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Effect of EMG-triggered stimulation on hand function in patients with stroke

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Abstract

Background: The primary source of disability in individuals over the age of 50 years is because of complications of atherosclerotic vascular diseases. Majority of the patients have residual paralysis which affects their functional ability to do their activities of daily living. Motor dysfunction leads to major post stroke disability and handicaps them to conduct activities of daily living. About 87% of motor impairments of upper limb and hand occur in acute stage and that impairment which continue with time lead to restriction of ADL's. **Objective**: To investigate the effect of EMG-triggered stimulation in the affected hand of chronic stroke patients. **Materials and methods:** Experimental trail in which 15 chronic stroke patients with impaired hand function were given EMG- triggered stimulation Primary outcome measure was the Jebson Taylor hand function test, voluntary control grading for hand. **Results**: There was significant improvement ($p<0.05$, CI=95%) seen in the components of Jebson Taylor test when results of pre and post readings were compared. **Conclusion**: This study concludes that EMG-triggered stimulation is effective on hand function in stroke patients and can be used as an adjunct to conventional rehabilitation to achieve a good prognosis in terms of functional improvement of hand.

Keywords:-EMG-triggered stimulation, Jebson Taylor Hand Function Test, Stroke patients, Voluntary Control.

Introduction

Stroke is hinderance of blood supply to the brain tissue due to any obstruction or restriction of a blood vessel by a clot formation inside the lumen or bursting of any blood vessel. This leads to lack of oxygen and nutrients causing damage to the neurons. Hence, this may result into physical and/or mental disabilities. The symptoms may be dependent on duration of the attack, part of brain tissue affected and damaged, and also the size of the core area and the penumbra area affected. According to the latest World health Organization (WHO) reports, about 15 million people suffer from stroke annually. Stroke is the second leading cause of death and fourth leading cause of disability according to the reports of the world consensus[1-5].

The primary source of disability in individuals over the age of 50 years is because of complications of atherosclerotic vascular diseases. Majority of the patients have residual paralysis which affects their functional ability to do their activities of daily living. Motor dysfunction leads to major post stroke disability and handicaps them to conduct activities of daily living. About 87% of motor impairments of upper limb and hand occur in acute stage and that impairment which continue with time lead to restriction of ADL's. The majority of stroke patients consider hand function to be the major problem as there is difficulty in performing fine motor skills. Various fine motor skills in which an individual is engaged are writing, dressing-undressing, buttoning-unbuttoning, zipping-unzipping, and latching-unlatching of the doors, lifting small objects like beans, pebbles, etc.; self-feeding with spoon or hand. The above mentioned activities require fine motor skills of precision, prehension, grasp. After an upper motor lesion these tasks are near to impossible for a post stroke patient[2,3].

After an attack of stroke the clinical picture of the patient may vary depending on the area of focal deficit. There may be changes in level of consciousness, sensory impairments, and motor impairments, cognitive impairments, perceptual impairments, speech impairments, coordination impairments and balance & gait impairments. After an acute focal deficit the impairments resolve spontaneously within three weeks period provided that the brain tissue swelling is subsided. The neurologically affected cells lead to permanent damage. When the metabolic reserves decrease there is a requirement of high levels of energy. Hence, there is a requirement of opulent blood perfusion for the delivery of glucose and oxygen to the brain parenchyma. Cerebral blood flow is 17% of an individual's cardiac output. The cerebral blood flow is dependent on the levels of oxygen, carbon dioxide, pH, local vasodilatation or vasoconstriction. Any change in the viscosity of the blood or intra cranial pressure will result into changes in the cerebral blood flow[6,7].

Deprivation in the levels of oxygen and energy level (ATP) below normal metabolic substrates lead to the pathophysiologic changes in the brain tissue. The affected area of the brain parenchyma is termed as the "core are" whereas the area surrounding the core area which consists of some viable neurons is termed as the "penumbra". The functioning of the neurons cease when they are unable to maintain the normal Trans membrane ionic gradients. This leads to ions and electrolyte imbalance which in turn causes apoptosis and neurotic cell death cascades; ultimately leading to the infarction.

The brain homunculus represents the anatomical partitions of mtor and sensory cortex. It depicts the perception of the human body parts within the brain area which basically describes the distribution of the neurons to a particular body segment.The size of the actual body parts is not proportional to its cortical homunculus presentation. The areas such as hands, lips and face occupy unduly large areas of the cortex when compared to the trunk or legs. This contributes to the large proportion if cortical space which is required to control the composite and fine movements of the hand and fingers. Hence, these body parts have wide spread innervation owing to the significance of the fine motor skills. The understanding of the brain homunculus helps to describe the pattern of sensory and motor skills. Loss of function will widely depend on the artery damaged and the region it supplies[7,8,9].

