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HIGH-INTENSITY ELECTROMAGNETIC STIMULATION CAN REDUCE SPASTICITY IN POST-STROKE PATIENTS

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ABSTRACT

Background: Level of spasticity in post-stroke patients allow for the predictability of the patient's level of recovery. The study aimed to assess the anti-spastic effect of high-intensity electromagnetic field stimulation in post-stroke condition.

Methods: 30 post-stroke patients, randomized into two groups participated. The treatment group (TG) was delivered ten therapies to spastic muscles with high-intensity electromagnetic stimulation. The control group (CG) was delivered ten electrotherapy sessions in the spastic muscle area combined with kinesiotherapy. Modified Ashworth Scale (MAS) was used as a primary outcome measure to evaluate the level of spasticity. Secondary outcome measure, Barthel Index of Activities of Daily Living (ADL) was used to evaluate the patient's quality of life. Results were obtained pre-treatment, post-treatment and after 1-month follow-up was completed.

Results: During the 1-month follow-up, TG improved results up to 66% decreasing spasticity from 2.33±0.90 in the beginning to 0.87±0.64 points on the MAS. The CG, during the 1-month follow-up, improved up to 31% decreasing spasticity from 2.13±0.74 in the beginning to 1.47±0.74 points on the MAS. According to Barthel Index, 81% level of improvement was observed in TG during 1-month follow-up vs. 72% level of improvement observed for the CG in a 1-month follow-up.

Conclusion: The evaluation showed greater spasticity reduction in TG - 66% vs. 31% in the CG after the 1-month follow-up visit. Results suggest that high-intensity electromagnetic stimulation is an effective extracorporeal physical modality for spasticity management in post-stroke patients.

Keywords: spasticity, stroke, high-intensity electromagnetic field stimulation, Super Inductive System

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INTRODUCTION

Spasticity arises from upper motor neuron lesions due to a lesion in pyramidal tracts, and it is diagnosed with the resistance felt by the passive movement in opposite direction which is velocity dependent [1]. Defined by Lance, in 1980 as "a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex as one component of the upper motor syndrome [2]." Still, the pathophysiology of the condition is not entirely understood but can be attributed to an imbalance in inhibitory and excitatory inputs to the motor neuron pool.

Approximately, the annual occurrence of ischemic and hemorrhagic stroke is nearly 183 per hundred thousand in the US. The prevalence of stroke among people between 25-74 years is 2%, with a higher rate in an older community [3]. CDC estimates that 2% of the US community has a long-term or lifelong need for help to accomplish activities of daily living as a result of a TBI [4]. Spasticity appears at a variable rate within these communities. Some studies [5, 6] have shown that this condition affects nearly 35% of patients with stroke, more than 90% with CP [7] and nearly 50% of patients with TBI. Comprehending these patterns helps to predict patients expected functional status, as well as deformities of joints that may occur, help in planning treatment [7, 8].

Common spasticity symptoms include: increased muscle tone, pain, decreased functional abilities and delayed motor development, bone, and joint deformities, etc. [9]. Extrinsic factors like constipation, infections of urinary-tract, or bed sours might aggravate spasticity [10, 11]. Spasticity can have functionally limited, and severe consequences are resulting in lessen joint mobility, diminished muscle flexibility or sleep disorders due to airway obstruction [12].

The poor blood flow to the brain resulting in cell death is well-known as the medical condition of stroke [10]. Two main types are familiar in the medicine: ischemic stroke secondary to lack of blood flow and hemorrhagic stroke secondary to bleeding [11]. In 1970 the WHO defined stoke as a "neurological deficit of cerebrovascular cause that persists beyond 12 hours or is interrupted by death within 24 hours" [12]. Some statistics show that in the UK the incidence of stroke is 152 000, that means in every 4 minutes one is affecting [13]. In *Table 1* below is shown stroke incidence in the UK where, according to the statistics, men are at 25% high on risk, and onset is also more in younger age compared to women [14, 15]. However, the fact that women are living longer makes the overall incidence of stroke more than in men.

Country	Strokes per year in men	Strokes per year in women	Strokes per year overall
England – 2007	57, 488	68,457	125,945
Scotland – 2009	6, 532	7,830	14,362
Wales – 2014-15	3,602	3,820	7,422
Northern Ireland – 2013/2014	2,209	2,207	4,416
United Kingdom	69,831	82,314	152,145

Table 1: Statistics excerpt of Incidence of stroke in the United Kingdom (13 – 15).

(Post-) Stroke consequences, including spasticity, are regarded as one of the important health problems all over the world [16,17]. A broad range of prevalence of spasticity up to 42% in the first post-stroke year was reported in various published reports at district examination time points [18-25].

High-intensity electromagnetic field stimulation

Mechanism of action

High-intensity electromagnetic field targets neuromuscular tissue and induces electric currents, which depolarize neurons resulting in concentric muscle contractions. The high-intensity electromagnetic field in-depth penetration and the stimulation of the entire area are resulting in anti-spastic effect [26].

