the Efficacy of Integrating Neuromuscular Electrical Stimulation with Swallowing Training in the Management of Dysphagia post-stroke dysphagia：Meta analysis

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Introduction. This meta-analysis aimed to evaluate the safety and efficacy of utilizing neuromuscular electrical stimulation in conjunction with swallowing therapy for the management of dysphagia in individuals post-stroke.

Methods. Through a comprehensive search across databases such as PubMed, Web of Science, and EMBASE. The selected studies were analyzed using RevMan software for statistical assessment. The focus was on comparing outcomes between patients undergoing neuromuscular electrical stimulation combined with swallowing therapy (SRT) and those undergoing SRT alone. The primary outcome measures included Functional Oral Intake Scale (FOIS) and Functional Dysphagia Scale (FDS). Safety considerations were also assessed by examining the occurrence of adverse events or side effects in the treatment group.

Results. Patients undergoing neuromuscular electrical stimulation in combination with SRT for the treatment of swallowing disorders following a stroke demonstrated significantly greater benefits in terms of FOIS compared to those receiving SRT alone (Mean Difference [MD]=1.60, 95% Confidence Interval [CI] [1.38, 1.81], P<0.001). Moreover, the same treatment group exhibited a significantly greater improvement in FDS compared to the SRT-alone group (MD=2.08, 95% CI [1.51, 2.66], P<0.001). Importantly, the analysis of safety parameters revealed no serious adverse events or side effects in the treatment group.

Conclusion. In conclusion, the combined approach of neuromuscular electrical stimulation and swallowing therapy proves to be a safe and effective method for addressing swallowing disorders post-stroke. The observed significant improvements in both FOIS and FDS

underscore the potential benefits of this therapeutic combination.

Keywords. neuromuscular electrical stimulation；swallowing training；stroke；dysphagia；Meta-analysis

INTRODUCTION

Stroke is a prevalent neurological condition that has a significant impact on both the patient's health and survival rates with high morbidity and mortality. Stroke can cause damage and death in the brain region, lead to paralysis of the body parts, language disorders, cognitive disorders, and seriously affect the quality of life of patients[1,2]. Dysphagia is one of the common complications in stroke patients. Swallowing disorders can cause food, liquid, saliva, etc. to stay in the mouth, throat, esophagus and other parts for a long time, causing serious consequences such as asphyxia, pneumonia, and seriously affect the quality of life and rehabilitation of patients[3].Dysphagia after stroke is a challenging clinical problem. At present, the traditional methods of swallowing rehabilitation include drug therapy, dietary changes, swallowing training and other methods. However, these traditional treatments have limitations and are often not effective in improving swallowing function, especially in patients with severe swallowing disorders[5-7].

Neuromuscular electrical stimulation (NMES) and swallowing training have been widely used to treat swallowing disorders after stroke. With the development of science and technology, neuromuscular electrical stimulation combined with swallowing training has been widely used as a new type of swallowing rehabilitation therapy[8-10]. Studies have shown that the combination of local electrical stimulation and swallowing training can effectively improve the contraction strength and coordination of the swallowing muscles, thus improving the swallowing function[11,12]. In addition, Electrical stimulation targeting the neuromuscular system in conjunction with therapeutic interventions for swallowing dysfunction can also promote nerve regeneration and functional recovery, thus accelerating the recovery of swallowing

function[13].

Multiple studies have investigated the effectiveness of combining neuromuscular electrical stimulation with swallowing training in the treatment of dysphagia following a stroke, with results suggesting promising outcomes[14-16]. However, the small sample sizes and inconsistent findings of these studies make it difficult to draw convincing conclusions. Therefore, it is necessary to conduct a meta-analysis to comprehensively analyze the data from existing studies and further evaluate the efficacy and safety. This will help clinicians better guide treatment, improve the rehabilitation of patients with swallowing disorders.

MATERIALS AND METHODS

In this paper, relevant clinical research literature will be retrieved from international databases such as PubMed, Web of Science and EMBASE, and screened independently by two personnel. The key word retrieval method is used to search the relevant literature in these databases. At the same time, we will manually search the list of references in these literature to ensure that no relevant studies are missed.

Screening Criteria

The literature was screened based on the following criteria: patients with dysphagia after stroke were treated with neuromuscular electrical stimulation combined with swallowing training, This paper with sufficient efficacy and safety data. Non-original studies, such as reviews, reviews or abstracts of meetings, were not included.

