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EFFECT OF REPETITIVE TRANSCRANIAL MAGNETIC STIMULATION WITH ACTIVITY BASED THERAPY ON FUNCTIONAL OUTCOMES IN INDIVIDUALS WITH INCOMPLETE TRAUMATIC SPINAL CORD INJURY

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ABSTRACT **Objective-** To determine the effect of Repetitive Transcranial Magnetic Stimulation (rTMS) on functional outcomes in incomplete spinal cord injury. **Study Settings:** Department of Physiotherapy, Punjabi University, Patiala, Neuroots, Patiala, India. **Method:** One group, experimental design. Assessment was taken at Day 0 & Day 30 for all the participants of the group. **Study Design:** Pre-post study. **Study Participants:** Individual within 20-50 years of age group diagnosed with traumatic spinal cord injury. **Sampling Method:** Purposive Sampling **Sample Size:** 7 Individuals diagnosed with traumatic spinal cord injury were taken as study population. **Intervention:** the experimental group received rTMS, ABT (Activity Based Therapy) and Surface Spinal Stimulation for 6 days per week for 4 weeks. **Outcome Measure:** American Spinal Injury Association Impairment Scale- Lower extremity score, WISCI-II, SCIM-III, SCI-FAI. **Results-** Repetitive transcranial magnetic stimulation showed significant changes in the all outcome measure i.e. ASIA-LEMS by 13 ± 9.63 to 17 ± 10.75 ($p<0.01$), in WISCI-II by 8.43 ± 1.13 to 10.57 ± 1.99 ($p< 0.05$). In SCIM-III by 8.57 ± 8.26 to 70.29 ± 8.10 ($p<0.01$) and in SCI-FAI by 14.43±5.88 to 19.86±6.67 ($p< 0.01$). rTMS showed significant changes in functional outcome & enhance the locomotor activity of the SCI individuals. **Conclusion-** This Study concluded that the baseline and post-intervention data significantly varied after incorporating rTMS, Activity based therapy (ABT) and Surface Spinal Stimulation (SSS) among SCI individuals.

KEYWORDS : ABT, SSS, ASIA, SCIM-III, SCI-FAI.

INTRODUCTION

Spinal cord injury (SCI) is defined as a lesion of neural structures of the spinal cord, that eventually results in variable degrees of motor and sensory impairments, autonomic or bowel dysfunction [4]. Spinal Cord lesion can occur from both traumatic and nontraumatic processes. The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) published by American Spinal Injury Association (ASIA) defined incomplete SCI as 'preservation of any sensory and/or motor function below the neurological level that includes the lowest sacral segments S4-S5 (sacral sparing). Complete SCI is defined as 'absence or no preservation of sensory and motor function in the lowest sacral segments, i.e. no sacral sparing [12].

The global incidence rate is expected to be 13.0 to 163.4 per million people, while the prevalence rate is 490 to 526 cases per million population among developed countries[11]. The incidence rate of India was estimated to be 15-20 per million population per year and prevalence rate of 92.5 and 849.8 cases per million is noted in India and Nepal [16] [7]. Further tetraplegia was found to be more common than paraplegia, both in developed and developing countries and majority of the studies showed that incomplete injury was more frequent than complete injury [11].

Traumatic SCI may lead to partial (incomplete) or complete sensorimotor function loss below the injury level. Spinal Shock is a temporary clinical state of flaccid paralysis post -SCI, characterized by loss of motor, sensory, autonomic and reflex activity at or below the lesion level. Rehabilitation should strive for maximum recovery of locomotion and function after SCI. Ambulation is often expected as the first goal to be established for a SCI individual. The prognosis of ambulation recovery in people with traumatic SCI ranges from 3% for complete injury, i.e. American Spinal Injury Association Impairment Scale (AIS) score A to 95% in incomplete injury (AIS D). Also, a person with motor complete and sensory incomplete SCI (AIS B) has 50% chances to ambulate [4]. Various barriers to regeneration have also been explored that restricts endogenous regeneration and anatomic plasticity after traumatic SCI, like loss of parenchymal volume followed by formation of microcystic cavitations, local deposition of chondroitin sulphate proteoglycans (CSPGs), along with other mechanisms. Traumatic SCI follows a sequela of neurologic impairements and complications that is ardous to cure [10]. Therefore, interdisciplinary management techniques must be incorporated in SCI rehabilitation.