Anti-spastic effect

The anti-spastic effect is achieved through post-facilitatory inhibition through affecting the spinal level of muscle tone control [27, 28]. Relaxing the spastic muscles and stimulating weakened muscles, a muscle balance and decrease of spasticity in the affected area are achieved. As well, high-intensity electromagnetic field causes higher blood perfusion of the exposed region, leading to circulation and trophic improvement.

Krewer C (2014) investigates 13 studies, tested the influence of magnetic stimulation over spinal roots or muscles in both healthy subjects and individuals with stroke or spinal disorders using different types of outcomes [29]. Considerable changes in neurophysiological, biomechanical and clinical outcomes were reported after magnetic stimulation. Further, there is a change noted in spasticity, and movement dynamics were also improved.

METHODOLOGY

The goal of this study was to evaluate the anti-spastic effect of high-intensity electromagnetic field stimulation in post-stroke condition. This was a randomized control study, in which 30 patients after stroke (n=19 "Hemiparesa dextra"; n=11 "Hemiparesa sinistra") participated (mean age 66.93±9.31; 25 women, five men). Patients were assigned to two equal groups – *Treatment Group* (TG) and *Control Group* (CG) – of 15 people. Patients with electronic and metal implants, cancer, and blood coagulation disorders were excluded from the study. The Modified Ashworth Scale (MAS) and Barthel Index of Activities of Daily Living (ADL) were used to comparing the results in different time periods.

Picture1: Application of Treatment

Picture 2: Kinesiology Assessment

Therapy protocol for the *treatment group*

Patients received ten daily therapies with a high-intensity electromagnetic stimulation device (BTL-6000 Super Inductive System, BTL Industries Ltd.). The therapy was delivered after placing the applicator above the pathological area (contactless delivery), with the parameters that can be seen in Graph 2. Firstly, agonist muscle in the upper extremities was stimulated to achieve post-facilitatory inhibition; subsequently, the weakened antagonist muscles were stimulated. The intensity of the therapy was set at the beginning and was increased/ decreased by patient's tolerance.

Therapy protocol for the *control group*

Patients from the CG also received ten daily therapies with electrostimulation applied directly to the antagonist muscles of the upper extremities.

The therapy parameters can be seen in *Table 2*. Additionally, kinesiotherapy, including Bobath approach and proprioceptive neuromuscular facilitation according to Kabat, was applied.

Therapy parameters	Therapy parameters	
	Treatment group (TG)	Control group (CG)
Therapies	10	10
Minute duration	9	8
Frequency	25 – 150 Hz	50 – 100 Hz
Pulse duration	280 microseconds	0.2 – 2.0 microseconds

Table 2: Therapy parameters for Treatment and Control groups.

DATA COLLECTION

Modified Ashworth Scale was used to evaluate spasticity level. Barthel Index was used as the secondary outcome measure. The data was obtained pre-, post-treatment, and 1-month follow-up. Average improvements (Mean±SD) and levels of improvement (%) were calculated. Statistical evaluation was performed by using Student's t-test where values of $p<0.05$ were considered statistically significant.

RESULTS

Changes in Spasticity

All patients completed the study reporting no adverse side-effects. There was a significant spasticity reduction in both groups. The TG showed spasticity reduction from 2.33±0.90 to 1.00±0.65 and on the 1-month follow-up, the results significantly improved to 0.87±0.64. The CG also showed good results, spasticity reduction from 2.13±0.74 to 1.67±0.62, as well as the 1-month follow-up the results were 1.47±0.74. *Table 3* below shows the results of the two groups.

Parameter	Treatment Group					Control Group				
	Pre-	Post	p	1mFU	p	Pre-	Post	p	1mFU	p
	Mean± SD	Mean± SD		Mean± SD		Mean± SD	Mean± SD		Mean± SD	
MAS	2.33± 0.90	1.00± 0.65	<0.05	0.87± 0.64	<0.05	2.13± 0.74	1.67± 0.62	<0.05	1.47± 0.74	<0.05

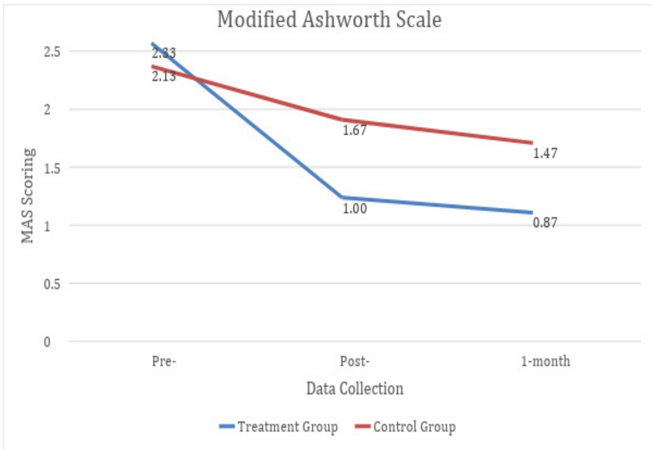
Table 3: MAS Results

Calculated levels of improvement (in %) show there is a statistically significant reduction of spasticity in both groups. The TG shows 61% improvement in the post-treatment assessment vs. 18% improvement for the CG. On the 1-month follow-up, the TG shows 66% improvement vs. 31% for the CG. The results can be seen in *Table 4*.

