventional swallowing rehabilitation training or neuromuscular electrical stimulation or no comparison; **(O)** Functional Oral Intake Scale (FOIS), Penetration Aspiration Scale (PAS), Dysphagia Severity Scale (DOSS), Dysphagia Handicap Index (DHI), Pooling-Sensation Collaboration Age (P-SCA), Videofluoroscopic Dysphagia scale (VDS), etc.

Studies that were published within the past decade and were in the English language were included. Additionally, the review excluded non-primary research publications, including commentaries, case reports, case series, review articles, editorial letters, and abstracts, in order to preserve methodological rigor and relevance. These sources do not provide adequate empirical evidence to substantiate robust clinical conclusions. The protocol for this systematic review was prospectively registered and approved in the PROSPERO database under the registration number CRD420261502763, thereby guaranteeing transparency and adherence to the most effective systematic review methodologies.

2.3 Study Selection

Relevant keywords were systematically used to identify potentially eligible studies during the initial search across selected electronic databases. After retrieval, duplicate records were identified and removed using the Rayyan.ai platform to ensure each study was reviewed only once. Reviewers then conducted title and abstract screening to assess study relevance to this review's objectives. All screening steps—including duplicate removal, initial screening, and eligibility checks—were managed within Rayyan.ai to maintain consistency and minimize selection bias.

Full-text articles of potentially eligible studies were assessed based on predefined eligibility criteria, including aspects such as study design, population, interventions, comparators, outcomes, and publication specifics. Reviewers held regular consensus meetings to address any discrepancies, disagreements, or uncertainties that arose during the screening and data extraction phases.

Unresolved issues during scheduled discussions were addressed promptly through online platforms, such as messaging applications and virtual meetings, ensuring timely clarification and methodological transparency. This structured and iterative process ensured that all included studies met the criteria and that the selection procedure remained systematic, reproducible, and unbiased.

2.4 Data Extraction

Each study included in this review is characterized in a separate table, then the data are presented in another table. The characteristics for each study in this review are: 1) Authors and year of publication; 2) Number of participants; 3) Mean age of participants; 4) Intervention and Duration; and 5) Comparison and duration. Meanwhile, the extracted study data are presented in the following order: 1) Authors and year of publication; 2) Assessment; 3) Time of assessment; 4) Group and 5) Significance in the form of p-value.

2.5 Quality Assessment

We evaluated the methodological quality and potential risk of bias of the randomized controlled trials included in the study using Review Manager version 5.4.1 with the Cochrane Risk of Bias Tool (RoB 1). To be more precise, we investigated five categories of bias: selection bias (which encompasses random sequence generation and allocation concealment), performance bias (which involves the blinding of personnel and participants), detection bias (which involves the blinding of outcome assessment), attrition bias (which involves incomplete outcome data), and reporting bias (which involves selective outcome reporting).

Assessment of risk of bias for articles with non-RCT designs employing the Agency for Healthcare Research and Quality (AHRQ) assessment. The AHRQ is comprised of fundamental design, selection bias, performance bias, attrition bias, detection bias, and reporting bias.

3. RESULTS AND DISCUSSION

3.1 Study Selection

A preliminary search in three electronic databases (PubMed, Cochrane Library, and ScienceDirect) yielded 100 articles and 27 duplicate articles were removed. Then, authors read the title and abstracts of the remaining 73 articles for preliminary screening, resulting in 12 eligible articles for further analysis. However, about 2 articles could not be retrieved due to the unavailability of the full-text paper, resulting in only 10 articles being assessed for eligibility. Four articles published >10 years. Finally, this review included a total of 6 studies. Search flowchart and selection method were summarized in **Figure 1**.

