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# Role of EMG Biofeedback Training for Spasticity Reduction in Neurological Disorders: A Narrative Review

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## ABSTRACT

Spasticity is one of the disabling complications of upper motor neuron dysfunction and is seen in many neurological disorders. Spasticity management is one of the toughest problems in neuro-rehabilitation. Biofeedback training using electromyography (EMG) has been suggested as an adjuvant treatment for improving voluntary motor control in patients suffering from neurological disorders.

The objective of the narrative review was to examine the current evidence regarding the efficacy of EMG biofeedback training for the reduction of spasticity in various neurological disorders and also discuss its relevance in physiotherapy practice.

A narrative literature review was conducted using the peer-reviewed journal articles, systematic reviews, and clinical studies on EMG biofeedback and spasticity in various neurological disorders such as stroke, cerebral palsy, multiple sclerosis, and spinal cord injuries.

When compared with conventional physiotherapy, the reviewed evidence suggests that EMG biofeedback training may enhance voluntary muscle activation and functional outcomes. While results in multiple sclerosis were limited and largely case-based, stronger and more consistent evidence was observed across populations affected by stroke and spinal cord injury.

EMG biofeedback appears to be a promising adjunct modality in the rehabilitation of spasticity in neurological disorders. However, further well-designed studies with standardized protocols are required to strengthen clinical recommendations and expand their application in physiotherapy practice.

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***Keywords***: EMG biofeedback; Spasticity; Stroke; Cerebral palsy; Multiple sclerosis; and Spinal cord injury.



## Abbreviations

1. EMG; Electromyography
2. CP; Cerebral Palsy
3. SCI; Spinal Cord Injury
4. MS; Multiple Sclerosis
5. UMN; Upper Motor Neuron

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6. MAS; Modified Ashworth Scale
7. FES; Functional Electrical Stimulation
8. ADL; Activities of Daily Living
9. SCIM; Spinal Cord Independence Measure

## INTRODUCTION

When allied to other factors of upper motor neuron syndrome, spasticity is a velocity-dependent increase in muscle tone marked by exaggerated tendon jerks, leading to the stretch reflex being excessively agitated. (Lance, 1990; Shu et al., 2021; Young, 1994). A range of neurological diseases have a correlation with spasticity, affecting 17–38% of stroke survivors, 67% of people with multiple sclerosis (MS), 68–78% of people with spinal cord injury (SCI), 85% of individuals with cerebral palsy (CP) (Liebherr, 2017). Up to 79% of people with SCI, 47% of those with MS, and 9–10% of those who have had a stroke suffer severe or life-threatening spasticity. (Shourijeh et al., 2025) figure 1 illustrates the prevalence of spasticity across these neurological disorders.

Spasticity is common in neurological diseases such as stroke, cerebral palsy, multiple sclerosis, spinal cord injury, and other CNS lesions. It can result in pain, contractures, joint deformities, pressure ulcers, impaired mobility, falls, and sleep disturbances. impacts postural stability, functional independence, and motor control (Dietz & Sinkjaer, 2012; Shourijeh et al., 2025). Conventional physiotherapy approaches (i.e., stretching, strengthening, and task-oriented training) are widely used; however, further therapeutic strategies are often required for better treatment outcomes.

Electromyographic (EMG) biofeedback training is a therapeutic modality that provides real-time audio or visual feedback of muscle activity and helps the patient to enhance voluntary control of muscle activation (Kim, 2017). EMG biofeedback may reduce spasticity, strengthen muscles, increase active range of motion, motor skills, and functional performance in patients with neurological disorders through improving motor awareness and facilitating appropriate muscle recruitment. (Wang et al., 2024; Yousefian Molla et al., 2025).

This narrative review is meant to summarize and analyze the existing literature on the role of EMG biofeedback training in reducing spasticity in neurological disorders, with emphasis on mechanisms of action, clinical effectiveness, and implications for physiotherapy practice.

