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Immediate Effect of EMG Biofeedback Relaxation as an Adjunct to Conventional Physiotherapy for Reducing Muscle Spasticity in Patients with Stroke: An Experimental Study

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Abstract: ***To determine immediate effect of EMG biofeedback relaxation along with conventional physiotherapy on spastic muscles, 20 stroke patients were taken and allocated into two groups; experimental group was given EMG biofeedback relaxation along with conventional physiotherapy and control group was given only conventional physiotherapy. Spasticity was measured before and after treatment on Modified Tardieu Scale. A statistically significant difference was found in the spasticity post treatment between the experimental group and control group and it was concluded that EMG biofeedback relaxation along with conventional physiotherapy has better immediate effects than only conventional physiotherapy in reducing muscle spasticity.***

Keywords: EMG Biofeedback relaxation, spasticity, stroke, Modified Tardieu Scale, conventional physiotherapy

1. Introduction

Stroke is one of the leading causes of death and disability in India. The estimated adjusted prevalence rate of stroke ranges from 84-262/100,000 in rural and 334-424/100,000 in urban areas. The incidence rate is 119-145/100,000 based on the recent population studies in India.[1]

Due to the frequency of strokes occurring in the middle cerebral artery, commonly affected tracts are the corticospinal and corticobulbar pathways controlling the upper extremity. For thisreason, even though the lower extremity can also be very impaired, the upper extremity tends to be more affected after a stroke in a large number of individuals. Indeed, approximately 50% to 75% of individuals who suffer astroke experience impairments in the arm that substantially affect or impede normal daily function. A widespread neural impairment observed following stroke is decreased voluntary motor drive, which manifests as significant weakness of the affected upper (or lower) extremity. Other neural impairments include hyperactive stretch reflexes, referred to as 'spasticity',[2] caused by upper motor neuron lesions presenting as velocity-dependent increases in muscle response to passive stretch[3] and a loss of independentjoint control. Loss of independent joint controlis clinically referred to as abnormal synergies with theflexion synergy reported to be the most prevalent abnormalsynergy observed in the upper limb. The flexion synergymanifests as an *involuntary* coupling of elbow, wrist, andfinger flexor muscles as an individual attempts to lift theirparetic arm at the shoulder. Neural impairments are significantenough as to substantially restrict any useful function in the arm in individuals with moderate to severe impairment.The decrease in voluntary use of the arm, combinedwith the involuntary drive to the flexors, can result in a *flexionbias*, where an individual exhibits a flexed posture ofthe paretic arm even during rest. In addition, after astroke, individuals can experience secondary symptoms such as pain, increased stiffness, and joint contractures, allof which further limit an individual's quality of life and functional use of the paretic arm. Because a stroke is an injury to the brain, much researchhas justifiably been focused on the resulting neural deficits.However, the impaired neural drive combined with the limiteduse and the consistently flexed posture of the impairedarm likely contributes to secondary changes of the muscleswithin the limb, which can be expected to exacerbate the motor deficits seen in the chronic stroke population and furtherlimit function.[2]

Biofeedback is a self-regulation technique through which patients learn to voluntarily control what were once thought to be involuntary body processes. This intervention requires specialized equipment to convert physiological signals into meaningful visual and auditory cues, as well as a trained biofeedback practitioner to guide the therapy. Using a screen such as a computer monitor, patients get feedback that helps them develop control over their physiology. Just as looking into a mirror allows one to see and change positions, expressions, etc., biofeedback allows patients to see inside their bodies, with a trained practitioner serving as a guide directing them to use the feedback to regulate their physiology in a healthy direction. Much like physical therapy, biofeedback training requires active participation on the part of patients and often regular practice between training sessions. Clinical biofeedback may be used to manage disease symptoms as well as to improve overall health and wellness through stress management training. Research has shown that biofeedback interventions are efficacious in treating a variety of medical conditions.

Surface electromyography (sEMG) is perhaps the most common physiological variable monitored using biofeedback. sEMG is used in a variety of disorders such as tension headache, chronic pain, spasmodic torticollis and temporomandibular dysfunction.