Data Extraction and Quality Assessment

We will use a standardized data extraction table to extract basic information, study design, sample size, intervention measures, results and other information of each paper, and evaluate the quality of the study, including randomization process, blind method, integrity, data loss and selection bias.

Statistical Analysis

We using RevMan (ReviewManager, Version5.3). The data were divided into continuous variables and binary variables. Mean difference (MD) with 95% confidence intervals (CI). Odds ratios (OR) with 95% confidence intervals were used to analyze the dichotomous variables, and a suitable model was selected based on heterogeneity test results. When I^2>50% or chi-square p <0.10, including adverse events and side effects, were evaluated. Publication offset was evaluated using funnel plots. At the same time, We will perform a sensitivity analysis to assess the study results' stability and dependability.

RESULTS

Results of Literature Search and Selection

In this study, "neuromuscular electrical stimulation", "stroke", "dysphagia" and other terms were used to retrieve a total of 634 literatures. In the process of preliminary screening and full text reading, we excluded 367 duplicate references.261 literatures that did not conform to the research topic, had irrelevant data or had low data quality, and 6 qualified literatures were finally included for meta-analysis (Figure 1).

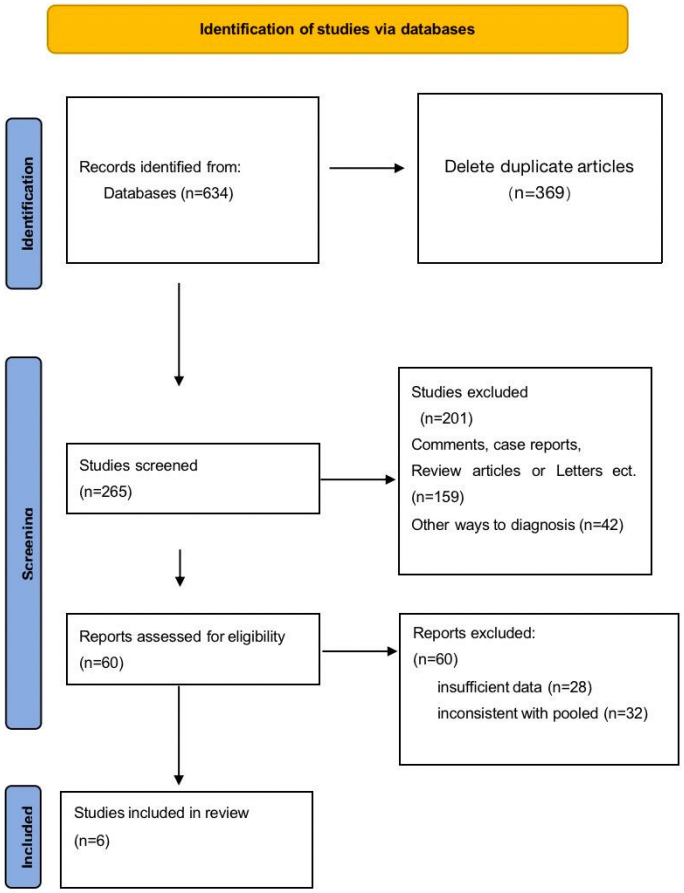


Figure 1. The flowchart of literature screening process for study inclusion is presented

A Summary of The Features of The Included Literature

A total of 6 literatures were included in this study, including 3 RCTS and 7 controlled clinical studies with a sample size ranging from 20 to 200.The included trials ranged in publication from 2011 to 2022.All studies compared EA plus SRT with SRT alone. Treatment plan. The stimulation parameters and training intensity vary, including the frequency, width and intensity of the stimulation current.

Table 1 Basic information included in the study

Study	Year	Sample size	Gender (male, female) number	Mean age	Course of disease (experiment and control)
Tan[26]	2022	63	34,29	64	3.41±0.23/3.43±0.21
Xia[27]	2011	120	76,44	65.32±14.29	8.94±3.62
Wang[28]	2019	28	21,7	61.43 ± 11.237	66.79 ± 38.623/67.50 ± 47.622
Yang[29]	2012	16	9,7	70.44 ± 12.59	25.2 ± 11.5/26.9 ± 7.8
Kushner[30]	2013	92	54,38	49-91	
li[31]	2015	118		50-80	

Offset Risk Included In The Study

We assessed the risk of bias in all included trials and conducted quality assessments for all included trials based on QUADAS guidelines (Figure 2, Figure 3). The quality of the study was high and the overall risk of bias was low. More details are shown in the figure.