Activity-based therapy can be defined as the intervention that is engrossed on enhancing motor and sensory function below the level of injury, rather than compensation strategies for accommodating for the loss, in order to improve gross function post SCI. Surface spinal stimulation (SSS) is a tool for spinal cord stimulation. It targets deeply situated neural structures within the spinal canal with the goal of offering bilateral multisegmental input to the spinal cord and consequently modifies the excitability of its networks [14]. rTMS involves repetitive delivery of biphasic magnetic pulses over a specific cortical site; stimulating the corticospinal tract, primary motor cortex (M1) and spinal cord so as to induce neuronal reorganization.

The present study is an attempt to evaluate the effect of repetitive transcranial magnetic stimulation along with ABT and SSS in individuals with incomplete spinal cord injury and determine the changes in neural circuit in spinal cord post-intervention. This might help to overcome the current treatment limitations in post-SCI rehabilitation and a wide understanding of neural modulation offered by rTMS, ABT and SSS. So, the present study emphasized the need of using rTMS along with ABT and SSS in rehabilitation of SCI individuals.

Objectives Of The Study

To find the effect of rTMS along with Surface Spinal Stimulation and ABT in individuals with incomplete traumatic SCI on:Lower extremity motor function through American Association of Spinal Cord Injury-lower extremity motor score (ASIA- LEMS), Gait through Walking index for Spinal Cord Injury (WISCI-II), Physical Independence through Spinal cord independence measure (SCIM), Gait through Spinal cord injury functional ambulation inventory (SCI- FAI).

Method

Study Design:

The present study was experimental in nature in which the effect of Repetitive Transcranial Magnetic Stimulation (rTMS) along with ABT and SSS on functional outcomes with individuals with Spinal cord injury was observed. Individuals were selected based on the selection criteria. This study has been conducted according to the international standards of good clinical practice, rules, and regulations of IRB and applicable policies and procedures relevant to the study design (Reference No.17/36/IEC/PUP/2022).

Participants:

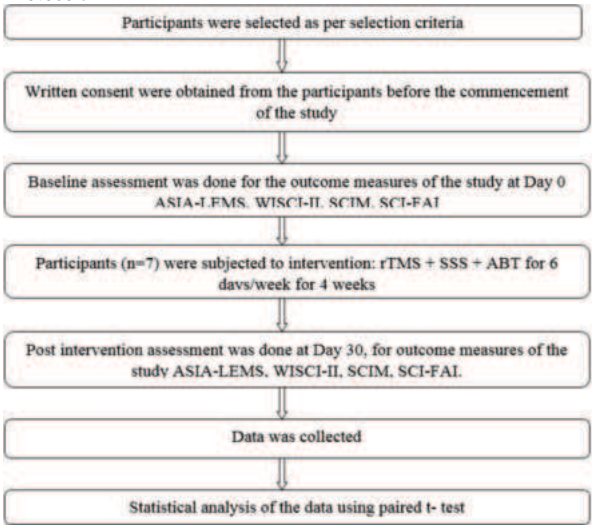
17 Traumatic Spinal Cord Individuals from Neurorehabilitation OPD,

Department of Physiotherapy, Punjabi University and Neuroots, Patiala, Punjab were evaluated. 7 individuals met the inclusion criteria and were preceded for further study procedure. Inclusion criteria was traumatic incomplete SCI, both male & female between age group of 20-50 years, follow the commands and willing to participate. Individuals with other neurological disease, history of epilepsy, risk of autonomic dysreflexia, non-cooperative individuals were excluded.

Study Intervention:

After the baseline assessments, the participants were asked to sit over the rTMS chair. MagStim Super Rapid magnetic stimulator equipped with a double-cone coil was held over the vertex. The participants were then stimulated with the prescribed parameters, i.e., high frequency rTMS of 20 Hz with 90% Resting motor threshold (RMT) intensity, delivering 1600 pulses for 15 minutes. The next step was Surface Spinal Stimulation (SSS) which was applied over the injured spinal level with adhesive electrodes placed para-vertebrally on each side of spine 5 cm apart. 4.5 cm × 9 cm electrode size was used with the carrier frequency of 2500 Hz modulated to beat frequency of 20 Hz to 80 Hz according to the tone of muscles, for the duration of 20 minutes. Activity-based therapy which includes Body supported treadmill training; over ground activities and walking, goal-oriented sit to stand activities, trunk control exercises was given to the individuals according to their needs, along with conventional physiotherapy. Treatment was given for 6 sessions per week for 4 weeks.

