Review Article

The Effectiveness of EMG Biofeedback to Improve Ankle Dorsiflexion in Stroke Patients: A Systematic Review

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Abstract:

Background: Stroke, results in some form of residual deficits even after recovery. Patients face difficulty in ambulating, probably because of reduced ankle dorsiflexion. Present systematic review aims to explore the literature-related to studies conducted on patients with Stroke for the effectiveness of electromyography biofeedback (EMG BF) therapy in the treatment of ankle dorsiflexion. **Methodology:** This study included nine randomised trials, all including patients who developed stroke after an episode of acute Ischemic infract. Use of databases Google Scholar, PubMed and CINHAL full text was done. **Results:** EMG muscle activity also showed improvement in 3 out of 9 studies. This may be attributed to gradual weight bearing and improving in muscle activity over the period of time. **Discussion:** EMG BF is useful for improving motor functions and walking speed as well as increasing ROM and muscle activation maybe because new pathways are formed or previous cerebral and spinal pathways and networks are activated by the stimulation with feedback or remaining proprioceptive senses are regulated by visual and acoustic warnings. **Conclusion:** There is gradual weight bearing and improvement in muscle activity post EMG BFB over the period of time.

Key words: EMG Biofeedback, Stroke, Ankle dorsiflexion

Introduction:

The World Health Organisation (WHO) defined Cerebrovascular Accident (CVA) or Stroke as 'Rapidly developed clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than of vascular origin.[1] It is the second-largest cause of death and the third-largest cause of disability worldwide.[1,2] Globally, one in four people over age 25 will have a Stroke in their lifetime. As per Global Stroke Fact Sheet 2022: In 2019, the worldwide incidence of Stroke was 12.2 million and the prevalence was 101 million, the most affected group being the elderly population.[3] India's geriatric population stood at 1.36 billion (2019) and will grow by twenty percent by 2025, a demographic that is described as vulnerable.[4] According to The Asian Stroke Advisory Panel, the overall incidence of Stroke ranged from 116 to 483/100,000 per year in Asia.[5]

Stroke causes a variety of deficits, including motor, sensory, perceptual, and language impairments. The most noticeable variation is motor weakness or hemiparesis on the one side of the body opposite the lesion, resulting in disability. Functional independence is mainly hampered because of difficulty in ambulation as in most of the cases the patient is unable to dorsiflex the ankle and perform the heel strike; the first component of the gait cycle.

Rehabilitation of ankle movement is a fundamental step in restoring walking in hemiparetic patients.[6] EMG patterns during ambulation are formed by angular changes and asynchronous, phasic bursts of pretibial and calf muscle activity which control the raising and dropping of the tip of the foot in swing at the beginning of the support phase.[7]

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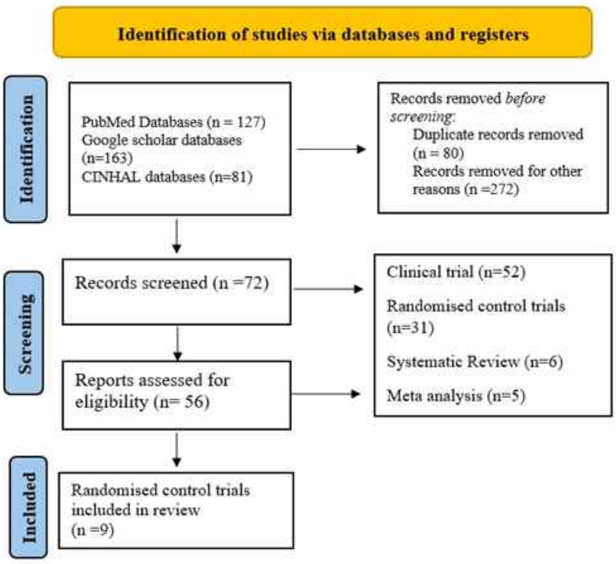
Auditory and visual Biofeedback has been demonstrated to improve the control learning of unintentional or intentional but damaged physiological functions. Provided continuous and direct communication between the physiotherapist and the patient regarding recovery of deficit. Visual Biofeedback is one of the techniques supporting motor learning techniques. Biofeedback therapy is based on the enhancement of myoelectric signals obtained from the muscles, which then were converted into visual and auditory signals with the aim to inform the individual about the activity of muscles.[8]