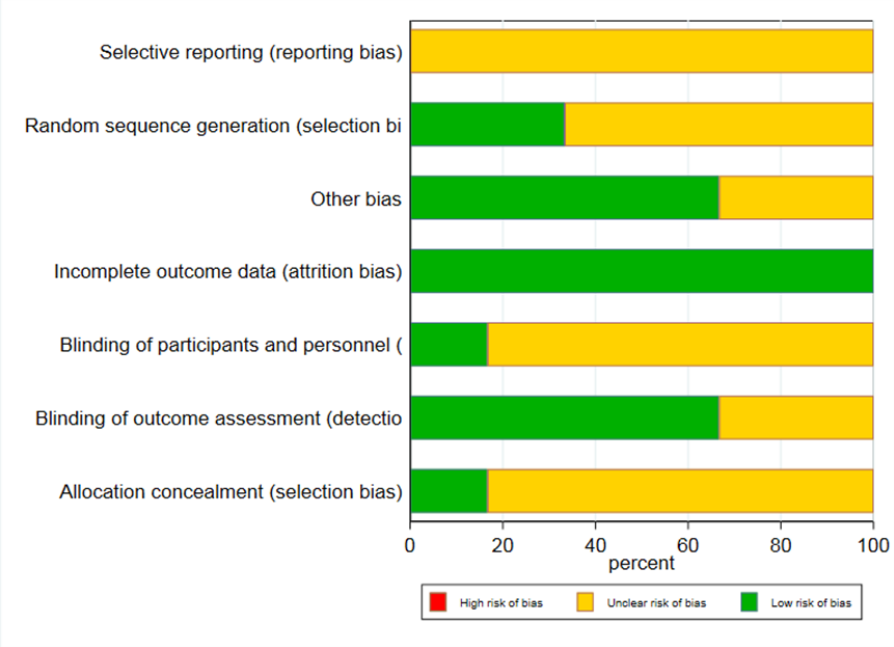


Figure 2. Migration risk diagram. Red means there is a high level of risk, yellow means there is an

uncertain level of risk, and green means there is a low level of risk.

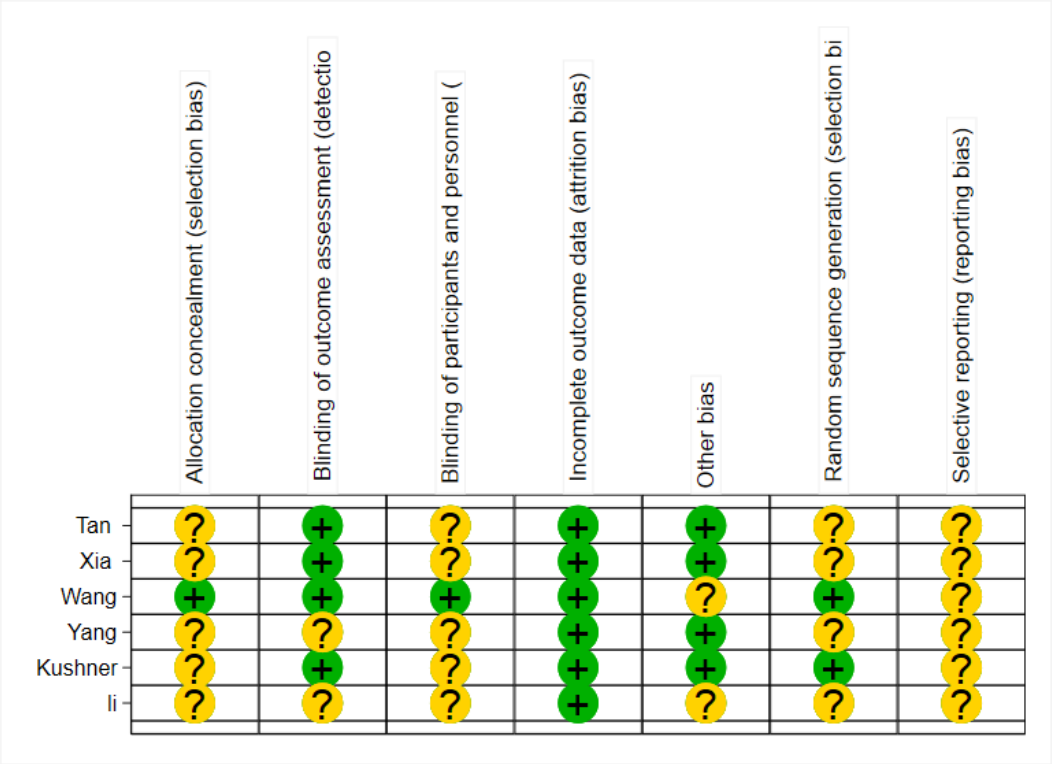


Figure 3. Migration risk diagram.

