DOI: https://doi.org/10.54393/pbmj.v6i05.872

PAKISTAN BIOMEDICAL JOURNAL

https://www.pakistanbmj.com/journal/index.php/pbmj/index

Volume 6, Issue 5 (May 2023)

Original Article

The Effectiveness of High Intensity Electromagnetic Stimulation in Spastic Stroke Patients

Muslim Khan[1*], Aftab Ali[1], Zakir Khan[1], Abid Jan[2], Shah Fahad[1], Samiullah Khan[1], Mansoor Ahmad[1] and Rakan Abdullah Alwabel[3,4]

[1]Iqra National University, Swat, Pakistan
[2]Khyber Medical University, Peshawar, Pakistan
[3]Ministry of Health, Saudi Arabia
[4]Diriyah Hospital, Riyadh, Saudi Arabia

ARTICLE INFO

Key Words:

Stroke, Spasticity, High Intensity Electromagnetic Stimulation(EMS)

How to Cite:

Khan, M., Ali, A. ., Khan, Z. ., Jan, A. ., Fahad, S. ., Khan, S. ., Ahmad, M. ., & Alwabel, R. A. . (2023). The Effectiveness of High Intensity Electromagnetic Stimulation in Spastic Stroke Patients : The Effectiveness of High Intensity Electromagnetic Stimulation. Pakistan BioMedical Journal, 6(05). https://doi.org/10.54393/pbmj.v6i05.872

***Corresponding Author:**

Muslim Khan
Iqra National University, Peshawar, Pakistan
drmuslim17@gmail.com

Received Date: 28th April, 2023
Acceptance Date: 19th May, 2023
Published Date: 31st May, 2023

ABSTRACT

In stroke patients, spasticity level allows to predict the patient's rehabilitation outcome. **Objective:** To evaluate the anti-spastic effectiveness of high intensity electromagnetic stimulation (HIES) in stroke patients. **Methods:** Twenty (n=20) spastic stroke patients were assigned randomly into two groups; the study participants were briefed about the aim & methodology of the study & written consent were taken. Ten therapy sessions were given to the stroke's patient spastic muscles in the treatment group (TG) with HIES, while in the controlled group (CG) 10 electrotherapy session along with kinesiotherapy was delivered. The outcome measures of the study were MAS (Modified Ashworth scale) & Barthel index (BI) was used as, for spasticity and for the patient's quality life evaluation, respectively. After the one-month therapeutic plan results were obtained & compared based on the pre-treatment score & post-treatment score on the afore-mentioned specified outcome measures. **Results:** The analysis of data shows that treatment group score improved significantly, up to 68% & similarly, spasticity decreased from 2.86±0.075 in the beginning to 0.58±0.86 points on MAS, while on the other hand, control group score up to 31% enhanced & on the MAS scale, spasticity diminished from 2.45±0.57 in the start to 1.49±0.87 points. As per Barthel index, improvement for CG & TG was 72% & 80% respectively. **Conclusions:** This study results shows that high intensity electromagnetic stimulation (EMS) is highly effective in the reduction of stroke-specific spasticity.

INTRODUCTION

Upper motor neuron lesions or lesions in the pyramidal tracts leads to post-stroke spasticity & it's assessed, by the resistance (velocity -dependent) in the opposite direction to the passive movements [1, 2]. Spasticity as defined by, Lance (1980) "spasticity is a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (increased tone) with exaggerated tendon jerks (Hyper-reflexia), resulting from hyper excitability of the stretch reflex as one component of the upper motor lesions or the pyramidal tracts lesions" [2]. Still, the patho-physiology needs to be investigated but at the moment, it is linked with the excitatory inhibitory imbalance in the motor neuron pool [3-6]. Stroke incidence (including both type of stroke; ischemic & hemorrhagic stroke) 183/100,0000 in the USA [3]. The prevalence is 2% among the age group 25-74 years with a maximum rate in the geriatric community [3]. According to CDC 2% of the USA-populations has a life-long need to accomplish their ADLs [4]. The spasticity rate varies among the upper motor neuron lesions patients. Some studies have reported that 35% stroke patients are spasticity- affected [5, 6] while more than <90% with CP [7] & approximately 50% TBI patients [7, 8]. These figures

