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EFFECT OF ARM ERGOMETRY TRAINING ON SPASTICITY AND MOTOR PERFORMANCE IN PERSONS WITH HEMIPLEGIA DUE TO STROKE

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ABSTRACT
Background: Motor deficits of the upper limb following stroke may range from total paralysis to partial paresis. There are three main components of compromised motor performance following stroke - weakness, impaired inter-segmental coordination, and hyper-reflexia or spasticity. Arm ergometry training has been found to improve motor conventional and reduce spasticity in stroke subjects. **Purpose:** The present study intended to examine whether repetitive arm ergometry training helps in reducing spasticity and improving motor performance. **Method:** A total 34 number of subjects were selected and randomly assigned to either of the two groups after meeting the inclusion and exclusion criteria. All participants underwent an initial baseline assessment of dependent variables – MAS, Fugl Meyer assessment –UE (shoulder, elbow). Both groups received conventional physiotherapy. Group 2 in addition, received arm ergometry training for a period of 4 weeks, 5 days/week. All participants received a follow up assessment after completion of 4 weeks. **Results:** Overall results of the study suggested that after 4 weeks of interventions improvement of motor performance in upper extremity was found in both experimental and conventional group as measured by Fugal Meyer Assessment -UE (FMA-UE shoulder/elbow motor score) and reduction in spasticity as measured by Modified Ashworth Scale(MAS). However, experimental group showed significantly more improvement than conventional group. **Conclusion:** Arm ergometry training with conventional therapy brings about more improvement in motor function than conventional physiotherapy alone.

KEYWORDS: Stroke, Arm Ergometry Training, MAS, FMA-UE.

INTRODUCTION
According to estimates by the WHO, stroke accounted for 5.7 million deaths and 16 million first-time events in 2005 and these numbers may reach 7.8 million and 23 million by 2030, respectively.[1] Stroke is the second leading cause of preventable death worldwide and the fourth leading cause of lost productivity, as measured by disability-adjusted life years.[2]

Stroke can be characterized as an interruption of the blood supply to the brain or hemorrhage into the brain tissue, commonly involving a disruption in the motor and sensory pathways.[3] The WORLD HEALTH ORGANIZATION (WHO) defines stroke as “rapidly developing clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than that of vascular origin”.[4]

One of the most common and obvious deficits following stroke is motor impairment.[5] Upper limb motor impairment has been estimated to affect between 50-80% of stroke patients.[6] Despite rehabilitation efforts, 50-75% of patients with initial upper limb impairment report persisting problems 6 months later.[7] Upper limb impairment is therefore a considerable problem following stroke and a significant contributor to stroke-related disability.[8]

Upper limb motor deficits can occur following damage to the motor cortex, pre-motor cortex, supplementary motor cortex or damage to the descending fibres of the corticospinal tract. The main characteristics of upper limb impairment following stroke include changes in muscle tone and strength, abnormal reflexes, impairment of volitional movements and sensory deficits.[9]

In recent years, understanding of motor learning, neuroplasticity and functional recovery after the occurrence of brain lesion has grown significantly. Repeated motor practice and motor activity have been identified in several prospective studies as favorable for motor recovery in stroke patients. The present investigation was based on the simple repetitive movement and was realized by arm cycling. The main purpose of training was to improve motor function and the use of the affected limb in daily life. Recovery itself can be attributed to several factors. One important aspect was to reduce spasticity, which often arises some months after a stroke in anti-gravity muscles. The anti-spastic effect of exercises on a motorized ergometer, which moves the legs similarly as during cycling, was documented by the F-wave, reflecting changes of motor neuron excitability during rhythmic movements.[10] Clinical follow-up by the Ashworth Scale assessment confirmed these results.[11] The assessment of spasticity is, however, controversial.[12] Even if spasticity is tested using its definition, i.e. a velocity dependent response to passive stretching, results have been ambiguous as shown with significant differences obtained in a supine and sitting position.[13] In the present context, the main purpose was to evaluate whether a rehabilitation program can lessen the degree of spasticity.