3.2 Characteristics of Included Studies

Four articles were RCTs and two were non-RCTs. One article had no comparator and five articles comparing surface electromyography biofeedback with conventional swallowing therapy. The outcomes assessed varied, including P-score, P-SCA, FOIS, DOSS, PAS, DHI, DSRS, DHI, VGF, SSA, or VDS. The duration of surface electromyography biofeedback given varies, between 30-45 minutes per session. (**Table 1**)

3.3 Outcome

The summary of outcome results are shown in **Table 2**. Nordio et al. (2022)[9] reported significant differences in p-score ($p=0.03$), P-SCA ($p=0.03$), and PAS-semisolid ($p<0.0001$) after 2 months of intervention between the sEMG biofeedback group and the control group. There was a more significant decrease in P-score, P-SCA, and PAS-semisolid in the sEMG biofeedback group than in the control group.

Alyanak et al. (2025)[10] reported no significant differences in FOIS ($P=0.581$), DOSS ($p=0.217$), and PAS-liquid ($p=0.260$) between the sEMG biofeedback group and the control group; however, there were significant differences in PAS-semisolid ($p=0.031$) and DHI ($p=0.041$) between the sEMG biofeedback group and the control group.

Benfield et al. (2023)[11] showed no significant differences in DSRS (2 weeks, $p=0.316$ and 90 days, $p=0.957$), FOIS (2 weeks, $p=0.094$, and 90 days, $p=0.711$), PAS 5 mL thin fluids ($p=0.138$), PAS 50 mL thin fluids ($p=0.141$), PAD 5 mL puree ($p=0.526$), and DHI (2 weeks, $p=0.250$; 90 days, $p=0.981$) between the sEMG biofeedback group and the control group. However, there was a greater decrease in DSRS, PAS 5 mL thin fluids, PAS 50 mL thin fluids, and PAS 5 mL puree parameters in the sEMG biofeedback group compared to the control group.

Meng et al. (2024)[12] demonstrated that the VGF scores of both patient groups increased in comparison to their previous scores, and the PAS scores were significantly improved ($p<0.05$). Additionally, the SSA scores of both patient groups were significantly improved compared to their previous scores, with a difference between the two groups of (<0.05). The VDS scores

of both patient groups were also significantly improved compared to their previous scores, with a difference between the two groups of ($p < 0.05$).

Park et al. (2019)[13] reported a significant decrease in VDS after the sEMG biofeedback ($p = 0.016$) and a significant decrease in PAS after the sEMG biofeedback ($p = 0.031$). Priya et al. (2023)[14] reported a significant increase in FOIS in the sEMG biofeedback group compared to the control group ($p = 0.01$).