DOI: https://doi.org/10.54393/pbmj.v6i05.872

show the importance of spasticity to be addressed & by comprehending these patterns especially stroke & CP helps in the predictions of these patients' functional recovery, along with joint-associated deformities that may occur, helps in planning long-term rehabilitation programs for these patients [8]. The spastic-clinical features (Intrinsic factors) include: a) decreased functional abilities b) increased muscle tone c) delayed motor development d) pain e) deformities associated with bones & joints [9-11]. Spastic-specific extrinsic factors such as: a) bed sours b) constipation c) infections of urinary tract, might exacerbate spasticity among spastic patients [10, 11]. Spasticity can result in functional limitation which leads to or resulting in a) reduced joint mobility b) sleep disorders due to airway obstruction c) diminished muscle flexibility [12]. Progressive cells death occurs in stroke due to reduced blood flow [12-14]. Stroke is of 2 types; a) Ischemic stroke (IS), caused by reduced or lack of blood flow b) Hemorrhagic stroke (HS), caused by blood vessels ruptures [11]. WHO defined (1970) stroke as a "neurological deficit of cerebrovascular cause that persists beyond 12 hours or is interrupted by death within 24 hours" [12]. Stroke incidence in the United Kingdom is 152 000, 1:4 ratios, it means, that, every 4th person is affecting [13]. Stroke incidence in the UK as shown in Table 1 where, as per statistics, comparatively men are 25% higher risk & higher incidence rate in the younger age as compared to corresponding women [14-16], but studies has shown that UK –women live longer as compared to men, which makes the overall stroke incidence higher in women as compared to men [17, 18].

Table 1: Stroke-Statistics in UK [13-15]

Province-wise stroke incidence in UK	Strokes-incidence/ year [men]	Strokes-incidence/ year [women]	Strokes-incidence / year [Total]
Scotland – 2009	57, 488	68,457	125,945
England –2007	6, 532	7,835	14,365
Wales (2014-15)	3,600	3,825	7,425
Ireland – (2013-2014)	2,200	2,200	4,420
U-K	69,820	82,317	152,155

Globally, Cardiovascular accident (stroke) is the leading cause of disability in adults. Worldwide, it is the 2nd major cause of mortality. In Pakistan, according to the available statistic the incidence of stroke is approximately 250 out of 100,000, & new cases raises to 350,000/year. Most of the stroke patient (80%) primarily lost the ability to walk & ambulate independently (functional independence loss in more than 80% stroke patients), which makes Stroke patients potential fallers due to loss of mobility, loss of balance due to spasticity & impaired proprioceptive input [17-20]. Spasticity is regarded all over the world one of the important health issues affecting the quality of life of stroke patients [16, 17]. Spasticity has been reported up to 42% in the 1st post-stroke years by various studies [17, 18].