Biofeedback also helps to make patients aware of the thoughts, feelings and behaviors related to their physiology. Over time, they can learn to self-regulate without feedback screens in front of them.[4]

Individuals affected by spasticity have a greater degree of motor impairment, more activity limitation, and a lower quality of life compared with those who are not affected by spasticity.Adequate assessment of spasticity is therefore required to optimize treatment choices and measure the response to intervention. The Ashworth Scale and the Tardieu Scale are the most commonly used clinical tools for assessing spasticity.Whereas the Ashworth Scale relies on a qualitative rating of spasticity,the Tardieu Scale also includes quantitative measurements of spasticity.The Tardieu Scale was shown to have superior construct validity,content validity,and reliabilityto the Ashworth Scale for spasticity assessment. The Tardieu Scale includes quantitative joint angle measures taken at 3 speeds of passive movements: as fast as possible, at the speed of a limb falling under the force of gravity, and as slow as possible.In the clinical setup, it may be difficult to standardizethe speed of a limb falling under the force of gravity. Hence, a clinically useful variation of the Tardieu Scale is the Modified Tardieu Scale (MTS). The MTS is designed specifically to identify an increase in muscle resistance caused by spasticity. Qualitative ratings of spasticity are also used in the MTS. The reliability of the MTS has been studied extensively in children with cerebral palsy. However, only a limited number of studies have assessed the reliability of the MTS in adults with neurologic injures. Most adult studieshave focused on upper limb muscles, with fewer studies focusing on lower limb muscles.[3,5,6]

Providing patients and indeed clinicians with biofeedback during rehabilitation can have potential therapeutic effects as it may enable users to gain control of physical processes previously considered an automatic response of the autonomic nervous system. In doing so it may offer the opportunity to improve accuracy during functional tasks, increase patient engagement in their rehabilitation and reduce the need for ongoing contact with healthcare professionals to monitor implementation of rehabilitation programs.[7] The purpose of this research is to explore the use of Biofeedback Relaxation device, especially the EMG in the clinical physiotherapy settings. Biofeedback relaxation could be a great tool which needs to be extensively used in clinical settings. It may help in releasing muscle tension and spasticity in patients with stroke. This study focuses on exploring immediate applications of the EMG Biofeedback Relaxation.

2. Literature Survey

1) Ju Hong Kim (2017); conducted a study on “The effects of training using EMG biofeedback on stroke patients upper extremity functions.”The subjects of this study included 30 hemiplegia patients whose disease duration was longer than six months. They were randomly divided into a control group (n=15) receiving traditional rehabilitation therapy and an experimental group (n=15) receiving both traditional rehabilitation therapy and training using EMG biofeedback. The program lasted for a total of four weeks. In order to examine the subjects’ functional recovery, the author measured their upper limb function using the Fugl-Meyer Assessment and Manual Function Test, and activities of daily living using the Functional Independence Measure before and after training. A comparison of the study groups revealed that those in the experimental group experienced greater improvement in upper extremity function after training in all tests compared to the controlgroup; however, there was no significant difference in terms of the activities of daily living between the two groups. The results of this study were as follows. Thus, stroke patients receiving intensive EMG biofeedback showed more significant upper extremity functional recovery than those who only received traditional rehabilitation therapy.

2) Meryem Dogan-Aslan et al (2010); conducted a study on “The effect of electromyographic biofeedback treatment in improving upper extremity functioning of patients with hemiplegic stroke.” This study evaluated the effect of electromyographic biofeedback treatment on wrist flexor muscle spasticity, upper extremity motor function and ability to perform daily activities of living in patients with hemiplegia with stroke. The findings indicate a positive effect of EMG-BF treatment in conjunction with neurodevelopmental and conventional methods in hemiplegia rehabilitation.

3) Shannon Jones Anstead (2009) conducted a study named “College Students and StressManagement: Utilizing Biofeedback and Relaxation Skills Training”. The study was undertaken to evaluate the effectiveness of biofeedback and relaxation skills training to help alleviate college students’ stress symptoms. Data was collected from 659 full-time college students who attended a total of of 1,170 biofeedback sessions over the course of two years. Results of the study indicated that the top three stress-related symptoms students experienced were feeling overwhelmed, feeling anxious and difficulty concentrating. Furthermore, the top stressors rated by students were too much to do, homework, classes and school. In addition, the top coping strategies utilized by students to manage their stress were prayer, exercise and talking to friends. Moreover, results also showed significant differences on all three pre and post measures regarding skin temperature readings, EMG readings, and students’ subjective self-report ratings of degree of stress. Specifically, students’ skin temperature increased and their muscle tension decreased, indicating less physiological tension at the end of the session. Furthermore, comparisons of students’ self report ratings of their degree of stress before and after the session indicated that they felt less stressed and more relaxed at the conclusion of the session. These findings lend support to the utility of colleges providing biofeedback and relaxation skills training as an intervention for college students to utilize.