Aim of the Study

The aim of the study was to investigate whether arm ergometry training reduce spasticity and improve motor performance in stroke.

METHODOLOGY

Study Design: Two groups, pre-test post-test structured, experimental study design.

Sample Size: A total of 34 subjects(26 male, 08 female), age range 30 to 60 years with mean age 47 with hemiplegia due to stroke, who fulfilled inclusion and exclusion criteria were recruited from Physiotherapy Department of Swami Vivekananda National Institute of Rehabilitation Training and randomly allocated into two groups.

Inclusion criteria:-Patient with hemiplegia due to stroke, age between 30 to 60 years, stroke duration up to 2 years, able to understand and follow simple verbal instruction**,** spasticity not exceed grade 2[MAS], able even with the paretic hand to reach the arm- pedal without pain and able to exercise using arm ergometer for at least 30 minutes.

Exclusion Criteria:-Extreme shoulder pain, inferior dislocation of the shoulder [>3cm], trophic skin changes, edema, prior rotator cuff surgery, bursitis, biceps tendinitis, recent cardiac event, inability to understand and follow simple verbal command, unconventional hypertension, reflex sympathetic dystrophy, contracture in the upper limb, patient who have received botox injection or acupuncture within past 6 months to the affected upper limb.

Procedure: After meeting the inclusion and exclusion criteria through an assessment proforma, informed consent was taken and subjects were randomly allocated to either of the two groups. All participants underwent an initial baseline assessment of spasticity by using the Modified Ashworth Scale (MAS) and functions by Fugal-Meyer Assessment Upper Extremity score FMA-UE.

Modified Ashworth Scale - The spasticity was assessed using the modified Ashworth scale. The MAS measures the level of resistance to passive movement and it is effective in clinical practice because of its ease and speed of use. This scale is widely used in research and has been highly investigated in many studies (e.g. to objectify the effect of treatment. The MAS evaluates a combination of soft tissue contractures and spastic dystonia in addition to spasticity itself.

Fugl Meyer Upper Extrimity Scale The Fugl- Meyer Assessment (FMA) upper extremity score was used to evaluate the various dimensions of motor weakness. FMA is a quantitative assessment tool that measures motor recovery after stroke in the shoulder, elbow, forearm, wrist, and hand. Points from 0 to 2 were given to each item according to the performance on the motor function evaluation (0: Unable to perform, 1: Performs partially, 2: Performs completely).

Both groups received conventional physiotherapy. The experimental group in addition, received arm ergometry training. Conventional programme was patient specific and consisted of task related functional movements of upper limb. It involved eccentric and concentric scapula protraction, shoulder and elbow movements, shoulder horizontal abduction and adduction movements, forearm supination and pronation, practice of shoulder movements in sitting, weight bearing exercises for upper limb tight structures. Movement was practiced for 30 repetitions for 5 days in a week for 4 weeks.

Arm ergometry training:-The patients were positioned in front of ergometer either in wheelchair or chair without arm rest so as not to hinder arm movements. They performed the arm training in ergometer in relatively low resistance for 30 minutes daily, 5 days a week for 4 weeks. Each training session comprised 15 min of arm cycling in forward direction and 15 min in a backward direction with a 5 min break in between. The patients grasped the handles or the affected hand was strapped to the handle depending on the severity of the deficits. The patient pushed the handle away by using shoulder flexion/protraction and elbow extension and pulled it towards the body by using shoulder extension/retraction and elbow flexion. The chest guard was used to prevent the patient from using the trunk while reaching forward. The Training performed without an active motor. Patients were not assisted in any way during the exercise apart from verbal encouragement from the therapist for the patient with severe paralysis, the contralateral arm performed movement practically by itself.

In this study a total number of 34 subjects with mean age 47.79±7.495 years, mean duration of injury 8.59±5.43 months, 16 right and 18 left side were taken & divided into two groups with 17 subjects in each group, namely experimental group (mean age 47.88±7.68, mean duration of injury 8±5.91, 8 right and 9 right) &conventional group (mean age 47.1±7.54, mean duration of injury 8.12±5.09).