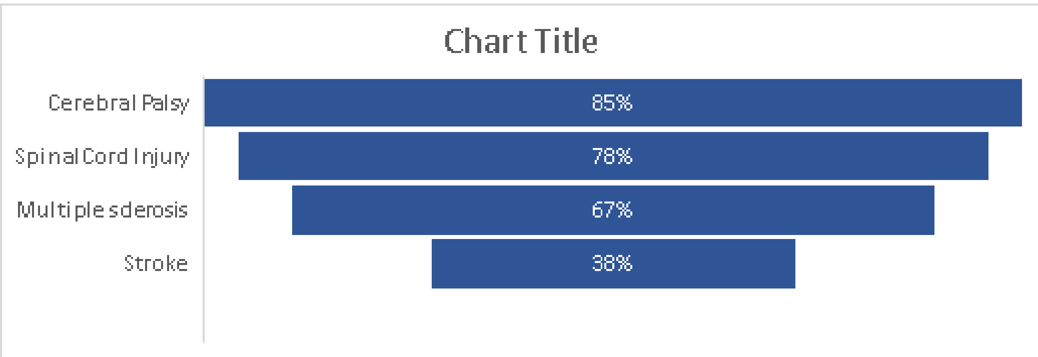


**Figure 1:** ***Prevalence of Spasticity Among Neurological Disorders***

## MATERIALS AND METHODS

### Literature Search Strategy

A literature search was performed using electronic databases such as PubMed/Medline, Cochrane Library, Google Scholar, and Web of Science. Peer-reviewed research studies, systematic reviews, and related clinical studies in English were considered. The search terms used included combinations of the following keywords: "EMG

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biofeedback," "spasticity," "stroke," "cerebral palsy," "multiple sclerosis," and "spinal cord injury." Boolean operators such as AND and OR were employed. The reference list of selected articles was also scanned to identify more relevant studies. Figure 2 illustrates the literature identification and screening process used in this review.

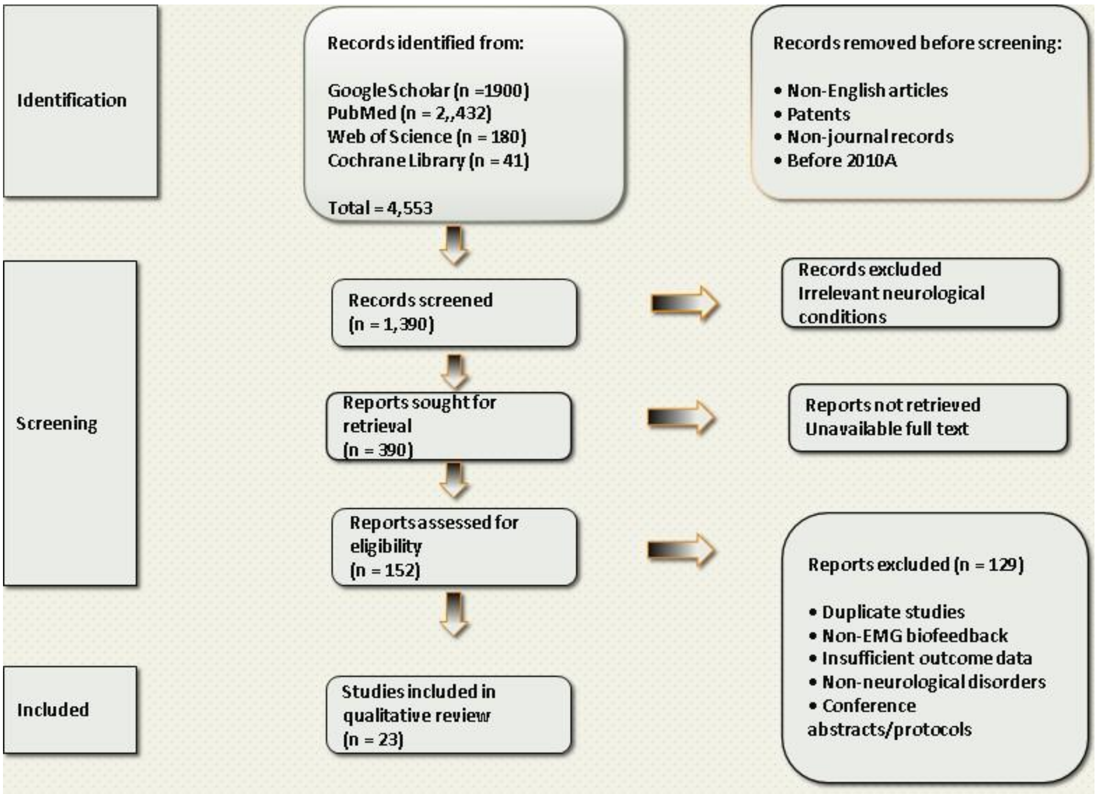


**Figure 2:** ***Literature Identification and Screening Process***

### Study Selection Approach

Articles were selected on the basis of their importance to the topic and their contribution to understanding the clinical application of EMG biofeedback in the management of spasticity and motor control in neurological populations. Due to the narrative nature of this review, no formal quality appraisal or quantitative synthesis was performed. Table 1 presents the inclusion and exclusion criteria applied when selecting studies for this review.