4) Erbil Dursun et al (2004) conducted a study on “Effects of biofeedback treatment on gait in children with cerebral

palsy". In this study, they evaluated the effectiveness of biofeedback treatment on gait function in children with cerebral palsy. Thirty-six children with spastic cerebral palsy and dynamic equinus deformity were included in the study. The biofeedback group consisted of 21 children who each received EMG biofeedback training plus conventional exercise programme. The control group consisted of 15 children who each received conventional exercise programme only. Active range of motion of the ankle joints, muscle tone of plantar flexors, and gait function of the children were evaluated and compared. The biofeedback group displayed statistically significant improvements regarding tonus of plantar flexor muscles and active ROM of ankle joints ($p<0.000$ for all parameters). Gait function showed statistically significant progress in both of the groups, but the biofeedback group was superior to controls. Children with cerebral palsy and dynamic equinus deformities may benefit from biofeedback treatment for ambulation.

5) D. Intiso et al (1994); conducted a study on "Rehabilitation of walking with electromyographic feedback in foot-drop after stroke." In this study, gait analysis was performed to evaluate the efficacy of electromyographic feedback compared with physical therapy. Sixteen patients with ischemic stroke were enrolled in the study. The experimental group (4 men, 4 women) received electromyographic biofeedback treatment together with physical therapy. The control group (5 men, 3 women) was treated with physical therapy only.Clinical and functional evaluations before and after treatment were performed using Canadian Neurological, Adams, Ashworth, Basmajian, and Barthel Index scales. Computerized gait analysis was performed in all patients and this study concluded that electromyographic feedback technique increases muscle strength and improves recovery of functional locomotion in patients with hemiparesis and foot-drop after cerebral ischemia.

6) Steven L. Wolf et al (1983) conducted a study on "Electromyographic Biofeedback Applications to the Hemiplegic Patient: Changes in Lower Extremity Neuromuscular and Functional Status". In this study,the efficacy of EMG biofeedback in improving neuromuscular and functional measures of involved lower extremities in an Experimental Group of chronic stroke patients (n = 7) was examined. Differences in pre treatment-post treatment measures of the Experimental Group were compared with those of groups of chronic stroke patients receiving no treatment (n=6), biofeedback treatment of the involved upper extremity only (n = 16), and general relaxation training (n=8). All examinations were performed in a blind fashion. The experimental group showed significant improvement in active range of motion at the knee and ankle that appeared to result from increases in EMG output to muscles governing these movements. Experimental patients did not improve substantially in walking speed over different terrains but did require significantly fewer or less complex assistive devices to walk.

7) Karen Smith (1979); conducted a study named "Biofeedback in strokes."The effectiveness of biofeedback therapy, using the electromyograph, was compared with conventional physiotherapy treatments in eleven hemiparetic patients with severe disability of the upper limb. These were divided randomly into two groups, a group of six patients receiving biofeedback treatments and five receiving physiotherapy treatments with conventional techniques. The results showed greater improvements in the biofeedback group in most fields of testing, and the patients in this group had a greater degree of control over the patterns of movement in the upper limb and the relaxation of spastic muscle groups. It was concluded that a wide range of hemiparetic patients should benefit in some degree by treatment of this form.

8) Alfonso Amato et al (1973); conducted a study on "Use of electromyographic feedback to increase inhibitory control of spastic muscles." In this case report, electromyographic (EMG) feedback was used to train a patient to inhibit spastic muscles voluntarily. The EMG activity was recorded with surface electrodes placed over the belly of the medial gastrocnemius muscle and displayed on a meter. The patient trained himself at home for thirty minutes daily for two months. Following training, improved muscle control could be seen even without the use of the EMG feedback device.

3. Material and Methods

The study was conducted in Neuro Physiotherapy Department of Vikhe Patil Memorial Hospital, Ahmednagar and Puntamba Stroke Center. It was an experimental study. 20 stroke patients were taken as subjects for this study. Purposive sampling method was used. First ever stroke patients of sub-acute and chronic stage, both male and female, with increased tone in wrist flexors, elbow flexors and Mini Mental State Examination score of 24 or higher were included and recurrent stroke patients having severe co-morbidities such as cardiovascular diseases, neurological disorders, musculoskeletal disorders, metabolic disorders, those who underwent recent surgeries were excluded from this study. Ethical Committee Approval was obtained from IEC prior to beginning the study. The subjects were divided randomly into two groups; one is the experimental group wherein EMG relaxation was used along with conventional physiotherapy treatment and the other is thecontrol group, who received only conventional physiotherapy treatment. The materials used were electromyographic feedback relaxation device, surface EMG electrodes, universal goniometer, recording paste, sticking tape, pillow and treatment plinth. They filled out an informed consent form and received detailed instructions on how to perform the test. Pre-assessment was taken which included name of the patient, age, gender, duration of stroke, hand dominance, side of affection, Brunnstrom stage of recovery, range of motion and grading of spastic muscles on Modified Tardieu scale.