Electromagnetic stimulations (EMS) targets neuromuscular tissues & induce electric currents, resulting in the depolarizing of targeted neurons which leads into concentric muscle contractions of these recruited muscles. It has been reported that high-intensity electromagnetic- field infiltrated deeply in muscles targeted which leads to the neural excitation of the entire regions & produces recognizable anti-spastic effects [6, 3]. EMS effectiveness in spasticity is, as reported, through post-facilitatory inhibition by influencing neurologically spinal level of muscle- tone control [7, 8]. Thus, by EMS-based stimulating weakened muscles & relaxation of spastic- muscles are involved, a muscle balance is achieved which results in the spasticity reduction in the involved region [3]. It has been observed that high-intensity EMS field results in higher blood perfusion of the exposed region, leading to anti-spastic impacts by increasing significantly, blood flow to the region applied [12, 13]. In CNS lesions such as TBI or stroke ES (Electrical stimulations) generate movement. Its helps to regain voluntary motor functions of the paralyzed limb by developing neuro-prostheses. It helps CNS to relearn the execution of impaired functions in the post-CNS lesions patients [4]. It has been used for various impairments in the spastic stroke patients. Muscle fatigue is reduced by the asynchronous contraction provided [9]. Better results have been observed by the various studies in acute stroke rehabilitation. Electrical muscle stimulation (EMS) is electro-magnetic based device that generate muscle contraction through adjustable electrical impulses [10]. EMS-electrodes, which are attached to the skin generates electrical impulses identical to action potential (cells-AP) generated by the CNS [5]. The induced muscular contraction caused by the EMS devices are "synchronous contraction" ensuring that all motor units are stimulated at the same time in order to achieve group muscle actions [2]. It is used to prevent muscle disuse atrophy & for strength training among wide range of patients [6-9]. Thirteen (13) studies, carried out for the effectiveness of EMS over spinal roots or comparative studies comparing healthy & paralyzed muscles in stroke patients or RCTs on spinal cord disorders, with the use of various outcome measures [9]. Considerable changes in biomechanical, clinical & neurophysiological, outcomes as per ADLs were reported after the intervention of EMS among the spastic stroke patients. Further, it was noted that improvement in movement dynamic & reduction in spasticity among the study participants were observed [15].

METHODS

This study focuses on to evaluate effectiveness of high intensity electromagnetic stimulation in stroke-specific spasticity reduction. Thus, for the proposed study, we

DOI: https://doi.org/10.54393/pbmj.v6i05.872

designed RCT study, in which 20 patients (n=11 Left-hemiplegic; n=9 right hemiplegic participated (mean age 65.90±8.31; 8 women, 12 men) participated in 2-randomly assigned groups into Control Group (CG) & Treatment Group (TG) of 10 stroke patients each. Stroke patients recruited for this study were having a) no metal implants or electronic b) having no cancer c) having no blood coagulation disorders. MAS & BI (Modified Ashworth Scale & Barthel Index) were used for comparative analysis of its results in various time frame. The outcome measures of the study were MAS (Modified Ashworth scale) & Barthel index (BI) was used as, for spasticity and for the patient's quality life evaluation, respectively. Participants of the study received 10 daily electrotherapeutic sessions with a high-intensity EMS device made by BTL Industries Ltd, available in with the trade name, BTL-6000 Super Inductive System. Contactless- mode over pathological region were adopted for EMS therapy. We electrically stimulated targeted muscles of the upper extremity firstly to achieve post-facilitatory inhibition as per guidelines; after that, weakened antagonist muscles were electrically stimulated as follow up. EMS intensity was set at the beginning and modified & adjusted as per patient's tolerance level through constant's patient feedback by clinicians. CG-patients also received 10 -daily electrotherapeutic sessions with electrical stimulation applied to the antagonist musculatures of the upper extremities. In Table 2 therapeutic parameters used during this study are given. Additionally, to the CG, kinesiotherapy & proprioceptive neuromuscular facilitation (PNF) was applied as per Bobath's & Kabat approach. MAS & BI questionnaires-based data were obtained pre-, post-EMS sessions, of the study participants after a follow up of one month. Average improvements based on Means ± SD and percentage-based levels of improvement were calculated by using SPSS & Student's t-test with p<0.05 was used for comparison among the study's groups.

Table 2: Study's treatment parameters

Parameter	Therapeutic parameters used in the study	
EMS-parameters	TG	CG
Therapies sessions	12	12
Duration (Minuets)	10	10.0
Frequency	30 – 160 Hz	40 – 100 Hz
Pulse Duration	275 ms	0.5 – 2.0ms

*ms- Microsecond

RESULTS

No side effects were observed with the application & intervention of EMS among study's participants. The analysis of data shows that treatment group score improved significantly, up to 68% & similarly, spasticity decreased from 2.86±0.075 in the beginning to 0.58±0.86 points on MAS, while on the other hand, control group score up to 31% enhanced & on the MAS scale, spasticity diminished from 2.45±0.57 in the start to 1.49±0.87 points. As per Barthel index, improvement for CG & TG was 72% & 80% respectively (Table 3).