Data Collection

Measurements were taken prior to the beginning of treatment and were repeated finally after the completion of treatment protocol of 4 weeks duration.

Data Analysis

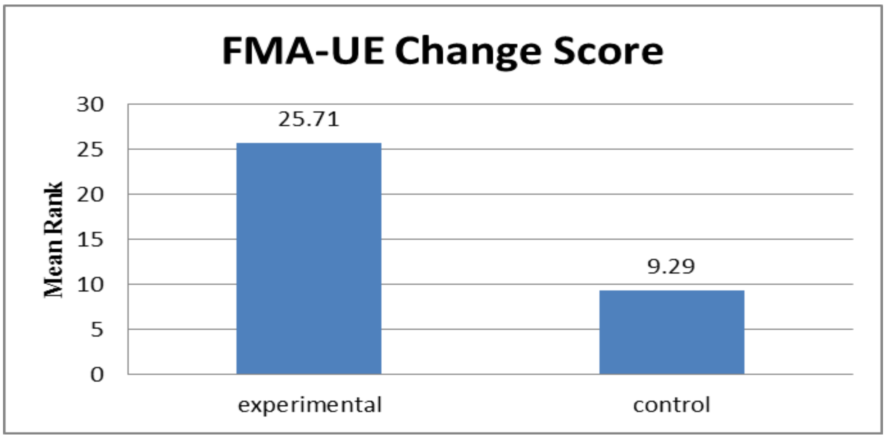
Data was analyzed using non parametric, Mann-Whitney U Test to test difference between pre to post change scores of conventional group with that of the experimental group.

RESULTS

Fugl Meyer Assessment-Upper Extremity

Graph 1 illustrates that the experimental group showed greater improvement post- treatment as compared to conventional group.

Mann Whitney U test showed that Z score is -4.880, value of test is 5.00 with p=0.000, indicating a significant difference in change of scores between groups.

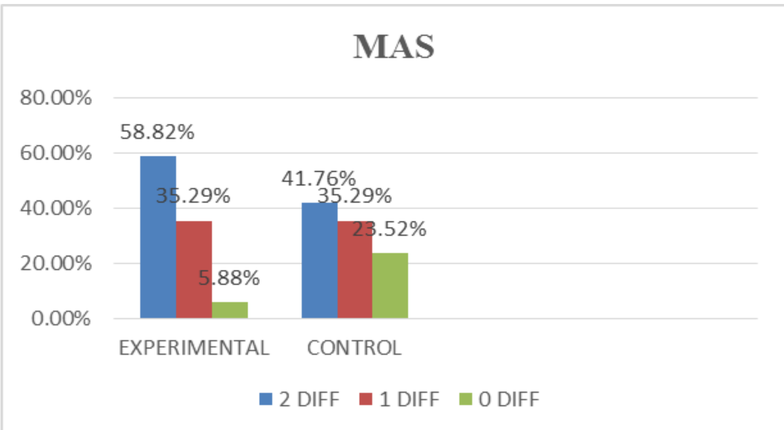


Graph 1: This graph indicates the change in FMA-UE (shoulder-elbow) score between experimental and conventional groups by Mann Whitney U test. It shows the mean rank experimental group is 25.71 and conventional group is 9.29.