Protocol:



RESULTS:

A total of 7 incomplete traumatic spinal cord individuals were selected (after meeting the inclusion criteria) from Neurorehabilitation OPD, Department of Physiotherapy, Punjabi University, Patiala, Punjab and Neuroots, Patiala, Punjab. Paired T-test was used within group comparison of pre and post recordings of outcome measures.

Effect of rTMS along with ABT and SSS on American Association of Spinal Cord Injury- lower extremity motor score (ASIA-LEMS):

Table 1.1: Comparison Of Mean Value For ASIA-LEMS Of Participants Between Pre And Post Intervals

ASIA	Mean	Standard Deviation	t value	p value
Pre	13	9.63	7.483	0.0003**
Post	17	10.75		

**Result is significant, p<0.01

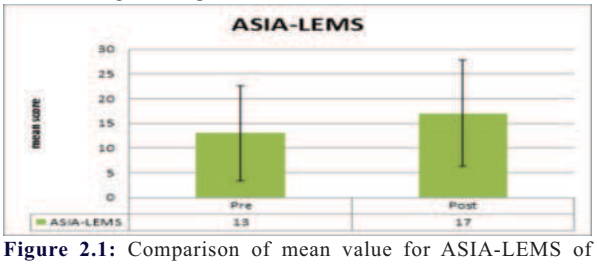


Figure 2.1: Comparison of mean value for ASIA-LEMS of participants between Pre and Post intervals

Table 1.1 describes the mean scores and standard deviation values of ASIA- LEMS, pre and post-intervention. The mean value and standard deviation of ASIA- LEMS, pre-intervention was 13 ± 9.63. Whereas, the post-intervention mean value and standard deviation was found to be 17 ± 10.75. t value calculated was 7.483 with a p value less than 0.01 (p< 0.01) that signifies significant difference between the two readings.

Effect of rTMS along with ABT and SSS on Walking index for Spinal Cord Injury (WISCI-II)

Table 1.2: Comparison Of Mean Value For WISCI Of Participants Between Pre And Post Intervals

WISCI	Mean	Standard Deviation	t value	p value
Pre	8.43	1.13	3.198	0.0186**
Post	10.57	1.99		

**Result is significant, p<0.05

Table 1.2 describes the pre and post mean and standard deviation values of WISCI. The pre- intervention mean value and standard deviation was 8.43 ± 1.13, whereas the post-intervention reading was 10.57 ± 1.99. The t value was calculated to be 3.198 with p value less than 0.05 (p< 0.05) that reveals significant difference in WISCI scores post-intervention.

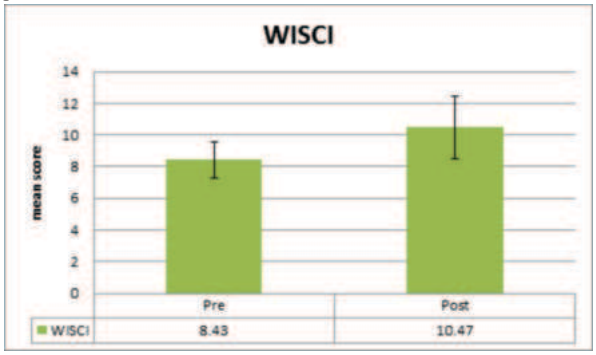


Figure 2.2: Comparison of mean value for WISCI of participants between Pre and post intervals

Effect of rTMS along with ABT and SSS on Spinal cord independence measure (SCIM):

Table 1.3: Comparison Of Mean Value For SCIM Of Participants Between Pre And Post Intervals

SCIM	Mean	Standard Deviation	t value	p value
Pre	58.57	8.26	5.867	0.0011**
Post	70.29	8.10		

**Result is significant, p<0.05

Table 1.3 reveals the mean and standard deviation values of SCIM, pre- and post-intervention. The baseline mean value and standard deviation of SCIM was 58.57 ± 8.26. Whereas, the post-intervention mean value and standard deviation was found to be 70.29 ± 8.10. t value calculated was 5.867 with a p value less than 0.01 (p< 0.05) depicting significant difference between pre- and post-intervention scores.