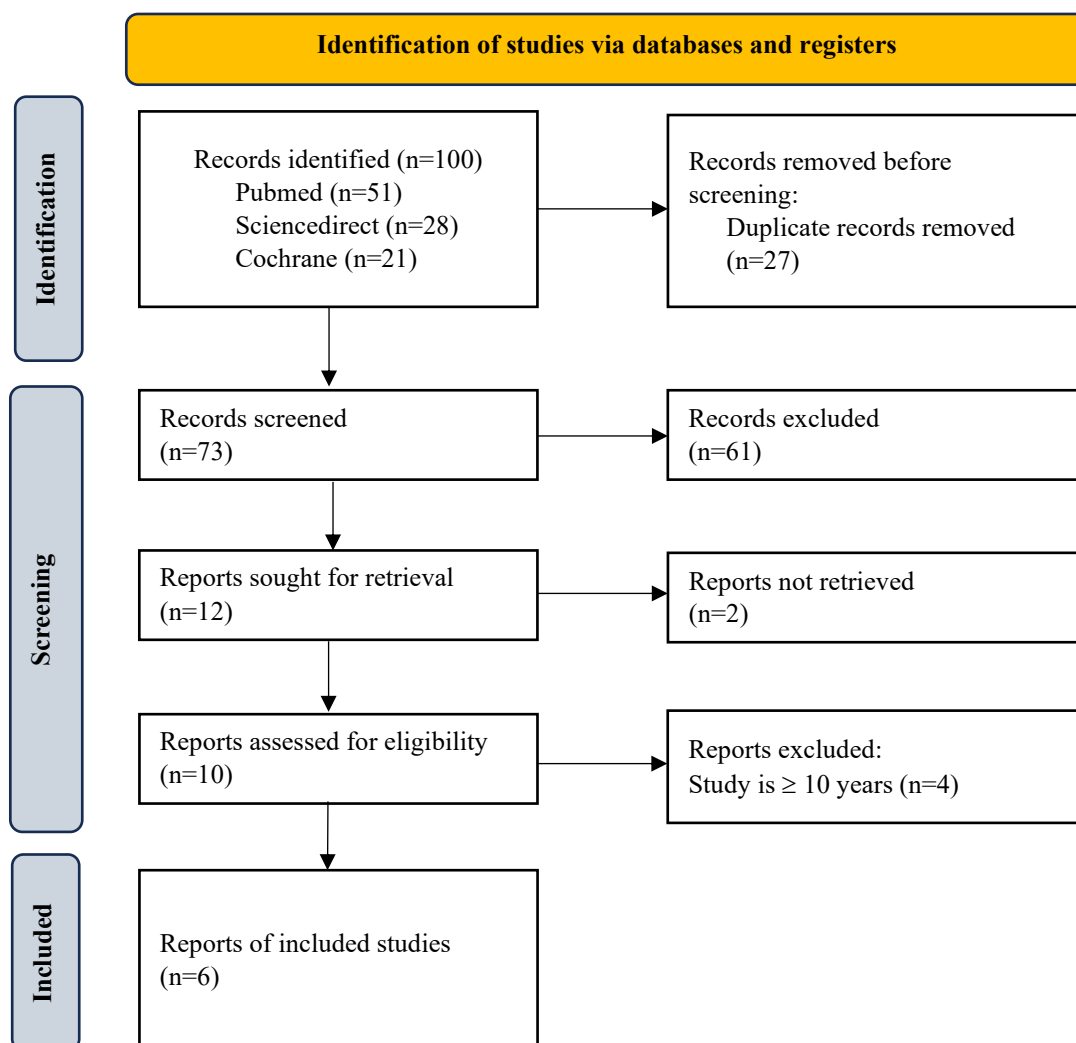


Figure 1. Study Selection Flowchart through 2020 PRISMA

Table 1. Characteristics of articles

No	Study (Author, Year)	Study Design	Number of Participants		Age (mean±SD)		Intervention	Duration	Comparison	Duration
			IG	CG	IG	CG				
1	Nordio <i>et al.</i> (2022)[9]	RCT	9	7	71.00±9.77	69.00±11.72	Conventional Swallowing Therapy +	40 minutes	Conventional Swallowing Therapy	40 minutes

							sEMG biofeedback			
2	Alyanak <i>et al.</i> (2025)[10]	RCT	16	17	63.38±11.38	60.59±12.54	sEMG biofeedback	30 minutes	Conventional Swallowing Therapy	30 minutes
3	Benfield <i>et al.</i> (2023)[11]	RCT	13	14	71.00±10.4	75.10±11.5	sEMG biofeedback	45 minutes	Conventional Swallowing Therapy	45 minutes
4	Meng <i>et al.</i> (2024)[12]	Non-RCT	30	30	65.62±1.31	66.63±1.32	sEMG biofeedback	30 minutes	Conventional Swallowing Therapy	30 minutes
5	Park <i>et al.</i> (2019)[13]	Non-RCT	10	n/a	n/a	n/a	sEMG biofeedback	30 minutes	No comparison	
6	Priya <i>et al.</i> (2023)[14]	RCT	6	6	61.00±13.15	63.00±10.08	sEMG biofeedback	30 - 40minutes	Conventional Swallowing Therapy	30 - 40minutes