**Table 1:** ***Criteria for Study Selection Approach***

| Criteria | Inclusion Criteria | Exclusion Criteria |
|---|---|---|
| **Study Design** | RCTs, systematic reviews, observational studies, case studies, meta-analyses, and relevant narrative reviews examining EMG biofeedback in neurological rehabilitation | Expert opinions, editorials, letters to the editor, conference abstracts, protocols, and other materials without full-text availability |
| **Population** | Individuals diagnosed with neurological disorders associated with spasticity, such as stroke, cerebral palsy, spinal cord injury, and multiple sclerosis. | Studies conducted exclusively on healthy individuals or on non-neurological populations |

| | | |
|---|---|---|
| **Intervention** | Studies investigating electromyographic (EMG) biofeedback as a primary or adjunct intervention (including surface EMG feedback and audio-visual feedback) for rehabilitation programs | Studies focusing only on pharmacological management, surgical interventions, and invasive neuromodulation. |
| **Outcomes Measures** | Studies reporting outcomes related to spasticity, voluntary muscle activation, motor control, gait performance, upper limb function, functional performance, or EMG activity | Studies not reporting any spasticity-related, motor, or functional outcomes. |
| **Language** | Studies published in the English language | Non-English Studies without an available full-text English translation |
| **Publication Type** | Peer-reviewed original research articles, systematic reviews, meta-analyses, narrative reviews, and clinical studies relevant to EMG biofeedback. | Theses, dissertations, unpublished manuscripts, grey literature, and protocol studies |

## RESULTS

### Spasticity in Neurological Disorders

Spasticity is considered a motor dysfunction that involves the increase in velocity-dependent stretch reflexes due to high muscle tone with tendon jerks, resulting from increased tone in the presence of a lesion in the upper motor neurons (UMNs). Spasticity can occur as the intermittent or constant activation of the muscles. (Lance, 1990; Rivelis et al., 2025; Young, 1994).

The upper motor neuron syndrome is characterized by certain signs and symptoms. The positive features include hypertonia, hyperreflexia, spasticity, and clonus. Paralysis, weakness, lack of dexterity, and muscle fatigue are negative symptoms. (Angulo-Parker & Adkinson, 2018) When the part of the brain that controls movement is damaged, it can make the nerves in the spine get overexcited. This means they react much to things like stretching. When the nerves in the spine are too active, it can cause spasticity. (Nair & Marsden, 2014; Rivelis et al., 2025; Yelnik et al., 2010).

Spasticity is a problem for a lot of people with conditions, like those who have had a stroke, multiple sclerosis, spinal cord injuries, and cerebral palsy. It is a problem that can really affect people's lives, making it hard for them to move around, do things they need to do, and enjoy their lives. Upper motor neuron syndrome and spasticity can be very disabling. (Angulo-Parker & Adkinson, 2018; Lance, 1990; Shourijeh et al., 2025) figure 3 illustrates this progression from an upper motor neuron lesion to spasticity and its functional consequences.

### Biofeedback Training: Concept and Mechanism

Electromyography biofeedback gives us information about our muscles and how they move in real time. Provides visual and auditory information which helps us keep our muscles working correctly and our body in the right position. This also helps us move normally. (Alyanak et al., 2025; Kim, 2017)

EMG-Biofeedback uses a tool to track what our muscles are doing in real time. It shows us what is happening inside our body so we can learn how to control it. EMG-biofeedback electrodes measure the electrical signals from our muscles. This information is then made louder and shown to us so we can see or hear what is going on (Martino Cinnera et al., 2023). When we use biofeedback several times, it enhances sensorimotor integration and supports motor relearning (Odermatt et al., 2025; Sanders et al., 2023), facilitates cortical re-organization, and triggers neuroplastic changes within the central nervous system through practice-dependent mechanisms. (Alyanak et al., 2025) Figure 4 illustrates this feedback mechanism.