For Group A (experimental group): To perform the biofeedback test, open Relax 101 software. Connect the surface EMG electrodes to the patient at the designated positions; active on the muscle belly of the spastic muscles, passive on muscle tendon and third electrode between the active and passive electrodes which would act as the ground electrode. Add the record of the patient by clicking ADD RECORD tab. Save it and exit. Enter the ACQUISTION tab.

Click Start Acquisition option. If waveforms for the channel are irregular then the sensors should be repositioned. Various artifacts can be seen, when patient is winking (eye movement artifacts), swallowing saliva down, hyperventilating, locking maxilla, straining muscles. Allow the subject to settle down and stabilize for a few minutes. Click on the balance (Bal) control in the Channel Balance/Level Setting Bar (EMG option). Select the desired sensitivity (Sen) in the Channel Balance/Level Setting Bar. The patient should be advised to relax completely. When all the waveforms are displayed properly, click on Record button to start recording the data. Click the VIEW option from the menu bar and open the Animation view. Conventional physiotherapy treatment is given along with EMG biofeedback relaxation for a duration of 20 minutes. The feedback is given through video animation and percentage of muscle activity for the muscle tension and spasticity present in the muscle. To stop the recording, click StopRec button on the Tool Bar. After the treatment session, spasticity of muscles is assessed again using the Modified Tardieu scale and percentage of muscle activity for checking the immediate effects.

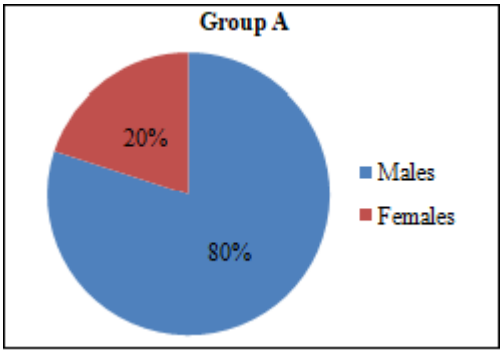
For Group B (control group): The conventional physiotherapy treatment comprises of passive range of motion exercises to affected joint- 10 reps, 3 sets, static stretching to muscles- 15 reps with 10 seconds, weight bearing to the affected joint- 10 reps with 10 seconds hold and the duration of treatment is 20 minutes. After the treatment session, spasticity of muscles is assessed again using Modified Tardieu scale for checking the immediate effects.

4. Result

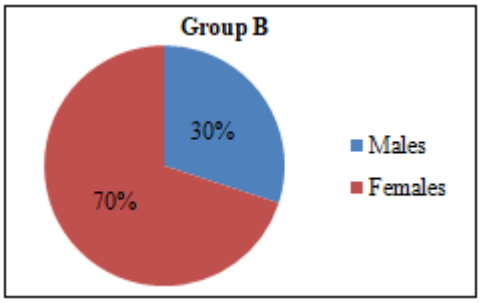
The results of this study were analyzed in terms of muscle activity percentage and spasticity indicated by Relax 101 software and Modified Tardieu Scale and comparison was made between pre-treatment and post-treatment values. The data was entered into an excel spreadsheet, tabulated and subjected to statistical analysis. Statistical analysis was done by GraphPad InStat software. Various statistical measures such as mean, standard deviation (SD) and test of significance such as unpaired t-test were utilized to analyze the data. The results were concluded to be statistically significant for Group A with $p<0.05$. Paired t-test was used to compare differences of values for pre-treatment and post-treatment within a single group and unpaired t-test was used to compare differences found in post-treatment spasticity between the two groups i.e. Group A (experimental group) and Group B (control group)

Table 1: Showing demographic profile in both the groups

	Group A (Experimental Group)	*Group B (Control Group)*
Age	41.8± 12.08	55.1± 16.23
Gender (M/F)	8(80%) / 2(20%)	3(30%) / 7(70%)
Duration of Stroke (in years)	2.449± 2.20	0.7819±1.19
Side of affection (Right/Left)	8(80%) / 2(20%)	6(60%) / 4(40%)