Table 2. Outcomes

No	Study (Author, Year)	Assessment	Time of Assessment	Group		p-value
				IG	CG	
1	Nordio <i>et al.</i> (2022)[9]	P-Score (mean)	2 Months	5	7	0.03
		P-SCA (mean)	2 Months	4.78	8.5	0.03
		PAS Semisolid (mean)	2 Months	1.22	1.67	<0.0001
2	Alyanak <i>et al.</i> (2025)[10]	FOIS	Pre	5.5 (3.5-6)	5 (5-6)	0.986
			Post	6 (5-6)	6 (5-6)	0.581
		DOSS [mean(IQR)]	Pre	4 (3-4)	4 (2.5-4.5)	0.363
			Post	4.5 (4-5)	4 (3-5)	0.217
		PAS-Liquid [mean(IQR)]	Pre	5 (4-6.75)	4 (4-6)	0.901
			Post	4 (2.5-5.75)	4 (4-6)	0.260
		PAS-Semisolid[mean(IQR)]	Pre	4 (2-5)	3 (2.5-4.5)	0.873
			Post	2 (1-2)	2 (2-4)	0.031
		DHI [mean(IQR)]	Pre	57 (48-65)	64 (50-75)	0.423

			Post	41 (32-50)	60 (45-73)	0.041
3	Benfield <i>et al.</i> (2023)[11]	DSRS (mean $\pm$ SD)	2 Weeks	3.2 $\pm$ 3.2	4.3 $\pm$ 2.3	0.316
			90 days	2.1 $\pm$ 4.2	2.0 $\pm$ 3.8	0.957
		FOIS(mean $\pm$ SD)	2 Weeks	5.0 $\pm$ 3.0	4.0 $\pm$ 2.0	0.094
			90 days	7.0 $\pm$ 1.0	7.0 $\pm$ 2.0	0.711
		PAS 5 mL thin fluids (mean $\pm$ SD)	2 Weeks	2.1 $\pm$ 1.4	3.0 $\pm$ 1.3	0.138
		PAS 50 mLs thin fluids (mean $\pm$ SD)	2 Weeks	3.2 $\pm$ 1.4	4.4 $\pm$ 2.1	0.141
		PAS 5 ml puree (mean $\pm$ SD)	2 Weeks	1.6 $\pm$ 1.2	2.0 $\pm$ 1.9	0.526
		DHI (mean $\pm$ SD)	2 Weeks	27.2 $\pm$ 21.9	18.9 $\pm$ 13.7	0.250
			90 days	24.1 $\pm$ 27.4	24.3 $\pm$ 25.4	0.981
4	Meng <i>et al.</i> (2024)[12]	VGF	Baseline	The swallowing disorder score (VGF) and Rosenbek penetration-aspiration scale (PAS) scores of the two groups did not differ significantly prior to treatment.		<0.05
			4 Weeks	The PAS scores were significantly improved, and the VGF scores of both patient groups were all higher than they were previously.		<0.05
		SSA	Baseline	Before treatment, there was no discernible distinction in the SSA between the two groups.		>0.05
			4 Weeks	The SSA scores of the two groups were considerably improved in comparison to the previous ones, and the difference between the two groups was substantial.		<0.05
		VDS	Baseline	Before treatment, there was no discernible distinction in the VDS between the two groups.		>0.05
			4 Weeks	Significant improvements were observed in the VDS scores of both groups in comparison to their previous scores, and the disparity between the two groups was evident.		<0.05
5	Park <i>et al.</i> (2019)[13]	VDS(mean $\pm$ SD)	Pre	51.71 $\pm$ 9.95	n/a	0.016 ^a
			Post	30.08 $\pm$ 15.80	n/a	

		PAS(mean±SD)	Pre	5.13±2.27	n/a	0.031 ^a
			Post	3.00±1.00	n/a	
6	Priya <i>et al.</i> (2023)[14]	FOIS (mean±SD)	Pre	1.67±0.52	1.67±0.52	1.00
			Post	5.00±0.63	3.67±0.52	0.01

FOIS= Functional Oral Intake Scale, PAS= Penetration Aspiration Scale, P-Score= Pooling Score, P-SCA = Pooling-Sensation Collaboration Age, DOSS = Dysphagia Severity Scale, DHI=Dysphagia Handicap Index, VDS= Videofluoroscopic dysphagia scale. ^a The statistical value of the average comparison between before and after

3.4 Risk of Bias Assessment

Four studies were RCTs and were assessed using Cochrane RoB-1 with Review Manager 5.4.1. All articles had low risk of random sequence generation, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. However, all articles had high risk of allocation concealment because they used simple randomization for allocation concealment (open random allocation). Summaries are shown in **Figure 2** and **Figure 3**. Two studies were non-RCTs, using the AHRQ to assess the risk of bias of studies with non-RCT designs. The summary can be seen in **Table 3**.

