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A Systematic Review On The Effects Of Electrical Stimulation on Spasticity In Hemiplegic Patients

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ABSTRACT

Background: Spasticity in patients who survived after stroke is due to various mechanisms, in which the pathophysiology is widely varying. The results may be promising if there is a possibility of setting a framework for selecting appropriate treatment options based on impaired mechanisms. So, there is a need to review the literature available on electrical stimulation techniques for managing spasticity after stroke.

Methods: 16 articles were included in this systematic review through electronic databases, including Pubmed, Google Scholar, Cochrane, library, Elsevier, Research Gate, and Science Direct, published between 2005 to 2022, which studied the effects of electrical stimulation on spasticity in hemiplegic patients as one of the interventions. Review articles, case studies, and studies with poor methodology were excluded from the review.

Results: Reductions in Spasticity and improvements in range of motion were noted with the application of NMES combined with other interventions. On sensitivity analysis related to the site of application of NMES, wrists showed no effects on both Spasticity and ROM, and elbows showed no effects on spasticity. When a range of motion is considered one of the outcome measures, the results supported the effects of NMES, and for other outcomes, the results did not confirm the effects of NMES.

Conclusion: 16 randomized controlled trial articles were reviewed, and positive effects of electrical stimulation on spasticity management were reported. Most of them reported recovery in plantar flexor spasticity. There is a scope for research on upper limb muscle spasticity and neurophysiological aspects of recovery that help in functional recovery.

Keywords: Spasticity, Electrical stimulation, Stroke, Motor dysfunction, Functional recovery.

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INTRODUCTION

Most stroke survivors often develop motor dysfunction and limb spasticity [1,2] that may limit their movement and functional ability and affect their quality of life [3,4]. Spasticity is involuntary velocity dependent, resulting in increased resistance to passive lengthening of muscles and tendons caused by a hyperexcitability of stretch reflex (Mukherjee and Chakravarty) [5]. Spasticity is caused by damage to the brain and spinal cord area, which is responsible for controlling muscle and stretch reflexes. The imbalance between the inhibitory and excitatory signals may be the reason for the disturbances in tone control in the muscles. People with brain injury and spinal cord injury can have varying degrees of spasticity [6].

The central nervous system (CNS) lesions may result in upper motor neuron syndromes, primarily spasticity. Spasticity may present in various types of multiple sclerosis, where it occurs as a symptom of the slowly deteriorating attacks on myelin sheaths. It is thus unrelated to the types of spasticity present in neuromuscular cerebral palsy-rooted spasticity disorders.

The effect due to spasticity includes the restriction of mental tasks on which an individual decides to perform a course of action, like static postures of limbs, painful muscle spasms, hyperactive reflexes, unusual posture, and development of contracture in severe cases [7]. Spasticity limits the voluntary motor capabilities of the patient if they leave untreated complications such as joint dysfunction [8].

25.3% of the stroke subjects show spasticity and a little high in that after the first-ever stroke. The incidence of spasticity mixed with paresis was noted at 39.5% in first-time stroke subjects. Severe spasticity was 10.3%, and disabling spasticity was around 9.4%. The risk factors for post-stroke spasticity are moderate to severe paresis, hemorrhagic stroke, and sensory disorder [9].

The inhibition of spasticity can be skilled through stimulations of either the agonist spastic muscle or its antagonist muscle [10, 11]. Several studies have reported the advantages of physical agents in treating muscle spasticity. The effects of different physical modalities have been examined, such as shock wave therapy, ultrasound therapy, cryotherapy, thermotherapy, vibration, and electrical stimulation.

Neuromuscular electric stimulation (NMES) has been used to reduce spasticity and improve range of motion in patients with stroke. Transcutaneous electrical nerve stimulation (TENS) can produce vibrations over the stimulated muscles and the surrounding regions at two to three times the sensory threshold. Moreover, this rapid stimulation of vibrations can trigger the primary afferent neurons that increase the release of acetylcholine, an important neurotransmitter that causes the contraction of muscles [12-14]. Reduction in the excitability of homonymous motor neurons to depleting acetylcholine during muscle fatigue may be one of the reasons for the reduction in muscle contraction if prolonged or repeated stimulation was given to spastic muscles. Spasticity tends to increase temporarily initially but then diminish progressively later. Transcutaneous electrical nerve stimulation reduces spasticity. NMES therapy is not simply ES; it involves FES therapeutic ES, Electromyogram EMG triggered NMES, and soon [15,16].

