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Effect of Neuro Muscular Electrical Stimulation (NMES) using Muscle Intelligence (MI) Action Technology and Functional Hand Orthosis in Improving Arm-hand Skilled Performance (AHSP) in Post-stroke Subjects – A Pilot Study

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ABSTRACT: Impaired hand function is a common consequence of stroke, affecting around 87 percent of stroke subjects leading to limited ability to perform their activities of daily living. So, the necessity arises to achieve and maintain improvement in both arm-hand function (AHF) and arm-hand skilled performance (AHSP). Neuromuscular electrical stimulation (NMES) is being commonly used in the rehabilitation of patients with neurological diseases. When electrical stimulation (ES) regimens are combined with mechanical strategies such as robotic training or neuroprosthetics, or other types of orthoses, better results are obtained. This is a pilot study with the objective of investigating the effectiveness of combining a neuro muscular electrical stimulation (NMES) regimen adjunct with a functional hand orthosis (Saebo Glove) in reducing wrist flexor spasticity and improving hand performance. A sample of 20 post-stroke subjects with hand function impairments were divided into two groups to compare the improvement in arm-hand skilled performance (AHSP) using Action Research Arm Test. The control group received the conventional physiotherapy management and the experimental group received neuro muscular electrical stimulation (NMES) using Muscle intelligence (MI) action technology combined with a functional hand orthosis, along with conventional physiotherapy management. Both groups showed improvement in arm hand skilled performance following intervention. The improvement in arm-hand skilled performance gained by experimental group was significantly better than the control group (0.005441). Sub-acute post stroke subjects treated with Neuro muscular electrical stimulation using Muscle intelligence action technology combined with a functional hand orthosis along with conventional physiotherapy management showed better improvement in arm-hand skilled performance than those who were given conventional physiotherapy management alone. In muscle intelligence action technology voluntary contractions are combined with stimulated contractions at the subject's own pace, so that the user is in control of his/her training. The Saebo Glove improves hand strength and mobility of patients so that they can effectively grab objects. These aspects contribute to the effectiveness of the treatment.

Keywords: Neuro muscular electrical stimulation, Functional hand orthosis (Saebo Glove), Arm-Hand skilled performance, Muscle intelligence action technology.

INTRODUCTION

Innovations in healthcare based on technological developments are the need of the hour as the social meaning and management of health are undergoing major changes. In the field of physiotherapy, new technologies in rehabilitation have recently occurred with the hope of improved outcomes. This pilot study was undertaken with the intention of applying technological innovations in the rehabilitation of post-stroke subjects.

One of the persisting and most common consequences of stroke is impaired hand function. More than two-thirds of stroke subjects, around 87 percent, undergo difficulties with arm function as a result of paralysis of the hand or upper limb. Typically, during the first three months after the stroke there is some recovery of motor control, which plateaus by 6 months. However, during this period of 3 to 6 months poststroke, 40 to 80 percent have incomplete recovery of functions in the upper extremity. An important aim of treatment in stroke rehabilitation is to achieve and maintain improvement in both arm-hand function and arm-hand skill performance. The term 'arm-hand function' (AHF) refers to the 'body function and structure level' of the International Classification of Functioning, Disability and Health (ICF). The term 'arm-hand skilled performance' (AHSP) refers to the arm-hand function in the ICF activity level, which includes both capacity and performance. Therapists set the goal of improving both AHF and AHSP through their various interventions.

Therapists use techniques such as passive stretch (usually done through splinting) to restore muscle

tone, and more recently, electrical stimulation to reduce tone. Usually, electrical stimulation is applied to the nonspastic, or antagonist muscle. When the antagonist muscle is stimulated, the afferent nerve pathways inhibit the spastic or agonist muscle polysynaptically (Alon and Dominico *et al.,* 1987). In neurological rehabilitation, neuromuscular electrical stimulation (NMES) is generally used. It increases Ib fibre activation through mechanisms that facilitate the Renshaw cell recurrent inhibition, on antagonist reciprocal inhibition, and on increasing cutaneous sensory stimuli. This leads to reduction of spasticity. When the application of NMES is combined with other interventions, reductions on spasticity and improvements in range of motion occur (Motta-Oishi *et al.,* 2013). To stimulate the paralyzed hand in a bilateral simultaneous motion, a surface electromyogram (EMG) of the unaffected hand has been experimented as a clue (Osu *et al.,* 2012). EMG triggered neuromuscular stimulation administered to acute stroke survivors has been found to enhance upper extremity motor recovery and functional recovery (Francisco *et al.,* 1998). There are clinical reports of stroke rehabilitation using a BCI system to trigger EEG-triggered NMES for finger function (Daly *et al.,* 2009) and upper limb training (Marquez-Chin *et al.,* 2016). NMES is used also for muscle reducing spasticity in stroke rehabilitation (Sahin *et al.,* 2012). MESH glove treatment is a technique, which has been found to improve arm and hand sensation and voluntary motor control, to normalize the hand temperature and reduce the swelling and spasticity (Cauraugh *et al.,* 2000). A study on the effect of an implanted cortical stimulator on hand and arm function in patients following ischemic stroke suggested that cortical stimulation with rehabilitation therapy produces a lasting treatment effect in upper extremity motor control and is not associated with serious neurological complications (Huang *et al.,* 2008).