Table 3: MAS Results

Para-meter	Treatment Group					Control Group				
	Pre Mean ± SD	Post Mean ± SD	p-value	1mFU Mean ± SD	p-value	Pre Mean ± SD	Post Mean ± SD	p-value	1mFU Mean ± SD	p-value
MAS	2.23± 0.92	1.00± 0.60	<0.05	0.87± 0.60	<0.05	2.23± 0.74	1.77± 0.62	<0.05	1.50± 0.76	<0.05

Spasticity reduction in %, showed considerable spastic reduction in TG & CG.TG shows 61% improvement on the selected scales in PTS (Post-treatment assessment) vs. CG 18% improvement, TG shows 68% improvement vs. 31% for the CG after one month follow up of study participants (Table 4).

Table 4: Improvement on MAS

Para-meter	Base reading (pre-treatment readings -T0			Post-treatment readings (T-1)			Post-treatment readings (T-1)		
MAS	TG	CG	p	TG	CG	p	TG	CG	p
	Means			Δ=T1-T0 %			Δ=T2-T0 %		
	2.40	2.30	NS	59%	17%	<0.04	68%	31%	<0.04

The effectiveness HIEMS has been observed by this study on spasticity reduction among the spastic stroke patients after 1-month follow-up shows that the reduction in spasticity is even increased by comparing with post-treatment results. BI which was used as secondary outcome measures, is a functional disability measure, used commonly. In TG, from 1.00±0.75 to 0.89±0.74 (p<0.05), MAS score dropped and in CG, from 1.69±0.89 to 1.56±0.70 (p<0.05), the MAS score decreased. With the interventions of EMS, the level of improvement changed significantly as study results demonstrates. The results showed that TG had 80**%** level of improvement as compared to 58% for the CG. Post-treatment results show that for TG an improvement from 58% to 66% as compared to 59% to 72% for the CG. This study observed that, result of TG continued to show improvement from 67% after treatment to 79-80%, On 1-month follow-up on the other hand, CG either showed an improvement from 59% to 72% (Table-5).

Table 5: BI – Level of improvement

Group	Parameter	Level of Improvement		
		Pre	Post	1-month follow-up
Treatment Group	Mean	58%	66%	80%
Control Group		59%	60%	75%

DISCUSSION

Neuromuscular electro-stimulation (NMS) is commonly used by clinicians, for its anti-spastic effects to reduce and improvement in joints ROM (Range of motion) in stroke patients worldwide. Yu *et al.*, conducted systemic review for evaluation of HIEMS anti-spastic effects, which comprised twenty-nine (29 RCTs) randomized controlled trials were included with 940 study participants [3]. NMS or

DOI: https://doi.org/10.54393/pbmj.v6i05.872

EMS were observed that it provided spasticity reduction and joint-ROM improvement by comparing with CG of spastic-stroke patients [16-18]. Another study has reported EMS –anti-spastic effects and reduction in MS-specific painful cramps in UE & LE (Upper extremity & lower extremity) of patients with multiple sclerosis. For TG, 6 EMS-therapeutic sessions were given to 18-MS patients with bilateral paravertebral stimulation, and sham stimulations on same number of sessions were given to the CG of MS patients. Self-reported spasm frequency, MAS –score and associated-pain intensity, general body pain or specific body pain and 25-feet walking test (qualitative & quantitative) were collected and analyzed as pre-treatment & post-treatment (2 and four weeks after) [10]. The study reported significant difference in muscle spasticity of MS patients & pain -associated spasm frequency, in TG & CG, with $P<0.05$. However, by comparing, pre-treatment & post-treatment score this study found no difference between both groups in body pain & 25-feet test. The conclusion of the study was that EMS is effective in spasticity reduction & improvement of MS-specific muscle spasm, however, study recommended, that further investigation is needed to evaluate its effects on QoL & ADLs [18-20]. Another study has reported ankle impairments improvement in spastic chronic stroke patients, which may have been caused by dynamic physiological influence of sensory inputs on synaptic plasticity. However, it has been observed that spasticity reduction in spastic stroke patients is pivotal to functional recovery and restoration of mobility & successful rehabilitation program [2, 3].