The therapeutic effect of faradic current on Spasticity: Spasticity reduction electrical stimulation is widely used by the therapist for the reduction of spasticity and to regain voluntary control. The effect of spasticity includes restriction of cognitive activities on which an individual decides to perform a course of action like static posturing of limbs, painful muscle spasms, hyperactive reflexes, abnormal posture, and contracture development in severe cases.

The Pathophysiological basis of spasticity is mainly due to abnormalities at different levels, including stretch reflex arc, spinal segment influence, supra-spinal mechanism, and mechanical factors [17,18]. The purpose of the study is to summarise the available electrotherapy treatment options for treating spasticity and to generate possible evidence for electrical stimulation.

NEED OF THE STUDY

Spasticity in patients who survived after stroke is due to various mechanisms, in which the pathophysiology is widely varying. The results may be promising if there is a possibility of setting a framework for selecting appropriate treatment options based on impaired mechanisms. So, there is a need to review the literature available on electrical stimulation techniques for managing spasticity after stroke.

METHODOLOGY

A systematic literature review was performed through electronic databases, including Pubmed, Google Scholar, Cochrane, library, Elsevier, Research Gate, and Science Direct, about the research articles on electrical stimulation for spasticity in hemiplegic patients as one of the interventions.

This study included randomized controlled trials about the effects of electrotherapy on spasticity in stroke survivors; the studies used Modified Ashworth's Scale and/or EMG as one of the outcomes to evaluate the effects of electrical stimulation on spasticity and the studies conducted between 2005 to 2022. Review articles, case studies, and studies with poor methodology were excluded from the review. A total of 1689 articles were identified in different data bases. Among all the articles based on the inclusion criteria 1250 articles were excluded. After careful examination for randomised controlled trials on human samples, availability full text, articles with intended outcome measures, 16 articles were finally reviewed from the remaining 439 journal articles.