However, research have suggested that if electrical stimulation (ES) is used along with other interventions, it has the greatest effect (Doucet and Mettler 2018). Specifically, when ES regimens are combined with mechanical strategies such as robotic training or neuroprosthetics, or other types of orthoses, better results are obtained in reducing wrist flexor spasticity and improving hand movement (Franck *et al.,* 2019). ES along with functional hand orthosis, in sub-acute stroke subjects with reference to the functional use of the impaired hand resulted in a significant improvement in hand function from no dexterity to dexterity. The patients also displayed a high-intrinsic motivation and sense of self-regulation, creating opportunities for a non- functional hand towards task-oriented training (Stein *et al.,* 2015).

As earlier researches have shown, deficits such as loss of volitional finger extension, muscle coactivation, and involuntary coupling of wrist and finger flexion with certain shoulder and elbow movements are hindrances to the restoration of hand function in sub-acute post-stroke subjects. Further, there is not much information about the prospective improvement or deterioration to be expected in stroke survivors in the sub-acute phase after stroke. So, clinicians find it difficult to make decisions about arm-hand treatment objectives and associated prognostics regarding arm-hand skill performance. To overcome these hurdles, this pilot study proposes to combine a NMES regimen adjunct with a functional hand orthosis. Further, flexion synergy at the elbow hinders voluntary stimulation of the flexor muscles of the wrist. Therefore, the spasticity reduction protocol will be aimed at the elbow as well.

NMES regimen makes use of a device which sends electrical impulses to nerves causing muscles to contract. Muscle strength and range of motion can be increased by the ES. In MI action technology voluntary contractions are combined with stimulated contractions. This takes place at the subject's own pace, so that the user is in control of his/her training. Users themselves must voluntarily and actively contract the muscle first to start the stimulation from the device. The Saebo Glove is a hand rehabilitation glove which is so designed as to improve hand strength and mobility of patients suffering from neurological and orthopaedic injuries and help them to effectively grab objects.

MATERIALS AND METHODS

In this pilot study, it was assessed the arm-hand skilled performance of a small sample of post- stroke subjects, comparing those who received NMES using MI action technology combined with a functional hand orthosis (Saebo Glove) along with conventional physiotherapy, with those who received conventional physiotherapy alone.

A sample of 20 post-stroke subjects with hand function impairments were divided into two groups, the experimental group and the control group of 10 each, to compare the improvement in AHSP. The control group received the conventional physiotherapy management, while the experimental group received NMES using MI action technology as well as NMES for spasticity reduction combined with a functional hand orthosis, along with conventional physiotherapy management hand functions were evaluated before and after intervention to analyze the improvement using Action Research arm test. 20 Stroke survivors in the age group 55-65 from hospitals in and around Bangalore who fulfilled the following criteria of selection were selected for the study.

Inclusion Criteria

- Left MCA infarct with Right hemiplegia
- Both male and female subjects
- Age of subjects between 55-65 years
- Duration of stroke between 3-6 months (late sub-acute)
- Grade 1 or 2 in Utrecht arm/hand test which shows moderately to severely affected arm- hand functions

- Subjects who gave informed consent
- Score > 24 in Mini Mental State Examination

Exclusion Criteria

- Severe problems of shoulder, arm, hand on paretic side like oedema and inflammation which hampers training
- Shoulder subluxation on paretic side
- Reflex sympathetic dystrophy
- Intolerance regarding application of electrical stimulation

Intervention Programme

The subjects then underwent a demographic data collection, and arm/hand function evaluation using Action Research Arm Test (ARAT) and then were randomly allocated to the 2 groups of 10 each. The intervention in control group included conventional physiotherapy management for stroke. The intervention in experimental group involved spasticity reduction in wrist flexors and elbow flexors using NMES in the antagonist muscles (wrist extensors and elbow extensors) for 15 minutes followed by repetitive task training of grasp and release with voluntarily triggered NMES using MI action technology of wrist extensors for 15 minutes, exercises wearing a functional hand orthosis (Saebo glove) and conventional physiotherapy management. The intervention lasted for 5 sessions per week for 6 weeks for both groups. At the end of intervention, post intervention scores of arm/hand function using ARAT were recorded.