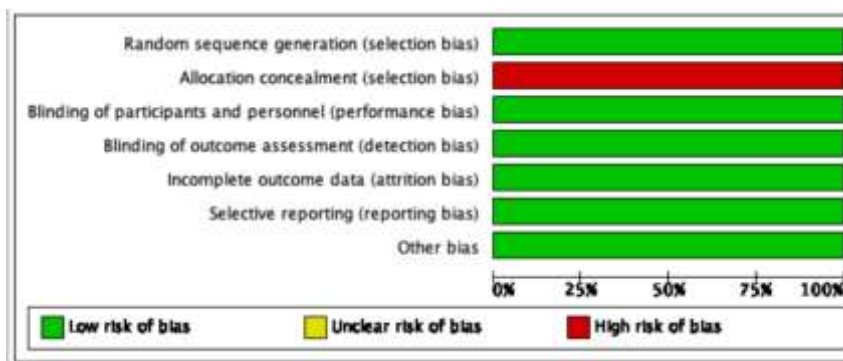


Figure 2. Risk of Bias Graph

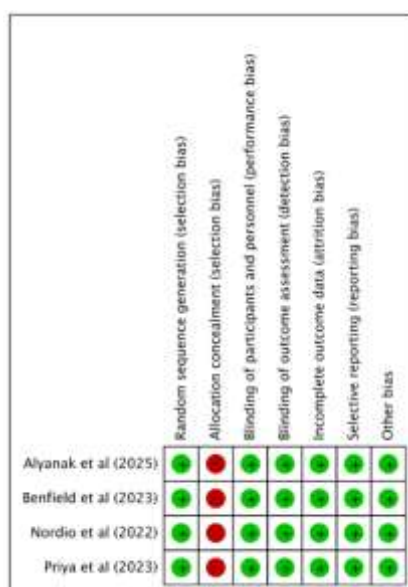


Figure 3. Risk of Bias Summary

Table 3. Risk of Bias for Non-RCT Articles

Assessment	Meng et al (2024)	Park et al (2019)
Basic Design	Retrospective	Prospective
Selection Bias		
Inclusion/exclusion criteria	Low Risk	Low Risk
Recruitment	Low Risk	Low Risk
Baseline characteristics similar or appropriated adjusted analysis	Low Risk	Low Risk
Comparison group	Low Risk	High Risk
Balance prognostic variables between groups through design or analysis approaches	Low Risk	Low Risk
Performance Bias		
Intervention Implementation	Low Risk	Low Risk
Concurrent/Concomitant Interventions	Low Risk	Low Risk
Attrition Bias		
Equality of length of followup for participants	Low Risk	Low Risk
Completeness of followup	Low Risk	Low Risk
Attrition affecting participant composition	Low Risk	Low Risk
Intention-to-treat analysis	Low Risk	Low Risk
Detection bias		
Blind outcomes assessment	Low Risk	Low Risk
Source of information re interventions/exposure	Low Risk	Low Risk
Source of information re outcomes	Low Risk	Low Risk
Reporting bias	Low Risk	Low Risk

3.5 Discussion

Swallowing therapy are relatively new to the utilization of electromyography biofeedback as an adjunct therapy technique for dysphagia. The initial application of electromyography (EMG) for biofeedback in speech therapy occurred in the 1990s, following Cray's initial publication in 1995, despite the fact that other healthcare professionals, have been utilizing this biofeedback instrument for decades. Self-monitoring techniques known as adjunct biofeedback are designed to disclose internal physiological events to the patient through visual and/or auditory signals [15] The objective of these methods is to manipulate these involuntary or subliminal events [15]