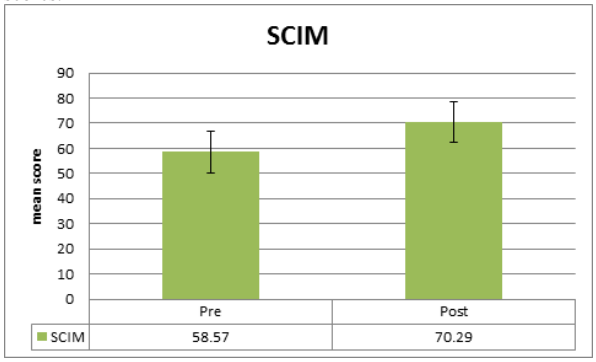


Figure 2.3: Comparison of mean value for SCIM of participants between Pre and post intervals

Effect of rTMS along with ABT and SSS on Spinal cord injury

functional ambulation inventory (SCI-FAI):

Table 1.4: Comparison Of Mean Value For SCI-FAI Of Participants Between Pre And Post Intervals

SCI-FAI	Mean	Standard Deviation	t value	p value
Pre	14.43	5.88	6.683	0.0005**
Post	19.86	6.67		

**Result is significant, p<0.01

Table 1.4 explains the mean and standard deviation values of SCI-FAI. The mean value and standard deviation pre-intervention was 14.43±5.88, whereas the post- intervention mean value and standard deviation was 19.86±6.67. t value calculated was 6.683 with a p value of less than 0.01 (p<0.01) that depicts significant results.

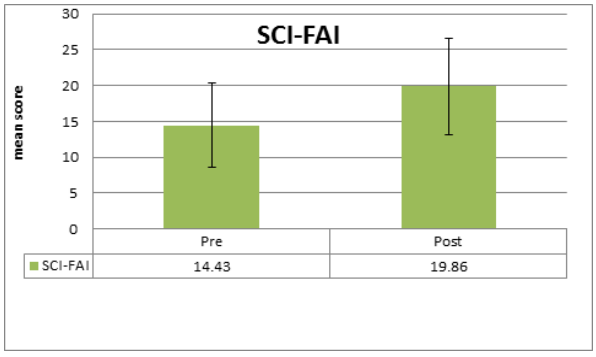


Figure 2.4: Comparison of mean value for SCI-FAI of participants between Pre and post interval

DISCUSSION:

In the present study, ASIA-LEMS (lower extremity motor score) was used as an outcome measure to track the recovery of voluntary capability and grade the degree and severity of impairment. It was found that the mean value and standard deviation of ASIA-LEMS, pre-intervention was 13 ± 9.63. Whereas, the post-intervention mean value and standard deviation was found to be 17 ± 10.75 (figure 2.1). The calculated t value was 7.484 with the p value less than 0.01 (table 1.2). Hence, the post reading signifies that rTMS along with ABT and SSS has a significant effect on lower extremity motor scores of individuals with traumatic incomplete spinal cord injury. Initially it was assumed that the nervous system is hard-wired and is irreparable, but later evidences demonstrated that the central nervous system is malleable and can learn after injury also [5]. Repetitive Transcranial Magnetic Stimulation (rTMS) is a non-invasive brain stimulation technique that brings about neuromodulation and synaptic changes in cortical and sub-cortical networks in individuals with corticospinal tract lesions, when combined with rehabilitation therapies that ultimately tempts changes in the corresponding descending corticospinal tract responsible for voluntary control [13], whereas Activity-Based therapy (ABT) activates the paralyzed extremities for promoting neurological improvement that includes body-weight supported locomotor training (LT), functional electrical stimulation (FES), exercises to control trunk, lower and upper limb musculatures comprising of assisted/resisted exercises to facilitate and strengthen the affected muscles along with task specific training [9]. Surface Spinal Stimulation stimulates the spinal cord with several electrical currents; large-diameter afferent fibers of the L2-S2 dorsal roots have the lowest thresholds for direct, electrical depolarization; and the ligaments and disc of thoraco-lumbar spine allow some current to flow through the spinal canal that eventually modifies the excitability of spinal networks [3]. This neural reorganization brought up by these modalities helps to regain the sensori-motor functioning in traumatic spinal cord injury individuals.