Furthermore, EMG biofeedback increases patient engagement and active participation during therapy by providing immediate performance-related feedback. (Alyanak et al., 2025; Toledo-Peral et al., 2022).

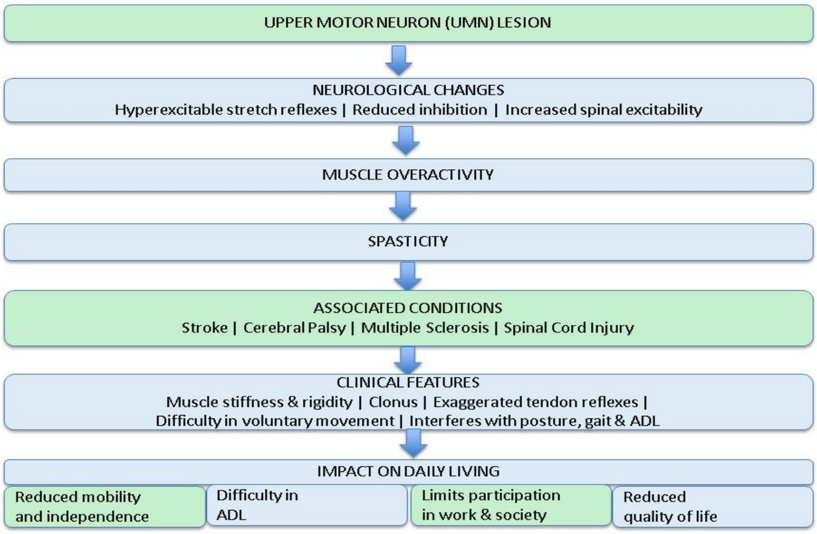


**Figure 3:** ***Schematic Representation of the Sequential Progression from UMN Lesion to Spasticity and Its Functional Consequences in Neurological Disorders***

**Role of EMG Biofeedback in Reducing Spasticity in Neurological Disorders**

Spasticity is a common motor impairment and has a major effect on voluntary movement and functional recovery. The role of electromyography (EMG) biofeedback training as an adjunct to standard physiotherapy in the management of spasticity is being investigated in several studies. EMG biofeedback provides immediate feedback of muscle activity so that people may develop more awareness and control of their muscle activation. (Kim, 2017; Toledo-Peral et al., 2022; Wang et al., 2024; Yousefian Molla et al., 2025) Frequently used outcome measures to assess the effectiveness of this intervention include the Modified Ashworth Scale, electromyographic activity parameters, and functional motor assessments. The findings suggest that EMG biofeedback training may be a useful method of therapy for alleviating symptoms of spasticity and improving motor control in neurological disorders. (Toledo-Peral et al., 2022; Wang et al., 2024; Yousefian Molla et al., 2025) table 2 summarizes the role of EMG biofeedback in the management of spasticity and functional recovery across the neurological conditions reviewed.

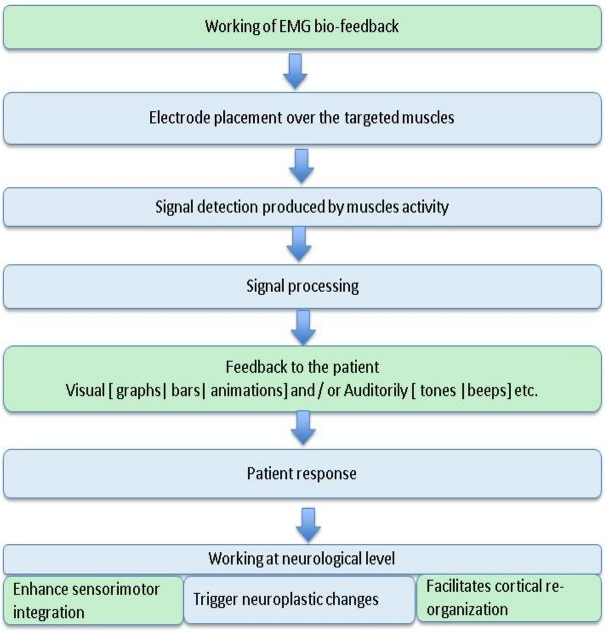


**Figure 4:** ***Schematic Representation of EMG Bio-Feedback Working***

**Table 2:** ***Role of EMG Biofeedback in Management of Spasticity and Functional Recovery Across Neurological Disorders***