EMG-triggered stimulation: Electromyography-triggered stimulation is a non-invasive technique designed for stimulating a muscle contraction. It also measures the electrical activity that occurs during muscle contraction and relaxation. It is used to help the patients learn new tasks or modify existing motor patterns. Auditory and visual cues provide instantaneous feedback. When the EMG-triggered stimulation is applied the electrical stimulation is triggered by the voluntary action of muscle to be stimulated. One of the prerequisite for EMG-triggered stimulation is the ability to tense the paretic muscle voluntarily to the extent that an EMG signal can be measured by a surface electrode. This corresponds to grade 2 muscle strength on MRC scale from 0 to 5 (grade 2= full range of motion in gravity eliminating plane). In majority of the devices, the threshold of the EMG signal to induce an electrical stimulation can be present an adjusted to grade 2. The electrical stimulation is triggered by EMG signal of the muscle activity registered by the surface electrode. Activation of an appropriate muscle induces an electrical contraction and the movement started voluntarily is concluded by electrical stimulation. Unlike the routine electrical stimulation during which a patient follows pre-given electrical movement pattern, during EMG-triggered stimulation the patient has to start the motion pattern on their own. This requires more personal motor and cognitive control than simple electrical stimulation. The EMG-triggered stimulation depends on spasticity, existing muscular strength (> grade 2/5 on MRC grading system), range of motion of affected extremity and the general physical and cognitive condition of the patient[13,14,15].

Jebson Taylor hand function test is one of the common assessment tools for assessing hand function of dominant and non-dominant side. This test consists seven sub tests involving activities of daily living including gross motor and fine motor activities; (i) Writing, (ii) Simulated page turning, (iii) Lifting small common objects, (iv) Stacking checkers, (v) Simulated feeding, (vi) Lifting large light objects (vii) Lifting large heavy objects. The time required to complete each sub-tests noted pre and post.

Need of the study

The prevalence of stroke is about 424/100,000 in urban area region. Long term disability is often associated with persistent impairment of the hand. Motor impairment of hand is a common manifestation after stroke and directly impacts the stroke survivor's function and quality of life. Despite the development of many programs for recovery after stroke, the effectiveness of rehabilitation in improving functioning and quality of life for patients with deficit more than 6 months after stroke has not been definitively shown. And the improvement in the upper limbs and hand is more limited than recovery of gait, even with neurological rehabilitation. There is need of developing therapeutic approaches for enhancing the hand function post stroke[7].

Moreover, this study is done in low cost setting for its use in clinical set-ups. On the other hand, EMG-triggered stimulation may reduce disability by improving recovery of volitional movement (therapeutic effect) or by assisting and replacing lost volitional movement (neuroprosthetic effect).

This study describes the effect of EMG-triggered stimulation for hand stroke rehabilitation and summarizes the research literature. EMG-triggered stimulation produces muscle contraction of target muscles for the purpose of restoring motor function by stimulating the required motor points[11,12].

As there are controversial reports about the effectiveness of electrical stimulation on spasticity rehabilitation, this study has been designed to study the effect of EMG-triggered stimulation on hand function in stroke patients.

Procedure

The study was conducted on 15 hemi paretic patients with stroke who came for neuro rehabilitation in physiotherapy outpatient department in Dr. D. Y. Patil College of physiotherapy, Pimpri, Pune. The subjects were given EMG-triggered stimulationon on hand. Those subjects who had; (1) stroke $\geq$1 year; (2)plateau in the maximum motor recovery after a conventional neuro rehabilitation; (3) <grade 2 on modified ashworth scale (4) no visual problems and cognitive impairment (MMSE >23) were included in this study. All the subjects had understood the purpose of this study, and provided written, informed consent prior to participation in this experimental study. This study was approved by the institutional review board[8].

Intervention

Patients received EMG-triggered stimulation for 30 minutes, on alternate days for 3 weeks. All the patients were given same conventional neuro rehabilitation. Patients received EMG-triggered stimulation on three muscles; extensor digitorum communis (EDC), dorsal interossei and abductor pollicis brevis on the affected hand. Two sets of 45 contractions were applied to each above mentioned muscles with one minute break in between.

The EMG-triggered stimulation included three surface electrodes; an active electrode, a reference electrode, a ground electrode and a stimulating hand held electrode. This stimulator could simultaneously perform acquisition of the EMG signal and transmission of electrical stimulation. Exact electrode placement was achieved by stimulating synergic group to find the target muscles. At first, the target threshold was set up to the limit of voluntary concentric contraction. When the subjects voluntarily performed finger extension till the threshold level, electrical stimulation was triggered to assist the muscle to achieve full range of motion. The parameters set to the EMG machine were; 0.1 s ramp, 5 s symmetrical rectangular biphasic constant current at 35 Hz, pulse width micro seconds, 2 s ramp down, 10-20 mA. A 4 seconds rest period was set between contractions to avoid muscle fatigue. Electrical stimulation was set to start after 20 seconds if the subject could not voluntarily exceed the target threshold. The EMG session was performed for 30 minutes once a day for 3 days/week (alternative working days) for 3 weeks[8,935,36].