Table 1: Comparative review of randamised control trails

DATA PRESENTATION:						
AUTHOR (YEAR)	POPULATION	TYPE OF STUDY	INTERVENTION	OUTCOME MEASURES	CONCLUSION / RESULTS	MUSCLE INVOLVED
Aysel GÜRCAN1, Barın SELÇUK2, Burcu ÖNDER3, Müfit AKYÜZ4 , Ayla AKBAL YAVUZ (2015)	32	RCT	Study group patients underwent electrical stimulation of the spastic agonist muscles for 20 min per day for 15 days in addition to the conventional program. On the other hand, control group patients underwent the conventional rehabilitation program only. The hemiplegic patients were clinically and electrophysiologically evaluated twice before and after the treatment within 24–48 h.	Functional Independence Measure (FIM) Modified Ashworth Scale (MAS) Goniometry	Electrical stimulation can be a good functional option for treating patients having plantar flexor spasticity because it can be applied at home, it has no side effect, it is cheap, it is easy to apply, and it has a good functional performance in addition to the conventional treatment for spasticity.	Agonist
Amir H Bakhtiary and ElhamFatemy Physiotherapy Department, Rehabilitation Faculty, Semnan University of Medical Sciences, Semnan, Iran (2007)	40	RCT	Fifteen minutes of inhibitory Bobath techniques were applied to one experimental group and a combination of 9 minutes of electrical stimulation on the dorsiflexor muscles and inhibitory Bobath techniques was applied to another group for 20 sessions daily	Modified Ashworth Scale (MAS) Electromyogram Goniometry	Therapy combining Bobath inhibitory technique and electrical stimulation may help to reduce spasticity effectively in stroke patients.	Antagonist
DilekKarakuş, Murat Ersöz, GönülKoyuncu, DilekTürk, Fatma Münevver Şaşmaz, Müfit Akyüz (2012)	28	RCT	Patients were randomly assigned to a functional electrical stimulation group or a control group. A standard rehabilitation program was applied to control group (n=14), and a standard rehabilitation program plus functional electrical stimulation of wrist and finger extensors were applied to the other group	Motricity index scores Modified Ashworth Scale (MAS)	Adding functional electrical stimulation to standard rehabilitation program has a positive improving effect on the upper limb motor function in patients with post-stroke hemiplegia. Turk J Phys Med Rehab 2013;59:97-102.	Antagonist
Ju-Shao Cheng, MS, Yea-Ru Yang, PhD, Shih-Jung Cheng, MD, Pei-Yi Lin, MS, Ray-Yau Wang, PhD, PT (2010)	15	RCT	Subjects were randomly assigned to an experimental or a control group. The experimental group received ES of ankle dorsiflexors in concert with a motor training paradigm that required the subject to dorsiflex the ankles in response to a cue while standing on a rocker board. After 30 minutes of this exercise, subjects received ambulation training focusing on ankle control for 15 minutes. The control group received general range of motion and strength exercises for 30 minutes, followed by 15 minutes of ambulation training focusing on ankle control. Sessions occurred 3 times a week for 4 weeks.	(EFAP)	Results suggest that repeated ES with volitional ankle movements can decrease dynamic ankle spasticity in subjects with stroke. Furthermore, such improvement parallels better gait symmetry and functional gait performance.	Antagonist
Sattam M. Almutairi 1 * † , Mohamed E. Khalil 1†, NadiahAlmutairi 2 and Aqeel M. Alenazi 3† (2021)	44	RCT	The intervention will be three times a week for 4 weeks for both groups.	MAS MMT 10-MWT 10-meter walk test Six-Minute Walk Test Timed Up and Go BI Medical Outcomes Survey (SF-36) FSS FES-I	Using 4 weeks of NMES will provide information about its effect in improving plantarflexorspasticity, dorsiflexor muscles strength, gait speed, mobility functions, and other self-reported health outcomes in people with chronic stroke when compared to NMES	Agonist and Antagonist
Sukanta K. Sabuta,*, ChhandaSikdarb, Ratnesh Kumarband Manjunatha Mahadevappaa (2011)	51	RCT	The functional electrical stimulation (FES) group (n = 27) received 20–30 minutes of electrical stimulation to the peroneal nerve and anterior tibial muscle of the paretic limb along with conventional rehabilitation program (CRP). The control group (n = 24) treated with CRP only. The subjects were treated 1 hr per day, 5 days a week, for 12 weeks.	(MAS), (MMT), (FMA) scale.	Therapy combining FES and conventional rehabilitation program was superior to a conventional rehabilitation program alone, in terms of reducing spasticity, improving dorsiflexor strength and lower extremity motor recovery in stroke patients.	Antagonist