This study aims to explore the literature-related to studies conducted on patients with Stroke for the effectiveness of electromyography biofeedback (EMG BF) therapy for improving ankle dorsiflexion concerning of specific study design, recovery stage of patient, patient distribution in the study, intensity of current used in treatment, duration of treatment intervention, frequency of treatment intervention, outcome measures used in the study and mechanism of improvement.

Methodology:

Systematic search was undertaken in commonly used search engine (PubMed) for the period from January 2012 to December 2022. The search strategy comprised of the following terms: Functional Recovery, Stroke, Longitudinal Study.



SELECTION CRITERIA FOR OBSERVATION STUDIES:

Only studies published in English language evaluating Ankle dorsiflexion and lower extremity function in patients with acute and subacute stroke were included.

DATA EXTRACTION:

The Data Analysis was done through Pub med Electronic Data base searched by GT. The Title and Abstract of all the retrieved results were then screened for eligibility by GT & SG. The Screening process was aimed at narrowing down the volume of articles by rejecting the studies that are not relevant or appropriate according to previously stated criteria, Full text version of all relevant articles was evaluated by GT and SG.

Results:

Table no. 1: Quality assessment of included articles using PEDro Scale

Authors	**Dost S G *et al* [8]**	**Tamburella F *et al* [9]**	**Bradley L *et al* [10]**	**Jung KS *et al* [11]**	**Jonsdottir J *et al* [12]**	**Gámez AB *et al* [13]**	**Tamburella F *et al* [14]**	**Pak NW *et al* [15]**	**Kwakkel G *et al* [16]**
Random allocation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Concealed allocation	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes
Groups similar at baseline	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Participants blinding	No	No	No	No	Yes	No	No	No	No
Therapists blinding	No	No	No	No	No	No	No	No	No
Outcome assessor blinding	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
Less than15% dropouts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intention to treat analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Between groups statistical Comparison	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Point measures and Variability Data	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PEDro score	8	9	9	9	8	8	6	8	9

Table no. 2: Summary of Randomised trial Studies:

S. N.	Author name	No. of Patients Included in study	Type of patients	Type of study	Intervention	Result	Interpretation
1	Dost S G *et al* 2019.[8]	40 Patients Group A (EMG BFB group): 20 patients Group B (control group): 20 patients	Patients who developed hemiplegia after CVA	randomized controlled study	**Group A:** EMG-BFB along with conventional physiotherapy **Group B:** Conventional physiotherapy **Duration of treatment:** 20 minutes each session **Frequency of treatment:** 5 days a week for 3 weeks.	MAS — $p > 0.05$ — r = 0.447 Ankle do ROM — $p > 0.05$ — r = 0.501 BRUNNSTORM LL stage — $p < 0.01$ — r = 0.517 MMAS (sit to stand — $p < 0.01$ — r = 0.453 MMAS walking — $p < 0.01$ — r = 0.409 All variables show significant improvement in lower extremity function	EMG BF is useful for improving motor functions and walking speed as well as increasing ROM and muscle activation maybe because new pathways are formed or previous cerebral and spinal pathways and networks are activated by the stimulation with feedback or remaining proprioceptive senses are regulated by visual and acoustic warnings.
2	Tamburella F *et al* 2019.[9]	12 Group A (EMG biofeedback): 6 patients Group B (torque biofeedback): 6 patients	Patients with Subacute stroke	randomized controlled study	**Group A:** Lokomat training, by a novel biofeedback (EMGb) **Group B:** Lokomat training, by commercial joint torque biofeedback (Rb) **Duration of treatment:** 40 minutes each session **Frequency of treatment:** 3 days a week.	MAS — Hip $p<0.001$ Knee $p<0.005$ Ankle $P<0.05$ MMT — 0.035 Barthel index — P=0.007 VAS score — P=0.011	Torque biofeedback has been proved effective for gait training Ensuring a successful treadmill stepping pattern has shown to induce task-specific sensory information that could promote plastic changes in the central nervous system that are required to improve walking function after stroke
3	Bradley L *et al* 1998. [10]	23 Group A: EMG BFB group Group B: control group	acute phase post stroke patients	Randomized controlled study	**Group A:** The EMG biofeedback group were treated using EMG as an adjunct to physiotherapy. **Group B:** same techniques, electrodes were used with this group of patients, but the EMG machine was turned off and faced away from the patient and the therapist to control the placebo effect.	Modified Bobath scale — $p <0.001$ — F = 11.77 Rivermaid mobility scale — $p <0.002$ — F = 9.01 MAS — $p <0.01$ — F = 12.71 10 m walk test — n.s Sensation and proprioception — n.s	This study showed no significant differences in the rate of improvement after stroke between the two groups.
4	Jung KS *et al* 2019. [11]	20 Group A: 10 Group B: 10	hemiparetic stroke patients	randomized controlled study	**Group A:** gait training with auditory feedback **Group B:** conventional gait training **Duration of treatment:** 30 minutes each session **Frequency of treatment:** 5 times a week, for 4 weeks	TIS score — p=0.053 — r = 0.99 TUG score — p=0.015 — r = 0.98 Muscle activation was significantly higher in the experimental group. No significant difference was found in the TIS score. Based on the TUG test, a significant improvement was observed	gait training with auditory feedback was beneficial might be attributed to training with auditory feedback as it reduces weight bearing against the cane, thereby facilitating walking in the upright position.