| Reference | Study Type | Neurological Condition | Population | Target Muscle Group | Type of EMG Biofeedback | Outcome Measures | Main Findings |
|---|---|---|---|---|---|---|---|
| Wang et al. (2024); Doğan-Aslan et al. (2012) | Systematic Review and Meta-analysis; Clinical trial | Stroke | Adult post-stroke patients | Upper/Lower limb muscles | Surface EMG feedback, Visual/auditory feedback | Modified Ashworth Scale (MAS), EMG activity, and upper extremity functional assessments | Reduction in Spasticity, improved voluntary control. |
| Alwhaibi et al. (2020). | RCT. | Cerebral Palsy | Children with spastic hemiplegic CP (5-8 years) | Affected upper extremity muscles | Audio-visual feedback | Visual-Motor Integration (VMI) score and Grasping subtests score, motor function assessment | Improved hand-eye coordination and motor function |
| Liebherr (2017) | Case study | Multiple Sclerosis | Adult patient with MS | Lower limb muscles | Auditory feedback | Spasticity assessment, gait parameters, EMG | Improved motor awareness, gait performan |

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|---|---|---|---|---|---|---|---|
| | | | | | | biofeedback performance | ce, and self-management of muscle overactivity |
| Cheung et al. (2019). Balbinot et al. (2022) | RCT; Scoping review | Spinal Cord Injury | Adults with subacute complete SCI | Lower limb muscles involved in gait and locomotion | Visual feedback integrated with gait training | Walking ability, SCIM mobility score, cardiopulmonary function, EMG activity | Improved functional mobility and motor recovery; indirect benefits of spasticity management have been reported, although direct evidence for spasticity reduction remains limited. |

The available evidence on the role of EMG biofeedback training in reducing spasticity across different neurological disorders is summarized in Table 2. Overall, EMG biofeedback has been reported as a useful adjunct to conventional physiotherapy, with stronger evidence in stroke and spinal cord injury populations and limited, case-based evidence in multiple sclerosis.

### Clinical Implications for Physiotherapy Practice

The studies I looked at say that EMG biofeedback training is really important for therapy when it comes to helping people with spasticity from neurological problems. It seems that EMG biofeedback can be an addition to regular physical therapy, rather than something that is used on its own to help people control their muscles better and use the right muscles when they are getting better. EMG biofeedback can really help with this. Biofeedback of EMG is a means of real-time visual or auditory data on muscle activity, which can help patients develop greater awareness of abnormal muscle activation patterns and is more relevant for patients with spasticity following lesions of the upper motor neuron. (Doğan-Aslan et al., 2012; MacIntosh et al., 2019; Wang et al., 2024).

From a functional rehabilitation perspective, EMG biofeedback appears to support task-oriented and motor relearning-based training with active participation of a patient and repeated practice with feedback. The application during activities such as gait training, reaching, grasping, and postural control can assist physiotherapists to monitor appropriate muscle recruitment while minimizing excessive co-contraction. The reviewed studies indicate that EMG biofeedback may prove to be most effective when implemented as part of structured rehabilitation programs, especially for those with mild to moderate spasticity who are able to read and respond to feedback cues (Liebherr, 2017; MacIntosh et al., 2019).

Personalization of EMG biofeedback clinical application needs to take into account cognitive status, severity of spasticity, stage of recovery, and overall functional goals. Evidence for its clinical use is stronger in stroke and spinal cord injury populations, but the literature for multiple sclerosis is limited and largely case-based. So, physiotherapists should use EMG biofeedback with caution and in conjunction with established therapeutic approaches, given the need for more high-quality studies to confirm clinical recommendations. (Balbinot et al., 2022; Cheung et al., 2019).

**Limitations of Existing Literature**

Even though the interest in the use of EMG biofeedback training to treat spasticity among different diseases still exists, several difficulties still exist in the existing literature. The first one is related to the heterogeneous design, methodology, and outcome measurements used in EMG biofeedback studies, making it difficult to compare results between different studies. EMG biofeedback training to manage spasticity has great potential, but additional research is needed to overcome the problems described above. Different lengths of training, their frequency, the muscles trained, and feedback types lower the applicability of the results. Also, many studies have small samples.