Primary Outcome Measurement

FOIS

In this study, 6 literatures were included, 3 of which used continuous data for FOIS and were included in this meta-analysis. Results showed that patients receiving neuromuscular electrical stimulation in combination with SRT for swallowing disorders after stroke had significantly higher benefits for FOIS than patients receiving SRT alone (MD=1.60, 95%CI[1.38, 1.81], P<0.001).Heterogeneity was significant (P=0.07，I^2=62%), and a random effects model was used for meta-analysis (Figure 4).When one article was excluded, heterogeneity decreased from 62% to 0%.Sensitivity analysis shows that the source of heterogeneity may be （Kushner/2013）.

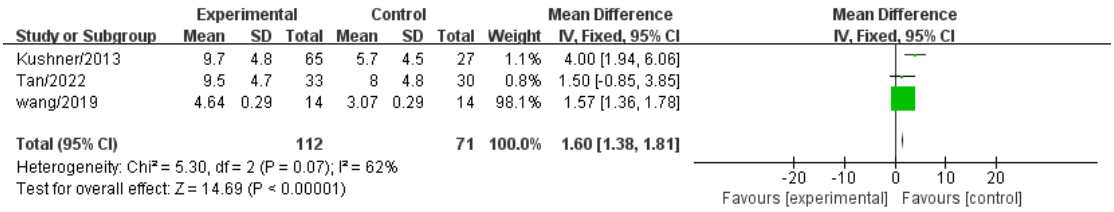


Figure 4 Forest map of FOIS benefits in patients receiving neuromuscular electrical stimulation combined with SRT for swallowing disorders after stroke

FDS

Six literatures were included in this study, three of which were FDS included in this meta-analysis. The results showed that patients receiving neuromuscular electrical stimulation combined with SRT in the treatment of poststroke dysphagic disorder had significantly greater benefit on FDS than patients receiving SRT alone (MD2.08, 95%CI[1.51, 2.66], P<0.00001, I^2=0%), and there was no heterogeneity. A fixed-effect model was used (FIG.5).

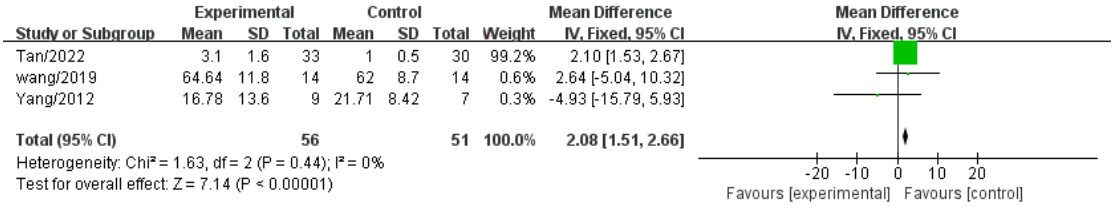


Figure 5 Forest map of FDS benefits in patients receiving neuromuscular electrical stimulation combined with SRT for swallowing disorders after stroke

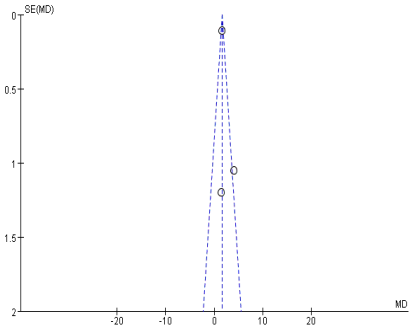
Adverse Event

In this meta-analysis, adverse events were evaluated for the included studies. Of the six studies included in the analysis, three explicitly reported adverse events during treatment. Of these, no adverse events were found in two studies, while one case of mild skin irritation was reported in the other study, which was resolved with treatment. In one of the two studies that reported no adverse events, it was clear that none of the