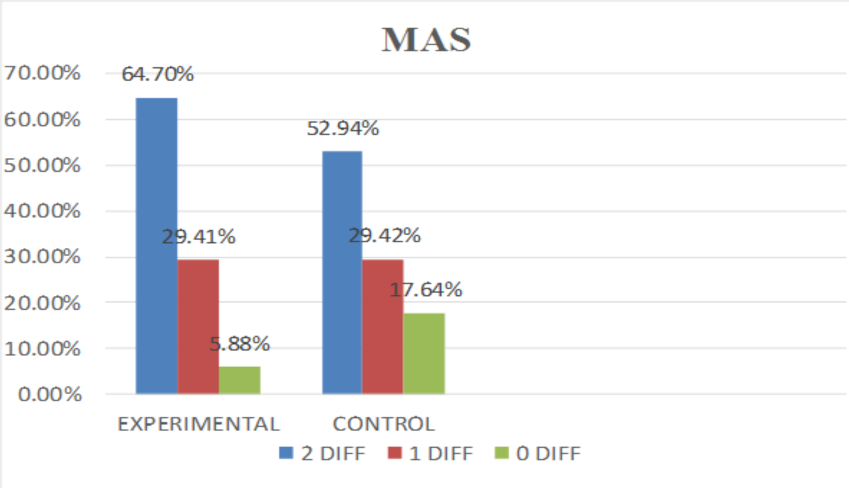
Modified Ashworth Scale

Graph 2.1 and 2.2 illustrates that there was reduction in spasticity in both the groups following treatment for 4 weeks. The experimental group showed greater improvement in the post- treatment measurements as compared to the conventional group. In elbow flexors there was 58.82% of patients had MAS grade reduction by two grades in experimental group compared to conventional group in which 41% patients MAS grade reduced by two. There was reduction in MAS score by one grade equally in both the groups. Only 5.88% patients did not show any reduction in experimental group compared to conventional group in which 23.52% did not show reduction in MAS grade.

In shoulder flexors, 64.70% of patients had MAS grade reduction by two grades in experimental group as compared to conventional group in which 52.94% patients had MAS grade reduced by two. There was reduction in MAS score by one grade equally in both the groups. Only 5.88% patients did not show any reduction in experimental group as compared to conventional.



Graph 2.1: Depicts changes in MAS of elbow flexors in both the groups.



Graph 2.2: Depicts changes in MAS of shoulder flexors in both the groups.

DISCUSSION

The purpose of this study was to investigate the effectiveness of arm ergometry training on reducing spasticity and improving motor performance in stroke subjects.

Overall results of the study showed that improvement of motor performance in upper extremity was found in both experimental and conventional group as measured by Fugl Meyer Assessment -UE (FMA-UE shoulder/elbow motor score) and reduction in spasticity as measured by Modified Ashworth Scale(MAS) however experimental group showed significantly more improvement than conventional group.

Both the experimental and conventional group participated in the conventional stroke rehabilitation program. The experimental group received an additional arm ergometry training program.

Fugl Meyer Upper Extrimity Scale (FMA-UE)

In this study there was improvement in FMA-UE from pre to post measurement after 4 weeks of intervention in both experimental and conventional group. The Shoulder and Elbow motor component of FMA-UE were evaluated. Mann Whitney U test with $p<0.00$ showed mean rank in experimental group was 25.71 and in conventional group was 9.29.

The conventional group showed improvement in post FMA measurement. The subjects in conventional group received conventional therapy consisted of task related functional movements of upper limb.

The improvement in conventional group could be due to improved motor conventional and functional recovery as Conventional exercises are linked to improve cortical reorganization, and changes in sensorimotor maps.

The more practice and repetition are key components of training which lead to more sensory input, feedback and permanent changes as new strategies and motor plan produced lead to learning a new skill or restore the lost skill. The nervous system provides sensory processing for perception of body orientation in space provided by visual, vestibular and somato-sensory systems. Sensory-motor integration is essential for linking sensation to motor responses (centrally programmed postural adjustments that precede voluntary movement).

Mechanism of new motor strategy:Information coming from periphery reaches to the spinal cord through spinal nerves, information coming from head and neck reaches to brainstem through cranial nerves. All the previous information reaches to the thalamus to be sensitized then to the post-central gyrus to be localized. Perception, cognition, new sensory strategies are produced by sensory areas which lead to increase of efficiency of synapses. After that information reaches to cerebellum and basal ganglion to be smoothened and prevention of excessive activity, then reaches to pre-central gyrus to produce permanent changes and new motor behavior.