CONCLUSIONS

This study results shows that high intensity electromagnetic stimulation (EMS) is highly effective in the reduction of stroke-specific spasticity. However, this study recorded fact that reductions in spasticity intended goal or positive results) remained unaffected at 1-month follow-up among the study participants. This electric therapy is painless & non-invasive, having no side effects & thus applicable to large range of spastic patients. The EMS offers considerable effectiveness because of contactless-therapy delivery to the spastic patients along with adjustable therapy parameters the adaptability of the tissue is negligible.

Authors Contribution

Conceptualization: MK
Methodology: ZK, AJ, SF
Formal analysis: MK
Writing-review and editing: MK, AA, SK, MA, RAA

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Source of Funding

The authors received no financial support for the research, authorship and/or publication of this article.

REFERENCES

[1] Prouza O, Kouloulas E, Zarkovic D. High-Intensity Electromagnetic Stimulation Can Reduce Spasticity in Post-Stroke Patients. International Journal of Physiotherapy. 2018 Jun: 5(3): 87-91. doi: 10.15621/ijphy/2018/v5i3/173931.

[2] Ruschil C, Dubois E, Stefanou MI, Kowarik MC, Ziemann U, Schittenhelm M, *et al.* Treatment of progressive multiple sclerosis with high-dose all-trans retinoic acid–no clear evidence of positive disease modifying effects. Neurological Research and Practice. 2021 Dec; 3(1): 1-10. doi: 10.1186/s42466-021-00121-4.

[3] Yu WY, Ma LX, Tian Y, Mu JD, Zhang Z, Sun TY, *et al.* Acupuncture alleviates menstrual pain in rat model via suppressing Eotaxin/CCR3 axis to weak EOS-MC activation. Evidence-Based Complementary and Alternative Medicine. 2022 Jan; 2022: 4571981. doi: 10.1155/2022/4571981.

[4] Liu Y, Chen YT, Zhang C, Zhou P, Li S, Zhang Y. Motor Unit Number Estimation in Spastic Biceps Brachii Muscles of Chronic Stroke Survivors Before and After BoNT Injection. IEEE Transactions on Biomedical Engineering. 2022 Sep; 70(3): 1045-52. doi: 10.1109/TBME.2022.3208078.

[5] Mohammadi A, Fard MR, Ma L, Mu J, Sun T, Yu W, *et al.* Analgesic effects and hemodynamic mechanisms of perpendicular and transverse needling at Sanyinjiao (SP 6) in patients with primary dysmenorrhea: a randomized controlled trial. Journal of Traditional Chinese Medical Sciences. 2021 Jul; 8(3): 248-56. doi: 10.1016/j.jtcms.2021.07.002.

[6] Yu WY, Ma LX, Zhang Z, Mu JD, Sun TY, Tian Y, *et al.* Acupuncture for primary dysmenorrhea: a potential mechanism from an anti-inflammatory perspective. Evidence-Based Complementary and Alternative Medicine. 2021 Dec; 2021: 1907009. doi: 10.1155/2021/1907009.

[7] Härtig F, Birschmann I, Peter A, Hörber S, Ebner M, Sonnleitner M, *et al.* Point-of-care testing for emergency assessment of coagulation in patients treated with direct oral anticoagulants including edoxaban. Neurological Research and Practice. 2021 Dec; 3: 1-9. doi: 10.1186/s42466-021-00105-4.

[8] Yoldaş Aslan Ş, Kutlay S, Düsünceli Atman E, Elhan AH, Gök H, Küçükdeveci AA. Does extracorporeal

DOI: https://doi.org/10.54393/pbmj.v6i05.872

shock wave therapy decrease spasticity of ankle plantar flexor muscles in patients with stroke: A randomized controlled trial. Clinical Rehabilitation. 2021 Oct; 35(10): 1442-53. doi: 10.1177/02692155211011320.