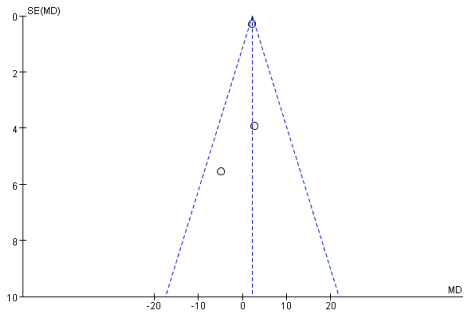
participants experienced symptoms of discomfort during treatment. The other study did not explicitly report adverse events, but participants underwent neurophysiological assessments before and after treatment and reported no abnormalities. In summary, neuromuscular electrical stimulation combined with swallowing training in the treatment of poststroke dysphagia performed well in terms of safety, and no serious adverse events or side effects were observed.

Assessment of Reporting Bias

FOIS and FDS scores, along with their corresponding 95% confidence intervals, were combined and analyzed using a funnel plot test to evaluate the potential for publication bias. The results, presented in Figure 6 (a-b), indicate that the funnel plots for both FOIS and FDS were symmetrical, suggesting that there was no significant publication bias.



6a: Funnel plot of FOIS



6 b: Funnel diagram of FDS

Figure 6 analyzed using a funnel plot test to evaluate the potential for publication bias

Sensitivity Analysis

Sensitivity analysis showed that patients receiving neuromuscular electrical stimulation combined with SRT in the treatment of dysphagia after stroke had no significant effect on FOIS and FDS. Excluding any literature in this study, the results did not change significantly, suggesting that the fixed-effect model used above was stable. Figure 7 (a-b)

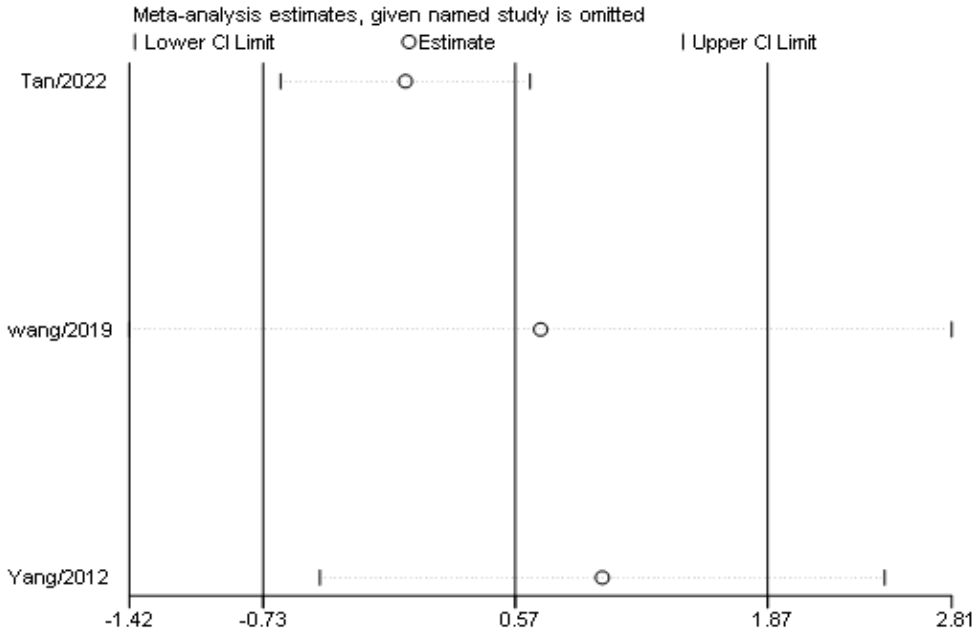


Figure 7a ： FOIS sensitivity analysis of neuromuscular electrical stimulation combined with SRT for post-stroke dysphagia patients