The second difficulty lies in the unevenness of research on EMG biofeedback training among different neurological diseases. Multiple sclerosis is poorly researched using the EMG biofeedback approach, and most research is not based on randomized controlled studies.

A combination of populations that have stroke and spinal cord injury has fairly convincing proof concerning EMG biofeedback. In terms of the scale of assessment of spasticity and functional progress in different studies, various scales are utilized. Despite the fact that many methods, such as the Modified Ashworth scale, are applied, the sensitivity of these scales to detect the change in function needs additional verification. Lack of follow-up may affect the possibility of understanding the longevity of the effect of treatment. It is necessary to conduct further trials related to EMG biofeedback training to learn about the efficiency of EMG biofeedback training.

There are many unanswered questions about EMG biofeedback treatment itself. Firstly, it still needs to be answered how often and how long the treatment should take place, what amount of EMG biofeedback is needed for that, and what kind of stimulation should be used. Further research is necessary to understand the degree of improvement that can be achieved with the help of EMG biofeedback treatment. Currently, the scientific literature pays more attention to the recovery of the lower limb rather than the upper one.

Therefore, the current findings should be interpreted with caution, particularly when generalizing results across different Neurological disorders and rehabilitation settings.

**DISCUSSION**

Spasticity is a major cause of motor problems and functional disability, leading to upper motor neuron lesions, especially in certain conditions, like stroke, cerebral palsy, spinal cord injury, and multiple sclerosis. The present review indicates that EMG biofeedback is an important adjunct to conventional physiotherapy, primarily by improving voluntary muscle activation, improving motor relearning, and facilitating task-specific functional recovery. The benefit varied across neurological conditions, and the overall evidence consistently supported the use of EMG biofeedback as a part of structured rehabilitation programs rather than as a single intervention. (Kim, 2017; Lance, 1990; Nair & Marsden, 2014; Rivelis et al., 2025; Shourijeh et al., 2025; Wang et al., 2024; Yelnik et al., 2010; Young, 1994). Strongest evidence is available for stroke rehabilitation. In a randomized control trial, (Kim, 2017) included 30 people with chronic stroke and discovered that four weeks of electromyography (EMG) biofeedback combined with traditional rehabilitation led to statistically more pronounced improvements in motor function of the upper limb, as assessed through Fugl-Meyer Assessment and the Manual Function Test, when compared with the traditional rehabilitation alone, without any statistically significant difference in functional independence between the groups. Similarly, in another randomized experiment, Doğan-Aslan et al. (2012) included 40 people with hemiplegic stroke and discovered significant decreases in wrist flexor spasticity and marked improvements in Brunnstrom recovery stages, Upper Extremity Function Test, Fugl-Meyer score for wrist-hand, active wrist extension, surface EMG activity, and Barthel Index after three weeks of EMG biofeedback added to neurodevelopmental rehabilitation. Both results agree with a recent systematic review and meta-analysis by Wang et al. (2024) demonstrating extra benefits of the integration of EMG biofeedback into conventional rehabilitation for upper-limb recovery after stroke. The positive effects found in stroke rehabilitation are biologically plausible and align with the proposed mechanisms of EMG biofeedback. EMG biofeedback helps the patient to actively participate by providing real-time visual and auditory information about muscle activation, improves awareness of abnormal muscle recruitment, and facilitates repeated task-oriented practice.

These processes have been shown experimentally to improve sensorimotor integration, promote cortical reorganization, and facilitate activity-dependent neuroplasticity, resulting in enhanced voluntary motor control rather than simple reduction of muscle tone (Martino Cinnera et al., 2023; Odermatt et al., 2025; Sanders et al., 2023). The evidence for cerebral palsy also supports the inclusion of EMG biofeedback in comprehensive rehabilitation programs. Alwhaibi and colleagues randomly allocated 45 children with spastic hemiplegic cerebral palsy to traditional physiotherapy, augmented biofeedback, or combined therapy. The children given the combination of augmented biofeedback and conventional physiotherapy scored significantly higher on Visual-Motor Integration and Grasping than those who received only one of the treatments. These findings indicate that multimodal rehabilitation leads to superior improvements in eye-hand coordination and upper limb motor performance. These observations are consistent with the systematic review by MacIntosh et al., which suggested that biofeedback interventions improve motor performance in cerebral palsy despite heterogeneity in intervention protocols and outcome measures (Alwhaibi et al., 2020; MacIntosh et al., 2019).