Yea-Ru Yang1 , Pei-Ling Mi1 , Shih-Fong Huang2 , Shiu-Ling Chiu1 , Yan-Ci Liu1 , Ray- Yau WangID1 (2018)	25	RCT	The experimental group received 20 minutes of NMES on either the tibialis anterior muscle (NMES-TA) or the medial gastrocnemius muscle (NMES-MG). The control group received 20 minutes of range of motion and stretching exercises. After the 20 minutes of NMES or exercises, all participants received ambulation training for 15 minutes. Training sessions occurred 3 times per week for 7 weeks.	GAITRite system (CIR system, Inc., Havertown, Pennsylvania) (MAS) spasticity index, EMG Goniometers	NMES on ankle dorsiflexors could be an effective management to enhance gait performance and ankle control during walking in chronic stroke patients. NMES on ankle plantarflexors may improve gait symmetry. PLOS ONE	Agonist and Antagonist
Denise Pripas, Allan Rogers Venditi Beas, Caroline Fioramonte, Pedro Claudio Gonsales de Castro, Daniel Gustavo Goroso, Maria Cecília dos Santos Moreira (2011)	6	RCT	WE used kinematic variables to enable the division of the Electromyography signal in two phases: disturbance and post-disturbance. The post disturbance, when the subject is recovering from the perturbation, is the phase of interest in this study	EMG	Spastic hemiplegic stroke patients present altered proximal-distal synergy in the spastic limb during maintenance of the balance after a motor self-disturbance. FES is a useful tool in reducing the Spasticity of GM by RI, but there is the possibility that the antidromic effect, caused by an electrical intervention, can inhibit certain muscle synergies such as the one that is used in the ankle strategy of balance, so it can be more difficult to maintain balance after a disturbance.	Antagonist
Marco Antonio Cavalcanti Garcia,1,2,3 João Marcos Yamasaki Catunda,1 MarcioNogueira de Souza,1 Ana Paula Fontana,4 SandroSperandei,5 and Claudia D. Vargas2 (2015)	14	RCT	A group of stroke patients (Experiment III) was also preliminary evaluated to ascertain SES effects at a low frequency (3Hz) applied for 30over the forearm spastic flexors muscles by measuring the wrist joint passive torque. Motor evoked potentials and the H-reflex were collected fromdifferentforearmand hand muscles immediately before and after SES and up to 5(Experiment I) and 10(Experiments I and II)	EMG	Based on the work of Ward, we proposed that an increase in the frequency of SES stimulation would allow theionic current to flow more deeply and so a larger pool of somatosensory receptors from different tissues adjacent to the SES would be recruited. However, even though we must recognize small participant size samples in Experiments II and III, the results provided by our experiments suggest that none of the investigated frequencies (3, 30, 150, and 300 Hz) of SES along with all the other chosen parameters seem to be able to operate as a key in switching modulatory effects in the CNS of healthy volunteers and stroke patients with spasticity.	Antagonist
Ziling Lin, MD and Tiebin Yan, MD, PhD 2010	46	RCT	All patients received a standard rehabilitation programme. Patients in the neuromuscular electrical stimulation group received neuromuscular electrical stimulation for 30 min, 5 days a week for 3 weeks. Measurements were recorded before treatment, at the 2nd and 3rd week of treatment and 1, 3 and 6 months after treatment ended.	(MAS) Modified Barthel Index (MBI)	Three weeks of neuromuscular electrical stimulation to the affected upper extremity of patients with stroke improves motor recovery. The effect persists for at least 6 months.	Antagonist
*1Suchetha P. S. [2]Dhanesh Kumar K. U. [3]Mallikarjunaiah H. S. (2017)	30	RCT	They were randomly assigned into two groups. Group A received anatagonist (triceps) muscle Neuromuscular electrical stimulation and Group B received agonist (biceps brachii) muscle Neuromuscular electrical stimulation for 2 weeks, one session per day for a duration of 30 minutes.	MAS and deep tendon Reflex Grading Scale	The study concluded that both the techniques resulted in reduction of spasticity and on comparison it was found that antagonist muscle (triceps) Neuromuscular electrical stimulation reduced spasticity more effectively than the agonist muscleNeuromuscular electrical stimulation	Agonist and Antagonist