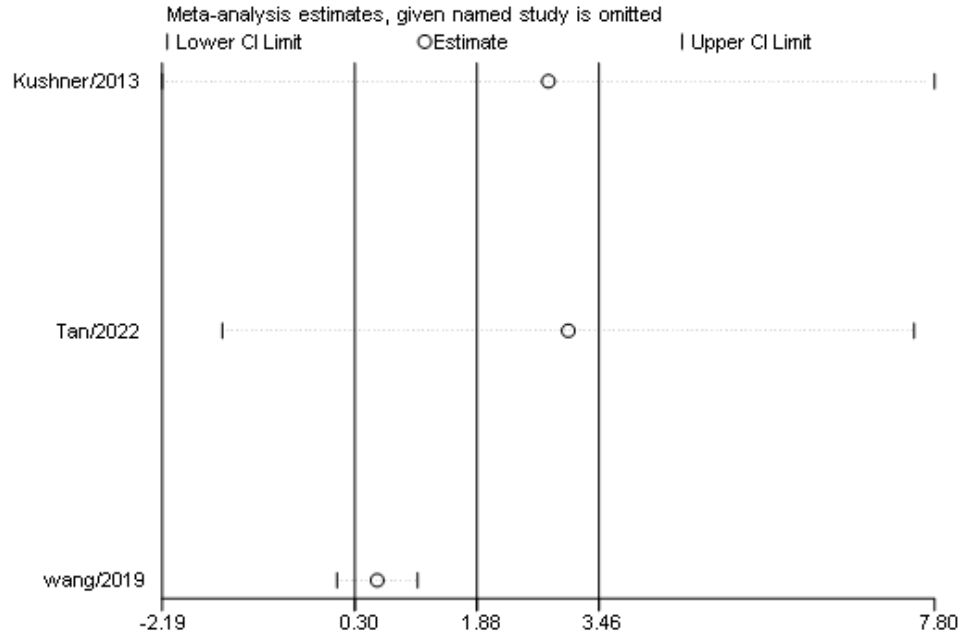


Figure 7b ： FDS sensitivity analysis of neuromuscular electrical stimulation combined with SRT for post-stroke dysphagia patients

DISCUSSION

The outcomes of the meta-analysis conducted in this study indicated a noteworthy positive impact of combining neuromuscular electrical stimulation with swallowing training in enhancing swallowing function among individuals grappling with dysphagia post-stroke[17,18]. Patients receiving neuromuscular electrical stimulation in combination with SRT for swallowing disorders after stroke had significantly higher benefits for FOIS than patients receiving SRT alone (MD=1.60, 95%CI[1.38, 1.81], P<0.00001).Patients receiving neuromuscular electrical stimulation in combination with SRT for swallowing disorders after stroke had significantly greater benefit on FDS than those receiving SRT alone (MD2.08, 95%CI[1.51, 2.66], P<0.00001).In addition, there are no adverse reactions to the treatment. The findings of this study provide a reliable option for the management of swallowing disorders after stroke and remind physicians and patients of the importance of swallowing function.

The effectiveness of using neuromuscular electrical stimulation alongside swallowing training to address post-stroke swallowing difficulties may be attributed to the underlying mechanism of this approach. Neuromuscular electrical stimulation can promote muscle contraction and nerve conduction, improve muscle strength and coordination, so as to promote the recovery of muscle contraction and swallowing function in the throat. Swallowing training can improve patients' awareness and control of swallowing, and enhance their ability to control and adjust the swallowing process[19-21]. The combination of neuromuscular electrical stimulation and swallowing training can achieve complementary effects and improve the therapeutic effect[22].

While the findings of this study suggest that the combination of neuromuscular electrical stimulation with swallowing training proves to be an efficacious therapeutic approach for addressing dysphagia following after stroke, the safety of this method should be noted. This study found that neuromuscular electrical stimulation combined

with swallowing training may cause some minor adverse reactions, such as dry mouth and throat discomfort, but these adverse reactions can be solved by reducing the intensity of the stimulus or adjusting the location of the stimulus. In addition, for some patients with severe heart disease, severe brain injury, neuromuscular electrical stimulation combined with swallowing training may not be suitable for use, should be judged according to the specific circumstances[24-25].

This study has certain limitations. First, the number of literatures included in this study is small, which may affect the stability of results. In addition, there are some limitations to our meta-analysis[23].In addition, although we tried our best to reduce potential bias in literature retrieval and screening, there may still be some missing studies or relevant data. Secondly, the sample size and quality of the literature included in this study vary, which may affect the reliability and generalization of the final results. Third, due to the differences in the studies included, we are unable to conduct a detailed analysis of the treatment plan, stimulus parameters, training intensity and other factors, which may have some influence on the final results[24-25].

In the future, further discussion should be made on how to better combine neuromuscular electrical stimulation with swallowing training for the treatment of poststroke swallowing disorders, and further optimization of stimulus parameters and training regimen. In addition, future research should also pay more attention to the evaluation of long-term efficacy and comparative studies with other treatments to better guide clinical practice.

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