Assessments were done at baseline and at the end of the treatment period (3 weeks). The outcome measures used in this study were the Jebson Taylor Hand Function Assessment, Voluntary control grades for hand explained by Brunstrom and Modified Ashworth scale. Basic demographic data and details of stroke were obtained from case notes.

Statistical analysis

The data collected were analyzed using SPSS (version 15). Total 15 participants were recruited in the study and statistical analysis was obtained from the observational values obtained from these participants before and after the treatment. Time taken to perform each given activity in Jebson taylor hand Assessment was calculated.

Table No-1
Gender distribution

Number of males	Number of females	Total
8	7	15
53.33%	46.66%	100%

Table No-2
Mean Age distribution

	Mean Age
Males	51.5
Females	58.8

Table No-3
Mean Jebson Taylor Hand function test score (Pre and Post) within the group

Jebson taylor hand function test	Pre Mean	Post Mean	SD	p value	t value
Writing	1.25	1.23	1.07	0.95	0.06
Simulated page turning	0.54	0.35	0.22	0.005	3.31
Lifting small common objects	0.81	0.57	0.40	0.03	2.36
Simulated feeding	0.73	0.39	0.55	0.03	2.38
Stacking checkers	0.60	0.34	0.41	0.03	2.42
Lifting light objects	0.69	0.45	0.26	0.005	3.37
Lifting heavy objects	0.61	0.38	0.35	0.02	2.55

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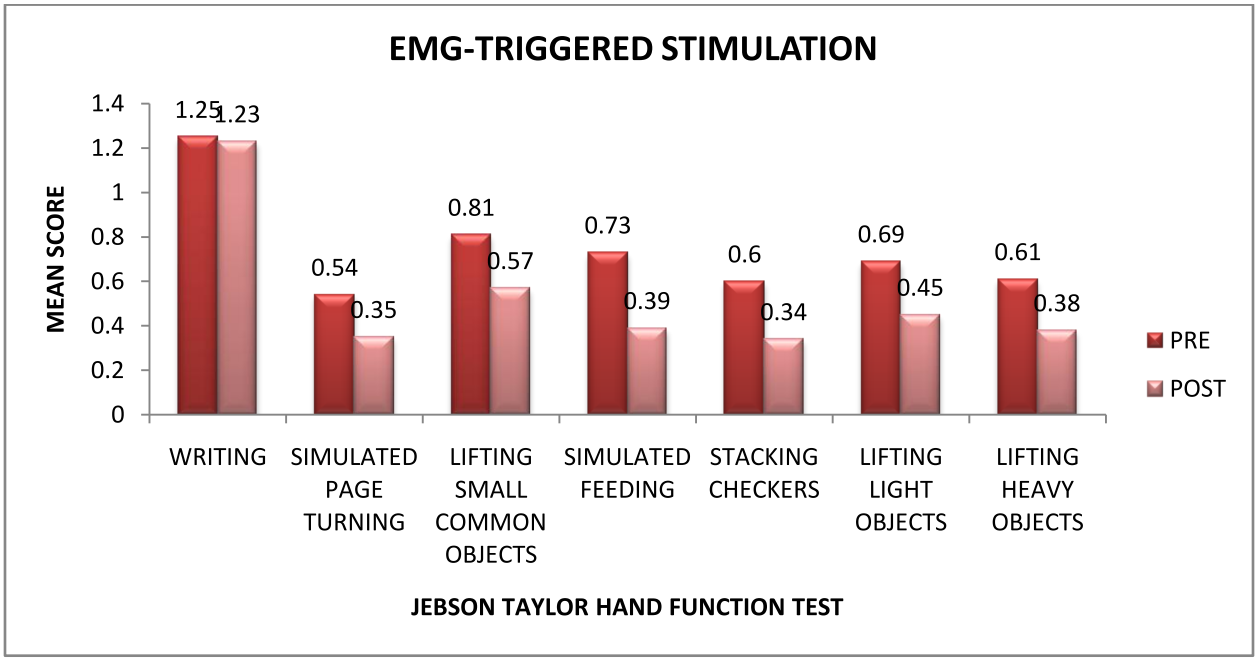
Graph No-1



Interpretation: The time required to complete all the components of the Jebson Taylor test was reduced after intervention. The difference between the pre and post within the group was statistically significant in all the components except in writing component ($p<0.05$)

Result

In this study, 15 stroke patients were included and were given EMG-triggered stimulation on hand nd statistical analysis was done. All the patients were assessed for hand function according to Voluntary Control grading for hand as explained by Brunstrom and by Jebson Taylor hand Function test. They were assessed pre and post intervention.