This means the process consists of learning of new skill then formation of motor command via tracts to final common pathway (alpha and gamma MN) to perform new behavior of skills or reacquisition of skills.

Anne Shumway cook: Motor learning theory suggests that, procedural learning develops slowly through repetitions of an act over many trials, and it is expressed through improved performance of the task it was practiced.[14,15]

Nudo RJ and Plautz EJ et al[16] have demonstrated in animal study that task-specific training can restore function by using non-affected parts of the brain which are generally adjacent to the lesion and/or recruiting supplementary areas of the brain. Some researcher like Bayona NA and Byl et al[17] has demonstrated that rehabilitation may be more successful if the tasks and stimuli are important and meaningful to the person. It has been shown in various studies previously that task-oriented training can result in improved hand function after stroke.

There was a significant improvement between the pre and post scores of the conventional group in FMA-UE Scale.

This finding was in supportive to the article published by Jang SH et al in which the effect of task oriented training in Cortical activation pattern in 4 chronic hemiplegic stroke patients were investigated.[18] A task oriented training program, consisting of 6 tasks, which were designed to improve hemiparetic upper extremity function, was performed for 40 min/day, 4 days/week for 4 weeks. The functional status of the affected hand and fMRI were assessed before and after the task oriented training program. fMRI were performed parallel with timed finger flexion-extension exercises at a fixed rate and concluded that cortical reorganization was induced by the task oriented training program in chronic hemiparetic stroke patients.

Fugl Meyer Assessment (FMA-UE) showed there was more improvement in post measurement in experimental group as compared to conventional group.

According to current evidence, mechanisms underlying improvement from repetitive training include the recruitment of ipsilateral corticospinal pathways, increased control from the contralateral hemisphere and normalization of inhibitory mechanisms.

Chollet et al., reported that ipsilateral corticospinal pathways have been demonstrated to exist as parts of the CST that do not cross at the pyramidal decussation.[19] The estimated percentage of uncrossed pathways is 10–20%, and some researchers suggest that their activation could be facilitated with bilateral training.[20]

Repetitive movements seem to be particularly effective in rehabilitation and motor learning.[21] The major mechanisms are attributed to synaptic plasticity and synaptic efficacy in existing neural circuits.[22] Alternative descending pathways, secondary and ipsilateral motor areas and other brain areas implicated in motor conventional can also contribute to motor recovery.

Natural symmetry of the human body and neural structures allows for easy duplication of this bimanual motions, since a stroke typically only affect one side of the body. the idea of bimanual rehabilitation is to physically couple the individuals arms allowing the healthy arm to assist the impaired in making motions.

Hellat M et al reported that the recovery of coordinated motor function after stroke onset has been associated with the practice of upper limb movements that required the activation of homologous muscles.[23] The repetitive bimanual coordinated movements enhanced upper limb corticomotor (CM) excitability and motor function post stroke.

The results of this study are in agreement with the studies of Diserens K et al.[24] who had conducted a study on repetitive arm cycling in post-stroke patients and found that arm cycling is beneficial in improving motor control. Whitall J et al conducted a study on repetitive arm movements in chronic stroke patients and which shown that repetitive arm movements with rhythmic auditory cueing improves motor function by reorganization in contralateral motor networks.[25]

In a study conducted by Lin et al.[26] on chronic stroke patients who had the disease for at least 6 months, the group that performed bilateral upper extremity exercises showed further improvement in spatial-temporal conventional of the affected upper extremity and Fugl-Meyer assessment scores than the conventional group.

Modified Ashworth Scale (MAS)

Spasticity were reduced in both the groups but experimental group showed more reduction in MAS grade then conventional group. Spasticity and exaggerated co-contraction are often the main reason for functional deficits in arm movements.

In elbow flexors there was 58.82% of patients had MAS grade reduction by two grades in experimental group compared to conventional group in which 41% patients MAS grade reduced by two. There was reduction in MAS score by one grade equally in both the groups. Only 5.88% patients did not show any reduction in experimental group compared to conventional group in which 23.52% did not show reduction in MAS grade.