Table no. 2: Summary of Randomised trial Studies (Contd..)

S. N.	Author name	No. of Patients Included in study	Type of patients	Type of study	Intervention	Result	Interpretation
5	Jonsdottir J *et al* 2010.[12]	40 Group A: 20 Group B: 20	patients with chronic mild to moderate hemiparesis	randomized controlled study	**Group A:** BFB application **Group B:** conventional therapy **Duration of treatment:** 45 minutes each session **Frequency of treatment:** 3 times per week for 3 weeks	Ankle power peak: 0.03 Gait velocity: P=0.14 Stride length: P=0.01 BFB treatment led to significant increases in conjunction with significant increases in velocity and stride length	A task-oriented BFB treatment was effective in increasing peak ankle power, gait velocity, and stride length in a population with hemiparesis.
6	Gámez AB *et al* 2019.[13]	28 Group A: 14 Group B: 14	stroke-derived hemiplegia	randomized controlled study	**Group A:** sEMG-B **Group B:** conventional physiotherapy **Duration of treatment:** 1 Hour per session **Frequency of treatment:** twice a week over a period of three months (24 sessions in total)	Upper limb FUGL M score: p=0.001 Lower limb FUGL M score: p<0.001 Isometric strength: p=0.734 EMG activity for affected lower limb: p=0.966 EMG activity for affected upper limb: P=0.011 increase in the average EMG activity of the extensor muscle of the hand and in the dorsal flexion of the foot than the control group	sEMG-B seems to be more effective than conventional physiotherapy as sEMG-B has demonstrated its usefulness in improving muscular torque recovery, articular and muscular recovery after surgery
7	Tamburella F *et al* 2017.[14]	10 Group A: 5 Group B:5	Subacute stroke patients	randomized controlled study	**Group A:** Active AFO **Group B:** Inactive AFO **Treatment duration:** 60 min per session each day **Treatment frequency:** 6 weeks of training, 5 days a week	MAS: T_0 p < 0.05; T_{End} p < 0.005 Spasticity and CI decreased significantly after training only in the EXP group, in association with a significant rise in active joint speed and active ROM	exercise information, provided by joint sensorization and vBFB, improved the efficacy of the conventional approach for treating ankle spasticity mainly attributed to direct relationship between the velocity of stretch and the onset of the stretch reflex in the Pts with chronic hemiparesis
8	Pak NW *et al* 2019.[15]	30 Group A: 15 Group B: 15	hemiplegic stroke patients	a preliminary, randomized, controlled study	**Group A:** visual feedback training with visual targets on gradual weight shifting **Group B:** visual feedback training on gradual weight shifting **Treatment duration:** 30 minutes **Frequency of treatment:** three sets per day, 5 days per week, for a total of 4 weeks	EMG Measurements: Recuts femoris; Tensor Fascia Lata; Gluteus medius Significantly larger gains were identified in the experimental group compared to the control group	Visual feedback training with visual targets during gradual weight bearing on the paretic side appears to improve the muscle activation and balancing abilities of hemiplegic stroke patients compared to visual feedback training alone.
9	Kwakkel G *et al 2016*.[16]	159	Patients with Ischemic stroke	The EXPLICIT-Stroke Randomized Clinical Trial	**Group A:** or usual care **Group B:** EMG-NMS or usual care	EMG-NMS did not result in significant differences	Three weeks of early mCIMT is superior to usual care in terms of regaining upper limb capacity in patients with a favourable prognosis