Spinal cord injury, on the other hand, despite having less supporting evidence, still shows significant clinical effects. Cheung et al. found that EMG biofeedback-guided robotic body weight-supported treadmill training for eight weeks had shown improvements in Walking Index for Spinal Cord Injury II, SCIM III mobility, gait asymmetry, maximum oxygen uptake, and peak expiratory flow when compared to the control treatment. This shows that EMG biofeedback could assist in gait recovery through active muscle contraction. Likewise, Balbinot et al. discussed the growing importance of surface EMG as a tool in neurorehabilitation, especially in movement retraining and motor performance evaluation, but there is not enough evidence about its effects on spasticity reduction. (Balbinot et al., 2022; Cheung et al., 2019).

The amount of evidence obtained from studies on multiple sclerosis is relatively small when compared to stroke and spinal cord injuries. From the case-based study conducted, improvement was observed with regard to the three aspects of motor awareness, walking ability, and self-management using EMG-assisted rehabilitation; nevertheless, there is no randomized control trial conducted to support the findings. Thus, current evidence suggests the use of this therapy in a clinical setting, but more controlled studies should be conducted in the future. (Liebherr, 2017).

Yet another randomized controlled trial on the use of EMG biofeedback during neurological rehabilitation was carried out. According to Alyanak et al. (2025), incorporating games based on EMG biofeedback in traditional dysphagia therapy led to substantial gains in the Functional Oral Intake Scale, Dysphagia Outcome and Severity Scale, Penetration-Aspiration Scale, and Dysphagia Handicap Index for post-stroke dysphagia patients.

However, despite promising results from the clinical point of view, there are still some methodological problems observed in the available literature. Heterogeneity was present concerning treatment duration, session frequency, targeted muscle groups, feedback types, outcome measures, and characteristics of the patients included. Additionally, many studies applied different clinical instruments for assessing patients' condition; therefore, quantitative analysis was not possible. The sample size in most of the studies was relatively small, and information about long-term follow-up was insufficient for understanding whether the positive effects were sustainable. (Alwhaibi et al., 2020; Balbinot et al., 2022; Cheung et al., 2019; Shu et al., 2021; Wang et al., 2024).

In general, the available evidence indicates that EMG biofeedback training is most efficient when combined with the use of a task-oriented patient-centered rehabilitation program focused on active participation and motor task

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repetition. The strongest evidence is currently available in the case of post-stroke rehabilitation, while some evidence has been obtained in patients with cerebral palsy and spinal cord injuries; the evidence in patients with multiple sclerosis is preliminary at this stage. (Alyanak et al., 2025; Balbinot et al., 2022; Cheung et al., 2019; Shourijeh et al., 2025; Wang et al., 2024; Yousefian Molla et al., 2025)

## CONCLUSIONS

The current narrative review demonstrates the application of EMG biofeedback training as an adjunct therapy in the treatment of spasticity and motor recovery in neurological disorders. As evident from the above literature review, EMG biofeedback training can help enhance voluntary muscle control along with traditional physiotherapy. The evidence is clearly available in cases of stroke and spinal cord injury patients. On the contrary, the evidence from CP and MS is insufficient and limited to case reports. Nonetheless, there is some suggestion that EMG biofeedback training can be clinically applied in certain patients of these neurological disorders. It is most effective when incorporated in goal-directed rehabilitation program. Overall, EMG biofeedback training is a useful adjunct therapy in neurorehabilitation. Nevertheless, further condition-specific research is required for future clinical practice.

## AUTHOR DECLARATIONS

**CRediT Author Statement / Author contributions**

**Manisha Mishra:** Conceived and designed the review; conducted the literature search and screening; performed data extraction and synthesis; wrote the original draft of the manuscript; prepared figures and tables
**Neha Dubey:** Supervised the review process; provided guidance on methodology and structure; critically reviewed and revised the manuscript for important intellectual content; approved the final version
**Gowrishankar Potturi:** Reviewed and approved the final manuscript.
**Mayank Kuma:** Reviewed
**KB Ranjeet Singh Chaudhary:** Reviewed
**Anjali Agarwal:** Reviewed

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**AI Statement:** Grammarly was used strictly for spelling, grammar, and clarity improvements without generating original content. The authors retain full responsibility for all ideas, interpretations, and conclusions presented in this work.



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