Graph 1: shows the percentage of gender wise distribution in the experimental group (Group A)

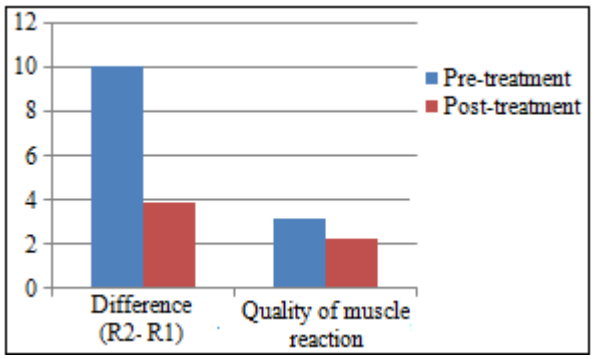


Graph 2: shows the percentage of gender wise distribution in the control group (Group B)

Above graphs show the gender wise distribution in both Group A and Group B. In Group A (experimental group), 80% males and 20% females participated whereas in Group B (control group), 30% males and 70% females participated.

Table 2: Shows the difference in spasticity on Modified Tardieu Scale pre and post treatment in Group A (experimental group)

	Group A (experimental group)		*p-value*
	Pre-treatment	*Post-treatment*	
	Mean ± SD	*Mean ± SD*	
Difference (R2-R1)	10.1 ± 3.54	3.9 ± 2.13	0.0022
Quality of Muscle Reaction	3.2 ± 0.78	2.3 ± 0.94	<0.0001

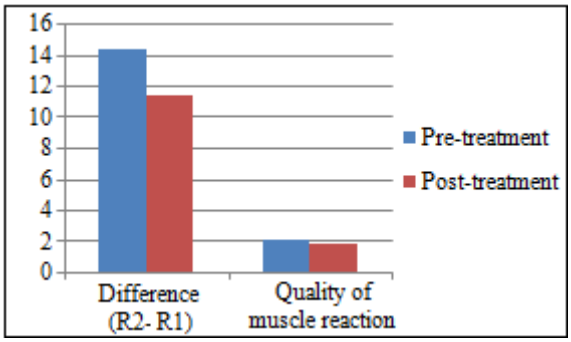


Graph 3: shows the difference in spasticity on Modified Tardieu Scale in Group A (experimental group)

In Group A (experimental group), the spasticity on Modified Tardieu Scale pre and post treatment along with EMG biofeedback relaxation was analyzed. The difference between R2 and R1 as well as quality of muscle reaction is statistically significant pre and post treatment in Group A.

Table 3: shows the difference in spasticity on Modified Tardieu Scale pre and post treatment in Group B (control group)

	Group B (control group) Pre-treatment Post-treatment		*p-value*
	Mean ± SD	*Mean ± SD*	
Difference (R2-R1)	14.5 ± 8.61	11.4 ± 8.51	<0.0001
Quality of muscle reaction	2.1 ± 0.87	1.8 ± 0.63	0.0811

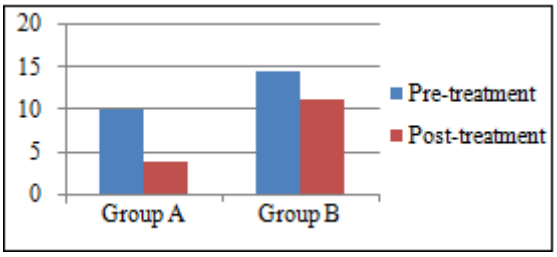


Graph 4: shows the difference in spasticity on Modified Tardieu Scale in Group B (control group)

In Group B (control group), the spasticity on Modified Tardieu Scale pre and post conventional physiotherapy was analyzed. The difference between R2 and R1 is statistically significant but the quality of muscle reaction is statistically not significant pre and post treatment in Group B.

Table 4: Shows a comparison in difference (R2-R1) between Group A (experimental group) and Group B (control group)

	Group A (experimental group) Pre-t/tPost-t/t		*Group B (control group)Pre-t/ t Post-t/t*		*p-value*
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	
Difference (R2-R1)	10.1 ± 3.54	3.9 ± 2.13	14.5 ± 8.61	11.4 ± 8.51	0.0145



Graph 5: Comparison in difference (R1-R2) between Group A (experimental group) and Group B (control group)

In the above table and graph, the post-treatment values of difference between R2 and R1 of spasticity on Modified Tardieu Scale has been compared between Group A (experimental group) and Group B (control group). It is found to be statistically significant with p=0.0145

5. Discussion

This study aimed at finding out immediate effect of EMG biofeedback relaxation on spastic muscles in stroke patients along with conventional physiotherapy treatment. To accomplish this aim, 20 subjects were taken and allocated into two groups; Group A (experimental group) and Group B (control group).