Parameter	Pre-treatment (T0)			Post-treatment (T1)			1-month follow-up (T2)		
	TG	CG	p	TG	CG	p	TG	CG	p
MAS	Mean±SD			ΔT1-T0 %			ΔT2-T0 %		
	2.33	2.13	NS	61%	18%	<0.05	66%	31%	<0.05

Table 4: MAS Level of improvement

These results indicate the effect of high intensity-electromagnetic stimulation on the spasticity reduction after stroke. 1-month follow-up results show that the positive effect is even increased compared to the post-treatment results. In the TG, the MAS score decreased from 1.00±0.65 to 0.87±0.64 ($p<0.05$) and in the CG, the MAS score decreased from 1.67±0.62 to 1.47±0.74 ($p<0.05$). The results can be generalized in *Graph 1*.



Graph 1: Change in MAS

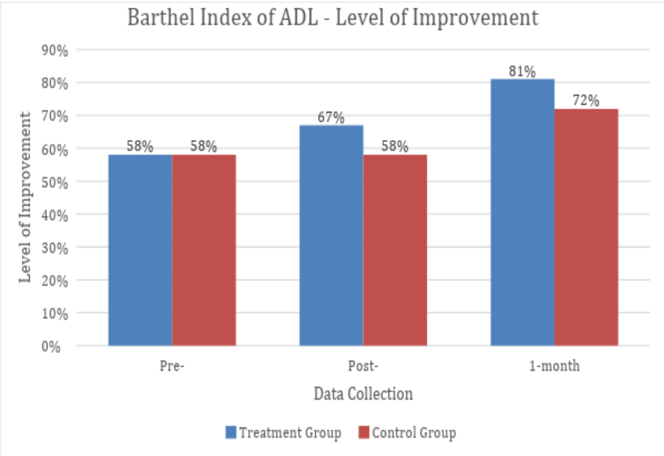
Changes in activities of daily living:

The Barthel Index (BI) is widely used a measure of functional disability (64). The index was established for use in patients with stroke and other neuromuscular disorders (64). Results shown in *Table 5* are calculated as MEAN (pre-, post-treatment, 1-month follow-up) in percentage.

Group	Parameter	Level of improvement		
		Pre-	Post -	1-month follow-up
Treatment group	MEAN	58%	68%	81%
Control group		58%	58%	72%

Table 5: BI of ADL – Level of improvement

Results show how the level of improvement has changed over the therapies. As it can be seen, that the TG had a 58% level of improvement vs. 58% for the CG. After the treatment, the TG shows an improvement from 58% to 68% vs. 58% to 58% for the CG. On the 1-month follow-up, the result of the TG continued to show improvement from 68% after the treatment to 81% on the follow-up. The result of the CG either shows an improvement from 58% to 72%. The generalized results and the change in the Barthel Index of ADL are shown in *Graph 2.*



Graph 2: Barthel Index of ADL - Level of Improvement

DISCUSSION

Neuromuscular electrostimulation is frequently used to reduce spasticity and improve the range of motion in individuals after stroke. 29 randomized controlled trials were included with 940 subjects in a systemic review conducted by Cinara Stein et al. (2015) to assess the effects of electrostimulation in spastic muscles after stroke [30]. The neuromuscular electrostimulation provided reductions in spasticity and increased the range of motion when compared with the control group after stroke [30].

Serag H. et al. (2014) [31] have studied the influence of magnetic stimulation on spasticity and painful cramps in the upper and lower limbs of multiple sclerosis patients. Eighteen multiple sclerosis patients were treated with bilateral paravertebral magnetic stimulation for six sessions (Group 1), and eight multiple sclerosis patients were given sham stimulation (Group 2) for the same duration like group 1. Modified Ashworth Scale, self-reported spasm frequency and degree of pain associated with it, general body pains, and 25-feet walking test were analyzed before and after treatment (2 and four weeks after). There was a considerable difference in muscle spasticity ($p=0.05$), spasm frequency and intensity ($p=0.0001$ for both) between the groups. There is no difference in 25-feet test and general body pains before and after treatment. As a conclusion, the magnetic stimulation helps to reduce spasticity and improves muscle spasms in MS patients. To generalize the improvement regarding Quality of life (QoL) and the activities of daily living further studies needed [31].

Beaulieu LD (2015) conducted a study in which improved ankle impairments in chronic stroke, where this improvement is assumed to be led by a dynamic influence of sensory inputs on synaptic plasticity. Reducing spasticity in patients after stroke is the key to recovery and restoration of mobility [32].

CONCLUSION

The study results demonstrate the effect of high-intensity electromagnetic stimulation on decreasing muscle spasticity in post-stroke patients. Of importance is the fact that the positive results remain unchanged at the 1-month follow-up. This therapy is non-invasive, painless and without side-effects, which makes it suitable for a large range of patients. The therapy offers a great advantage in that it allows for contactless therapy delivery. Due to adjustable therapy parameters, such as frequency and intensity modulations, no tissue adaptability occurs.

Acknowledgment

The authors declare no conflict of interest.

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