In shoulder flexors there was 64.70% of patients had MAS grade reduction by two grades in experimental group compared to conventional group in which 52.94% patients MAS grade reduced by two. There was reduction in MAS score by one grade equally in both the groups. Only 5.88% patients did not show any reduction in experimental group compared to conventional group.

The reduction in spasticity in the conventional group can be attributed to inhibitory pressure which dampens muscle tone during the conventional exercises. Pressure from prolonged weight bearing on hand dampens flexor tone. Also, stretching to tight muscles was included in conventional exercise protocol. Slow, maintained stretch applied at maximum available lengthened range activates golgi tendon organs and inhibits muscle tone due largely to peripheral reflex effects (stretch-protection reflex).[27] By sustained muscle stretch, spastic muscle hypertonus has been diminished and late EMG-potentials are reduced or have disappeared completely.[28] There is positive evidence supporting the immediate effects of single stretching session.[29] There is evidence supporting the effectiveness of weight-bearing exercises for reduction in spasticity in children with cerebral palsy.[30]

Reduction in spasticity in experimental group may be due to repetitive movement which reduces resistance of muscle. Some mechanical repetitive exercises are effective against spasticity and the excitability of motor neurons can be affected and changed by the exercise like circle movement of legs and these results are confirmed by the MAS in clinic Habituation of reflex activity to repeated stretch may result from a decrease in synaptic transmission caused by inactivation of presynaptic calcium channels. Lamontagne et. al., found that a decrease in resistance during repeated passive movements without concurrent changes in electromyographic activity was attributable to thixotropic characteristics of the stretched tissues.[31] According to Katz resistance against passive movement should diminish after repeated motion.[32] Dietz V, Berger W and O'Dwyer NJ concluded the mechanical changes in the musculotendinous unit may also be involved.[33,34] According to Katz half-hour cycling intervention may reflect a change in the reflex properties.[32] In his study on spastic hypertonia, a clear distinction is made between the intrinsic muscle changes and the altered reflex properties that contribute to heightened muscle tone. MMAS score improve after 30 minutes of passive cycling. In addition, Rosche et. al.,[10] reported that the mean F-wave amplitude, the mean F-wave/M-response ratio, and the maximum F-wave/M-response ratio were significantly lower after leg training with a motorized exercise-bicycle, documenting a decrease in the reflexive component of spasticity. CPM reduces the H-reflex amplitude immediately after the intervention[35] and also it could be due to carry over effect of conventional exercise.

The results of this study are in agreement with the study by Durner et al., who evaluated spasticity by the Ashworth rating scale immediately after training on an arm-trainer.[11] Furthermore, Roesche et al. reported that the mean F-wave amplitude, the mean F-wave/M-response ratio and the maximum F-wave/M-response ratio were significantly lower after leg training with a motorized exercise bicycle, documenting a decrease of spasticity.[10]

Yasaman Barzi et al, **found that arm cycling can access inter-**limb pathways after stroke and activate spinal control mechanism that may reduce spasticity.[36] Diserens K et al,[24] had conducted a study on repetitive arm cycling in post-stroke patients & found that arm cycling is beneficial in reducing spasticity and improving motor control. Stoykov et al, found in one study (n = 24) that indicates bilateral training may improve spasticity in chronic stroke.[37]

However, our results do suggest that the current content of conventional therapy is not optimal, at least for chronic subjects. More emphasis could be placed on repetitive practice of movements, and the use of maximal effort during these movements should be considered. Moreover, we have shown that these repetitive movements are effective if facilitated by an arm ergometer.

CONCLUSION: Arm Ergometry training with conventional therapy brings about more improvement in motor function than conventional physiotherapy alone.

Limitations: Small sample size, Participants of single geographic location, Carry over effect of the study has not been studied, Cardio respiratory effects have not been measured, and Elbow extension range has not been measured.

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