Skeletal muscles, including those that are involved in respiration, are composed of a combination of type 1 and type 2 fibers. Previous research has demonstrated that electrical stimulation is effective in stimulating type 1 fibers, while vasomotor activity is effective in stimulating type 2 fibers. The time efficacy of motor learning is enhanced by the use of biofeedback in therapy [13]. sEMG is comprised of two components: the first is the awareness or comprehension of internal responses, while the second is the acquisition of the ability to regulate these responses. The principles of operant conditioning underlie these two. The sEMG technique is employed in EMG biofeedback, which involves the detection and amplification of electrical signals

generated by depolarization of the myocyte membrane during muscle contraction. The EMG biofeedback instrument then provides feedback information. In this manner, the rehabilitation therapist instructs the patient on how to contract and relax the muscle in a functionally appropriate manner, and the patient consciously employs this knowledge to modify or alter specific physiological processes. Myoelectric biofeedback training for swallowing disorders has been demonstrated to primarily facilitate the displacement of the hyoid-laryngeal complex [8], [12]

The results of an fMRI study that demonstrated enhanced conscious control of swallowing with biofeedback are as follows: visual feedback during swallowing resulted in increased activation in frontal regions of the brain, suggesting that the feedback directs more attention to motor planning [7], [8] Consequently, individuals can more effectively regulate their muscle function by sensing and visualizing it. This method necessitates the utilization of equipment that is capable of capturing and transcribing the electrical signals produced by muscle contractions, typically an electromyograph. The electromyography device can be activated and the peaks and valleys associated with muscle activation and relaxation can be quantitatively captured by positioning electrodes on the suprahyoid muscle during swallowing [15] The motor unit action potentials generated by muscle contraction are detected by electrodes that are implanted on the skin. The amplitude of the sEMG signal increases as the intensity of muscle contraction increases, which results in sequential motor unit activation and an increase in the firing rate of all recruited motor units. This information can be represented graphically. The patient can utilize this feedback to enhance muscle activity [8]

In this systematic review, sEMG biofeedback can improve P-Score, P-SCA and PAS in the study of Nordio et al (2022); significantly improve semi-solid PAS in the study of Alyanak et al (2025), but not in FOIS, DOSS, and PAS-liquid; however, in the study of Benfield et al (2023) showed no changes at all based on DSRS, FOIS, PAS and DHI; increased VGF, SSA and VDS in the study of Meng et al (2024), increased VDS and PAS in the study of Park et al (2019) and increased FOIS in the study of Priya et al (2023). It can be concluded that as many as 4 studies showed that the sEMG biofeedback can provide more significant improvements in post-stroke dysphagia as shown in improvements in various parameters compared to the conventional swallowing therapy group; however, there are 2 studies that didn't show any significant differences in improvement between the sEMG biofeedback group and the conventional swallowing therapy group. However, this suggests that the sEMG biofeedback is an important adjunct to post-stroke rehabilitation to reduce post-stroke dysphagia. The results of this systematic review indicate that surface electromyography biofeedback improves swallowing rehabilitation scores. The broad pattern of DHI improvement across multiple domains highlights a significant improvement in swallowing-related quality of life. Given that the DHI is a validated 25-item index encompassing functional, physical, and emotional aspects of the impact of dysphagia, the post-therapy score changes in this review indicate that swallowing rehabilitation has a positive and holistic effect on patient well-being.[16] These findings suggest that providing the sEMG biofeedback intervention with a duration of 30-40 minutes per session is sufficient to provide a positive effect on post-stroke dysphagia patients.

4. CONCLUSION

Four studies showed that the sEMG biofeedback can provide improvements in post-stroke dysphagia in several parameters and may provide additional benefits, but there were 2 studies that showed that the sEMG biofeedback did not provide effects that were significantly different from conventional swallowing therapy

ACKNOWLEDGEMENTS

None

AUTHOR CONTRIBUTIONS

RNR, RH, NM determined the topic. RNR, RH, NM, NS, HM searched for articles, compiled a systematic review and put the articles together.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are not available

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