Table 1 &table 2 indicate the demographic distribution of gender and mean. Group A consisted of 53.33% of males and 46.66% females of females respectively. The mean age of males in was 51.5 and that of females was 58.8 respectively.

The normality of the data was determined by using Shapiro Wilk test in Win Pepi software ($p>0.05$). If the data were normally distributed the intra-group (within) analysis was done by applying paired t test whereas the inter-group (between) comparison was done by applying unpaired t test. In contrast, if the data were not normally distributed, the intra-group analysis was done by using Mann-Whitney Rank Sum Test whereas the inter-group analysis was done by using Wilcoxon Signed Rank Test. The statistical significance for inter group and intra group analysis was considered when $p<0.05$ at 95% confidence interval.

Table 3 and graph 1 states the comparison of pre and post readings of Jebson Taylor hand function test. The time required to complete all the components of the test was reduced after intervention with EMG-triggered stimulation. The difference between the pre and post within the group was statistically significant ($p<0.05$) in all the components except in writing component where $p=0.95$. This suggests that treatment with EMG-triggered stimulation along with conventional therapy is effective in improving hand function of stroke patients

Discussion

The present study was done to analyse the effectiveness of EMG-triggered stimulation on hand function in stroke patients. It was an experimental study where 15 stroke patients were recruited (n=15). The study was conducted in Dr. D. Y. Patil College of Physiotherapy, Pune. The treatment was given for 3 weeks; alternate working days. The hand function was assessed before and after the intervention of 3 weeks. The outcome measures used for assessing the hand function were Jebson Taylor hand function test and Voluntary Control Grading for hand according to Brunnstrom stages of recovery. The participants showed improvement after intervention functionally. There was statistical significant difference found in the outcomes after treatment with EMG-triggered stimulation.

Hwa Kyung Shin, et.al. conducted a study on 'Cortical effect and functional recovery by the electromyography-triggered neuromuscular stimulation in chronic stroke patients'. In their study they used a similar technique of application EMG-triggered stimulation as that of ours, the spectral variable was the determination functional MRI (fMRI). They investigated the effect of EMG-triggered neuromuscular electrical stimulation on functional recovery of the hemi paretic hand and the related cortical activation pattern in chronic stroke patients. The EMG-triggered stimulation was applied to the wrist extensor mainly the Extensor Digitorum communis (EDC) for 10 weeks. Four functional tests (box and block, strength, the accuracy index, and the on/offset time of muscle contraction) and fMRI were performed before and after treatment. Their study concluded that 10-week EMG-triggered stimulation can induce functional recovery and change of cortical activation pattern in the hemi paretic hand of chronic stroke patients. Their results paralleled ours in indicating the benefit of using EMG-triggered stimulation as we got significant improvement in the performance of Jebson Taylor hand function test and all its sub tests includingwriting, simulated page turning, lifting light common objects, stacking checkers, simulated feeding, lifting large light objects and lifting large heavy objects[8].

A study titled 'Electromyogram-Triggered Neuromuscular Stimulation for Improving the Arm Function of Acute Stroke Survivors: A Randomized Pilot Study' documented by **Gerard Fransisco et. al.** demonstrated a randomized pilot study on 9 stroke patients having upper extremity involvement of first unifocal non-hemorrhagic stroke. All the patients had detectable EMG signal from the surface of paretic extensor carpi radialis and voluntary wrist extension in synergy or in isolation. A 30 min intervention combined EMG-triggered stimulation and strengthening exercises during the rehabilitation stay. Their study concluded that EMG-triggered stimulation enhances the arm function of acute stroke survivors as there was a significant difference in the Fugl Meyer Score when compared with control groups. Similar to their findings, this study also found significant gains in the scores of Jebson Taylor hand function test and its sub-tests like writing, simulated page turning, lifting light common objects, stacking checkers, simulated feeding, lifting light large objects and lifting large heavy objects[16].

Conclusion

This study concludes that EMG-triggered stimulation effective in improving motor function of hand in stroke patient. It can be used as a adjunct therapy to improvise the hand function in stroke patients for early and good prognosis.

Limitations and future scope

Limitations-

a) The sample size was small

b) Follow up after the study was not considered

c) Carry over effect of the interventions was not studied

Future scope-

a) Extensive treatment duration (>3 weeks) can be set.

b) A randomized controlled trial can be carried out to study the effectiveness of this modality

c) Other electrical modalities can be compared with EMG-triggered stimulation to analyse the best ones useful in stroke patients.

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