Table 1: Intervention Schedule.

Sr. No.	Groups	No. of Subjects	Intervention	Intervention Duration
1	Group-A (Control Group)	10	Conventional Physiotherapy Management	6 weeks
2	Group-B (Experimental Group)	10	Conventional Physiotherapy Management Plus NMES using MI technology and functional hand orthosis	6 weeks

RESULTS AND DISCUSSION

Wilcoxon signed-rank test was used for within group analysis and the Mann Whitney U test was used for between group analysis. The scores of arm/hand function evaluation using ARAT collected for the experimental group before and after the implementation of the combined conventional therapy-NMES-MI-Saebo Glove regimen in the 10 subjects, are reported in Table 2. All participants showed improvement in performance. Similarly, the scores of arm/hand function evaluation using ARAT collected for the control group before and after the implementation of the conventional therapy regimen in the 10 subjects, are reported in Table 3. The participants showed modest improvement in performance. A comparative analysis of the scores of arm/hand function evaluation using ARAT between the control group and the experimental group before the implementation of the respective therapy regimens, reported in Table 4 and it shows no significant difference between the groups. This was done to assure the benefit of the combined regimen on subjects with similar pre-conditions. Comparative analysis of the scores of arm/hand function evaluation using ARAT between the control group and the experimental group after the implementation of the respective therapy regimens, reported in Table 5 and it shows that the difference between the groups is quite significant. This shows that the combined conventional physiotherapy-Neuromuscular Electrical Stimulation-Saebo Glove regimen is quite effective in improving the arm/hand function of post-stroke subjects than conventional physiotherapy alone.

Table 2: Within Group Analysis –Experimental.

Group	Measurements	Mean	S.D.	Mean difference	Z value	W value	Sig
Experimental	Pre test	18.4	1.9550	4.8	-2.5471	1	0.0532*
	Post test	23.2	2.936				

Table 3: Within Group Analysis --Control Group.

Group	Measurements	Mean	S.D.	Mean difference	Z value	W value	Sig
Control	Pre test	18.3	2.3593	2.7	-2.8031	0	0.00512*
	Post test	21	2.3570				

Table 4: Between Group Analysis --Control Pre &Experimental Pre.

Groups	Mean	Mean difference	Z value	U value	Significance
Control Pre	18.5	2.2	-1.81423	25.5	0.00541*
Experimental Pre	18.4				

Table 5: Between Group Analysis --Control Post & Experimental Post.

Groups	Mean	Mean difference	Z value	U value	Significance
Control Post	21	2.2	-1.81423	25.5	0.00541*
Experimental Post	23.2				

When ES regimens are combined with mechanical strategies such as robotic training or neuroprosthetics, or other types of orthoses, better results are obtained in reducing wrist flexor spasticity and improving hand movement.

Moreover, Saebo's energy-storing technology allows individuals suffering from spasticity to stretch comfortably and safely, resulting in increased motivation and compliance. It investigated the usability and effectiveness of a functional hand orthosis, combined with electrical stimulation adjunct to therapy-as-usual, on functional use of the moderately/severely impaired hand in sub-acute stroke patients. Arm-hand training featuring the dynamic hand orthosis in combination with electrical stimulation shows a shift from no dexterity to dexterity and that patients perceive a high-intrinsic motivation and sense of self-regulation.

This preliminary pilot work is limited and designing a larger controlled trial will allow in-depth statistical analysis and further exploration of other pertinent factors, so that professionals can better interpret these preliminary findings.

CONCLUSION

The results from this pilot study show that a 6-week program of a combined NMES-MI technology-Saebo Glove along with conventional physiotherapy management is feasible and likely to improve the AHSP by reducing wrist flexor spasticity and improving hand movement in post-stroke subjects with hand function impairment better than the conventional physiotherapy management. A larger and more comprehensive study is going on to further assess and expand on these preliminary findings.

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