Discussion:

Reviewing the literature on EMG biofeedback to improve ankle dorsiflexion and lower extremity functions in acute, subacute and chronic stroke patients, significant impairment in the active range of ankle dorsiflexion and other lower extremity parameters was observed. There is no other systematic review performed previously evaluating the effectiveness of Biofeedback therapy for improving dorsiflexion and lower extremity functions in stroke patients.

This study included nine randomised trials, all including patients who developed stroke after an episode of acute Ischemic infract. Acute and subacute stroke patients were included in 6 out of nine trials with all the trials comprising of 20 to 40 patients randomly allocated in two groups with patients in one group treated with EMG-BFB therapy with visual and auditory feedback and patients in second group treated with conventional physiotherapy. The type of stroke patients was not mentioned in other 3 studies.

5 out of 9 studies allocated the patients in treatment and control groups, where patients in treatment group were treated with EMG BFB therapy and other group patients were treated using conventional physiotherapy which included active stretches as well as electrical stimulation. There patients were treated for almost 20 to 40 minutes for 4-6 weeks with 4-5 patients per week.

The ankle dorsiflexors as well as well as other lower extremity functions were evaluated before and after treatment by means of different outcome measures. Modified Ashworth scale exhibited better reliability when statistically associated to inter rater reliability of scores of lower and upper extremities.[17] The large effect size was observed for improvement in tone assessed by Modified Ashworth scale in three out of 9 studies.

The neuromuscular response of stroke patients with spasticity is different from that of healthy subjects, which is reflected in the increased amplitude and decreased complexity of EMG activity. The involuntary muscle activity due to spasticity is not only manifested in the EMG amplitude, but also in spatial distribution.[18]

EMG muscle activity also showed improvement in 3 out of 9 studies. This may be attributed to gradual weight bearing and improving in muscle activity over the period of time. The FMA-S had high total score inter-rater reliability and internal consistency.[19] But according to the study by Ana Belén Gámez st al. in the year 2019 there was no significant improvement in the Fugel Mayer scale for lower extremity but the isometric strength improved after application of surface EMG. The TUG is also used to assess the performance change in stroke patients.[20] In a study by Kyoung-Sim Jung et al, TUG score showed significant improvement post EMG BFB treatment.

A study by Johanna Jonsdottir et al in the year 2010 also showed significant impairment in all the gait parameters. It is people with hemiparesis, may generate as much power as they are capable of without threatening stability. Another possible explanation for people with hemiparesis is that not using energy from the ankle push-off is a vestige from the more acute stage where this strategy would have been difficult to handle, both because of weakness and for general safety reasons.

Future scope:

As Modified Ashworth Scale was used as an outcome measure in 3 out of 9 studies, a meta-analysis can be conducted further on these studies. As EMG muscle activity was also used as an outcome measure in 3 out of 9 studies, a meta-analysis can be conducted further on these studies.

Conclusion:

EMG BFB therapy has proved to have a significant improvement in various parameters for improving ankle dorsiflexion and lower extremity function in 7 out of 9 studies. There is gradual weight bearing and improvement in muscle activity post EMG BFB over the period of time.

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