In the experimental group (Group A), the mean age of the participants was 41.8± 12.081 years and the gender ratio was 8:2 (8 males, 2 females). The mean duration of stroke was 2.449± 2.20 years and side of affection ratio was 8:2 (8 right, 2 left). In the control group (Group B), the mean age of the participants was 55.1 ± 16.23 years and the gender ratio was 3:7 (3 males, 7 females). The mean duration of stroke was 0.7819 ± 1.19 years and side of affection ratio was 6:4 (6 right, 4 left).

In the experimental group, which involved EMG biofeedback relaxation along with conventional physiotherapy treatment, percentage of muscle activity was noted on EMG biofeedback relaxation device. The pre-treatment mean was 74.9 ± 26.43 whereas the post treatment mean was 38 ± 26.50. A very significant difference is found statistically in the pre-treatment and post-treatment value of muscle activity percentage with p=0.0059.

Modified Tardieu Scale was used for measuring spasticity pre and post treatment in affected muscles of patients with stroke as it includes quantitative measurements of spasticity.In experimental group i.e. Group A, there is a significant difference seen in the spasticity measured pre and post treatment on the Modified Tardieu Scale. The difference between R2 and R1 as well as quality of muscle reaction is statistically significant pre and post treatment in Group A with p=0.0022 and p <0.0001 respectively.

This finding is similar to a few studies reviewed earlier. In the study, "The effects of training using EMG biofeedback on stroke patients upper extremity functions" by Ju-Hong Kim[8], stroke patients receiving intensive EMG biofeedback showed more significant upper extremity functional recovery than those who only received traditional rehabilitation therapy. In the study "Rehabilitation of walking with electromyographic feedback in foot-drop after stroke" by D. Intiso et al.[9], concluded that electromyographic feedback technique increases muscle strength and improves recovery of functional locomotion in patients with hemiparesis and foot-drop after cerebral ischemia. Karen Smith[10] conducted a study named "Biofeedback in strokes" and the results in this study showed greater improvements in the biofeedback group in most fields of testing, and the patients in this group had a greater degree of control over the patterns of movement in the upper limb and the relaxation of spastic muscle groups. Steven L. Wolf[11] et al conducted a study on "Electromyographic Biofeedback Applications to the Hemiplegic Patient: Changes in Lower Extremity Neuromuscular and Functional Status". In this study,the experimental group showed significant improvement in active range of motion at the knee and ankle that appeared to result from increases in EMG output to muscles governing these movements.

In control group i.e. Group B, there is no significant difference seen in the spasticity measured pre and post treatment on the Modified Tardieu Scale. The difference between R2 and R1 is statistically significant with p <0.0001

and quality of muscle reaction is statistically not significant pre and post treatment in Group B with p=0.0811.
Differences are found in post-treatment spasticity between the two groups i.e. Group A (experimental group) and Group B (control group). The difference between R2 and R1 of spasticity on Modified Tardieu Scale has been compared between Group A(experimental group) and Group B (control group) and it is found to be statistically significant with p=0.0145.

Biofeedback Relaxation is a simple, non invasive, painless treatment method with no side effects. Biofeedback Relaxation increases cognitive and sensorimotor performance to relax hyperactive muscles and to recover muscle strength. The visual and auditory feedback provided through Biofeedback Relaxation is useful to gain control over involuntary bodily functions. The significant difference seen between the experimental and control groups can be attributed to the video animation in the EMG Biofeedback Relaxation device which resulted in better immediate results i.e. reduction in spasticity of affected muscles post-treatment as compared to the pre-treatment values on Modified Tardieu Scale.

6. Conclusion

This study concludes that there is an immediate effect of EMG biofeedback relaxation along with conventional physiotherapy treatment seen on spastic muscles in patients with stroke.EMG biofeedback relaxation along with conventional physiotherapy has better immediate effects than only conventional physiotherapy in reducing muscle spasticity in patients with stroke.

7. Limitations

As only immediate effects have been studied in this study, long term effects of EMG Biofeedback Relaxation should also be studied for a broader perspective. Also, the sample size is relatively small. The future scope of this study would be a larger sample size.

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