Yasin DEMİR, a Rıdvan ALACA, b Kamil YAZICIOĞLU, c Evren YAŞAR, d Arif Kenan TAN (2018)	29	RCT	Stroke patients met criteria and accepted to be in study were randomly allocated to routine physiotherapy (control group) or routine physiotherapy + FES (FES group). Primary [Fugl-Meyer and (MAS)] and secondary measures [range of motion, Motor Activity Log-28 (MAL-28), Jebsen-Taylor test, handgrip strength, Short Form-36] were assessed before treatment (t0), at the second week of therapy (t1) and after treatment (t2)	MAS GONIOMETRY	Upper extremity FES can be preferred as an additional method in upper limb rehabilitation to improve spasticity, motor functions, handgrip strength and level of independence in performing activities of daily living in stroke patients.	Antagonist
Junqiu Du,[1]Shouyong Wang,[2]Yun Cheng,[3]Jiang Xu,[1]Xuejing Li,[1]Yimin Gan,[1]Liying Zhang,[4]Song Zhang,[4]and Xiaorui Cui 2017	240	RCT	According to the treatment plan, the patients were randomly divided into four groups (60 cases in each group): (1) control group, only routine treatment; (2) NMES group, NMES on the basis of routine treatment; (3) rTMS group, rTMS on the basis of routine treatment; and (4) NMES+rTMS group, NMES combined with rTMS at the same time on the basis of routine treatment. This was an assessor-blinded randomized controlled study. This study protocol has been reviewed by the medical ethics committee of our hospital, and all subjects have voluntarily signed the informed consent form.	MBI FMA MAS	NMES combined with rTMS can conspicuously improve the upper extremity motor function and activities of daily life of stroke patients with hemiplegia, which is worthy of clinical application and promotion.	Antagonist
Manigandan G and Bharathi K[*] 2017	10	RCT	Ten subjects were randomly allocated into two groups (Group A and Group B). For 5 subjects in Group A, conventional therapy was given (Passive stretching and Passive range of motion). For other 5 subjects in Group B, Transcutaneous electrical nerve stimulation was applied over belly of Gastrocnemius muscle for 60 minutes at 100 Hz frequency, 200 microseconds of pulse width with 2 or 3 times sensory threshold along with conventional therapy was given	MAS	On the basis of this study, it shows that application of TENS over Gastrocnemius can reduce the muscle spasticity in stroke patients.	Agonist
S-C Chen [1], Y-L Chen, C-J Chen, C-H Lai, W-H Chiang, W-L Chen 2005	24	RCT	Twenty-four neurologically stable stroke patients (aged 41-69 years, 12-35 months post-stroke), with spasticity graded 2 or 3 on the modified Ashworth scale, were recruited and divided into two groups. In the ES group, each patient received 20 min of surface ES once daily, 6 days per week for 1 month. In the control groups, ES was used with stimulation intensity kept at zero.	MAS, 10-m walking test	In this study, we demonstrated a way to suppress spasticity at a metameric site and to increase walking speed effectively by applying surface ES on the muscle-tendon junction of spastic gastrocnemius muscles.	Agonist
Sneha Khanna1 ,Jaskirat Kaur2* (2017)	30	RCT	A total of 30 subjects with spinal cord injury were considered for the study. They were divided into two groups randomly. Group 1 received agonist electrical stimulation (stimulation of triceps surae) and group 2 received antagonist electrical stimulation (stimulation of tibialis anterior) for 20 min, once daily, and 5 days per week for two weeks.	MAS DEEP TENDON REFLEX	This study concludes that both agonist and antagonist electrical stimulations for two weeks were effective in reducing spasticity in triceps surae muscle in SCI patients. There was no significant difference in spasticity reduction produced by agonist and antagonist electrical stimulations.	Agonist and Antagonist

DISCUSSION

The use of NMES in patients with neurological conditions has risen in recent ages. Its effects on reducing spasticity may be explained by its actions on increasing Ib fiber activation via mechanisms that facilitate the Renshaw cell recurrent inhibition, on reciprocal inhibition of antagonist, and on increasing cutaneous sensory stimuli.

Reductions in spasticity and improvements in range of motion were noted with the application of NMES combined with other interventions [10]. This study supports the application of NMES to reduce spasticity in stroke patients, which would benefit from cortical effects and motor control programs, improving functional activity [19]. The usage of NMES may not inhibit the use of the alternate hand but can facilitate the patient to use the affected hand for daily activities, improving ROM.

On sensitivity analysis related to the site of application of NMES, wrists showed no effects on both Spasticity and ROM, and elbows showed no effects on spasticity. It may be because of differences between trials. For example, participant groups varied between studies in time after stroke, time of treatment, degree of spasticity, and degree of functional deficit. A few factors like time after stroke, duration of treatment, severity of spasticity, and degree of ability to voluntarily contract may affect the responses of a muscle to electric stimulation. Another source of variation was the different conventional therapies used as comparator treatments in included trials: Bobath, Active leg cycling, SMART Arm, Conventional Occupational Therapy, Botulinum Toxin A, and Stretching with PNF technique. Furthermore, the different outcome measures, which were not always possible to combine, resulted in difficulty in confirming the effects of NMES.

Moreover, chronic tissue changes because of immobilization, atrophy, loss of sarcomeres, muscle conversion to connective tissue, and decreased resting length of the muscle may compromise the success of NMES. Also, the loss of motor units in the paretic arm, which might be caused by secondary trans-synaptic degeneration, could compromise effective NMES performance [20].

When we observe that the studies that favor the usage of NMES or NMES combined with other treatment techniques have a greater weight in determining the final result to range of motion, studies showed favorable results for the intervention. In contrast, the remaining studies did not favor any group.

CONCLUSION

Sixteen articles on randomized controlled trials were reviewed, and positive effects of electrical stimulation on spasticity management were reported. Most of them reported recovery in plantar flexor spasticity. There is a scope for research on upper limb muscle spasticity and neurophysiological aspects of recovery that help in functional recovery.

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