WISCI-II has been used as an outcome measure for quantifying the improvement in gait along with increase or decreases of manual and brace support. The pre- intervention mean value and standard deviation was 8.43 ± 1.13, whereas the post-intervention reading was 10.57 ± 1.99 (figure 2.2). The calculated t value was 3.198 with p value less than 0.05 that reveals significant result (table 1.2). Hence, it can be interpreted that rTMS along with ABT and SSS significantly improved ambulation in individuals with traumatic spinal cord injury. Studies reveals that higher the LEMS scores, greater is the ability to walk without physical assistance [8]. So, this statement can justify the above improvement in ambulation. Another reason can be the direct stimulation of supraspinal centers associated with gait by rTMS. Long term-potentiation (LTP) being one more possible reason for gait improvement, i.e. a long term enhancement in spinal network propagation resulting from their synchronous stimulation [18]. Improved motor balance in lower extremities was noticed post-high frequency rTMS, aiding in improved gait [13]. Intensive ABT has shown enhanced walking ability and neurologic recovery in chronic, motor- incomplete spinal cord injury individuals [19].

SCIM was used as an outcome measure to quantify the disability level and grade the degree of independence gained. It was found that the baseline mean value and standard deviation of SCIM was 58.57 ± 8.26. Whereas, the post-intervention mean value and standard deviation was found to be 70.29 ± 8.10 (figure 2.3). The calculated t value was 5.867 with a p value less than 0.01 (table 1.3). Hence, the post reading signifies that rTMS along with ABT and SSS has a significant effect on refining activities of daily living of individuals with spinal cord injury; hence offering a considerable improvement in quality of life. Existing literature supports the evidence that rTMS and extensive activity-based therapy enhances various domains of quality of life by reducing pain and spasticity, preventing complications, improving control over lower limb and trunk muscles; and hence increasing independence [1] [17]. A study established the combined effect of ABT and SSS, and reflected positive result on functional outcomes by stating that SSS and ABT can modulate the spinal networks, enhancing functional independence thereafter. The authors showed direct interaction between functional recovery, severity of injury and type and intensity of training and spinal circuits modulation [2].

SCI-FAI was used in the present study to assess walking function and quality of gait of SCI individuals. The mean value and standard deviation pre-intervention was 14.43±5.88, whereas the post-intervention mean value and standard deviation was 19.86±6.67 (figure 2.4). t value was found to be 6.683 and p value of less than 0.01 (p<0.01) was reported that depicts significant results (table 1.4). Hence, a significant improvement in gait function was found post-one month intervention of rTMS, ABT and SSS. Similar improvement was shown in a study depicting improved SCI-FAI scores by the combined use of ABT and SSS. The critical importance of descending pathways; neuromodulation, learning and memory capacity of spinal cord circuit; sensory input to the spinal cord and the automaticity of the spinal cord was being depicted for improvement in locomotor function [2]. The synchronized lower limb reciprocal movement, as performed in body-weight supported treadmill mimics normal walking that has the capacity to activate the gait centers in the spinal cord, i.e. the Central Pattern Generator (CPG); further eliciting enhanced locomotor activity [15]. rTMS on the other hand showed improvement in gait along with improved muscle and spasticity [6]. It has been suggested that rTMS can reach to areas in brain that can improve lower extremity motor balance, that can in turn hasten/ enhance the locomotor capacity in spinal cord individuals [13].

CONCLUSION AND LIMITATIONS OF THE STUDY

The current study concluded that the baseline and post-intervention data significantly varied after incorporating Repetitive Transcranial Magnetic Stimulation (rTMS), Activity based therapy (ABT) and Surface Spinal Stimulation (SSS) among SCI individuals. The participants showed improvement in degrees of impairment, mobility skills, functional ambulation and functioning in daily activities. Hence, rTMS, ABT and SSS proves to be a tool; effective for tapping the spinal networks providing considerable recovery, concomitantly improving functions, quality of life, productivity, life expectancy and satisfaction among individuals with traumatic spinal cord injury.

Small sample size was enrolled in the present study. Female SCI individuals were included, only male gender was included in the study. No follow up of the patient was done, to see the extended effects of these modalities. No laboratory assessment tools was used in the study. Control group was not included for comparison study. The present study demanded good and skilled man power. Costly modalities were used like rTMS, SSS and body weight supported treadmill.

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