[9] Hsu PC, Chang KV, Chiu YH, Wu WT, Özçakar L. Comparative effectiveness of botulinum toxin injections and extracorporeal shockwave therapy for post-stroke spasticity: a systematic review and network meta-analysis. EClinical Medicine. 2022 Jan; 43: 101222. doi: 10.1016/j.eclinm.2021.101222.

[10] Vinolo-Gil MJ, Rodríguez-Huguet M, García-Muñoz C, Gonzalez-Medina G, Martin-Vega FJ, Martín-Valero R. Effects of peripheral electromagnetic fields on spasticity: a systematic review. Journal of Clinical Medicine. 2022 Jun; 11(13): 3739. doi: 10.3390/jcm11133739.

[11] Li D, Cheng A, Zhang Z, Sun Y, Liu Y. Effects of low-frequency repetitive transcranial magnetic stimulation combined with cerebellar continuous theta burst stimulation on spasticity and limb dyskinesia in patients with stroke. BMC Neurology. 2021 Dec; 21(1): 1-8. doi: 10.1186/s12883-021-02406-2.

[12] Moon SW, Kim JH, Jung MJ, Son S, Lee JH, Shin H, et al. The effect of extracorporeal shock wave therapy on lower limb spasticity in subacute stroke patients. Annals of Rehabilitation Medicine. 2013 Aug; 37(4): 461-70. doi: 10.5535/arm.2013.37.4.461.

[13] In TS, Jung JH, Jung KS, Cho HY. Effectiveness of transcutaneous electrical nerve stimulation with taping for stroke rehabilitation. BioMed Research International. 2021 Aug; 2021: 9912094. doi: 10.1155/2021/9912094.

[14] Kwon DR and Kwon DG. Botulinum toxin a injection combined with radial extracorporeal shock wave therapy in children with spastic cerebral palsy: shear wave sonoelastographic findings in the medial gastrocnemius muscle, preliminary study. Children. 2021 Nov; 8(11): 1059. doi: 10.3390/children8111059.

[15] Kuzu Ö, Adiguzel E, Kesikburun S, Yaşar E, Yılmaz B. The effect of sham controlled continuous theta burst stimulation and low frequency repetitive transcranial magnetic stimulation on upper extremity spasticity and functional recovery in chronic ischemic stroke patients. Journal of Stroke and Cerebrovascular Diseases. 2021 Jul; 30(7): 105795. doi: 10.1016/j.jstrokecerebrovasdis.2021.105795.

[16] Wang X, Ge L, Hu H, Yan L, Li L. Effects of non-invasive brain stimulation on post-stroke spasticity: a systematic review and meta-analysis of randomized controlled trials. Brain Sciences. 2022 Jun; 12(7): 836. doi: 10.3390/brainsci12070836.

[17] Li D, Cheng A, Zhang Z, Sun Y, Liu Y. Effects of low-frequency repetitive transcranial magnetic stimulation combined with cerebellar continuous theta burst stimulation on spasticity and limb dyskinesia in patients with stroke. BMC Neurology. 2021 Dec; 21(1): 1-8. doi: 10.1186/S12883-021-02406-2.

[18] In TS, Jung JH, Jung KS, Cho HY. Effect of sit-to-stand training combined with taping on spasticity, strength, gait speed and quality of life in patients with stroke: A randomized controlled trial. Life. 2021 May; 11(6): 511. doi: 10.3390/life11060511.

[19] Hokazono A, Etoh S, Jonoshita Y, Kawahira K, Shimodozono M. Combination therapy with repetitive facilitative exercise program and botulinum toxin type A to improve motor function for the upper-limb spastic paresis in chronic stroke: A randomized controlled trial. Journal of Hand Therapy. 2022 Oct: 35(4): 507-15. doi: 10.1016/j.jht.2021.01.005.

[20] Lomovtsev I, Tsvetkova E, Gusakova E. Impact of Repetitive Peripheral Magnetic Stimulation on Post-Stroke Patients with Upper Limb Spasticity-A Randomized Controlled Trial. International Journal of Research in Physical Medicine & Rehabilitation. 2023 Feb; 1(1): 1-7.