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Effect of Graded Motor Imagery on Upper Limb Function in Stroke Patients-A Case Study

Rutu Parikh[1] Dr. Sumitra Sakhawalkar[2], Dr. Sayli Paldhikar[3], Dr. Snehal Ghodey[4]

[1]*Student, Maeers Physiotherapy College, Mumbai, Maharashtra*
[2]*Assistant Professor, Maeers Physiotherapy College, Mumbai, Maharashtra*
[3]*Professor and Head of the Department, Maeers Physiotherapy College, Mumbai, Maharashtra*
[4]*Principal, Maeers Physiotherapy College, Mumbai, Maharashtra*

ABSTRACT

Background and purpose-GMI is a dynamic state during which the representation of a specific motor action is internally reactivated within working memory without any overt motor output. Imagery of movement activates largely the same brain areas that are activated when movement are actually performed. Motor impairment after stroke is a major cause of permanent disability. Recovery of upper extremity is crucial in order to perform activities of daily living but is often variable and incomplete. It is proven that prolonged passive movement therapy in stroke patients neither improves performance nor induces cortical plasticity. And an early initiation of active movement becomes difficult due to lack of motor performance. Graded motor imagery (GMI) can be used to bridge this gap between passive therapy and active therapy.

Keywords: *Graded Motor Imagery (GMI), Stroke, Mirror Therapy (MT), Upper Limb Function.***1.INTRODUCTION**

1. INTRODUCTION

A stroke also called as cerebrovascular accident (CVA) is a rapidly developing loss of brain function due to disturbance in blood supply of brain caused by blocked or burst blood vessel. (1) WHO defines stroke as a neurological deficit of a cerebrovascular cause that persists beyond 24 hours. (2) There are two types of stroke are ischemic and haemorrhagic strokes. (1) Ischemic stroke is the most common type, affecting about 80 percent of individuals with stroke, and results when a clot blocks or impairs blood flow, depriving the brain of essential oxygen and nutrients. Haemorrhagic stroke occurs when blood vessels rupture, causing leakage of blood in or around the brain. (1)

Stroke is one of the leading causes of death and disability in India. (3) Stroke is no longer a disease of the developed world. Low and middle income countries like India account for 85.5% of total stroke deaths worldwide and number of disability adjusted life years in these countries was approximately seven times than the high income countries. (4)

Motor impairments frequently occur after stroke. It is estimated that after acute stroke approximately 80% of the patients have some form of motor impairment. About 20% of these patients regain at least part of their lost motor functions in the subsequent months; thus leaving 50-60% patients with chronic motor disorders. These disorders are often related to balance, timing and co-ordination, and to loss of strength and/or spasticity in the affected limbs. These motor impairments may substantially compromise quality of life after stroke. (5)

The most common deficit after stroke is hemiparesis of contralateral upper limb, with more than 80% of the stroke patients experiencing this condition. (6) The common manifestations of upper extremity motor impairment include-paresis, muscle weakness, changes in muscle tone, joint laxity and impaired motor control. (7) These impairments lead to loss of upper limb function leading to activity limitation and participation restriction causing a decrease in quality of life. (8) Therefore, much therapeutic effort is invested in functional recovery of motor skills after stroke. This functional recovery is in the form of neurological recovery which is defined as-recovery of neurological impairment and is often the result of brain recovery and reorganization. It has been increasingly recognized as being influenced by rehabilitation. Most spontaneous recovery occurs during the first 3 to 6 months of stroke. (9)

This brain reorganization occurs by a phenomenon called as neuroplasticity. Neuroplasticity is also known as brain plasticity or brain malleability is the ability of the brain to reorganize itself by forming new neural connections throughout the life. It allows the neurons in brain to compensate for injury and disease and to adjust the activities in response to new situations or changes in environment. [10]

Graded motor imagery (GMI) is a form of rehabilitation technique which uses the principles of motor recovery and neuroplasticity to promote graded cortical brain activation. [11] GMI is a dynamic state during which the representation of a specific motor action is internally reactivated within working memory without any overt motor output. [12] Imagery of movement activates largely the same brain areas that are activated when movement are actually performed. (13) GMI consists of three steps-

a. Implicit motor imagery (IMI)-also called as left right discrimination. Consists of identifying whether a limb is right of left.
b. Explicit motor imagery (EMI)-consists of imagining a movement without actually performing it.
c. Mirror therapy (MT)-consists of a technique that uses visual feedback about motor performance using a mirror box. [13]

GMI has been successfully used in treatment of persistent and complex pain states like-complex regional pain syndrome and phantom limb syndrome. [14 15] abundant evidence is also available regarding practice of motor imagery in athletes and healthy individuals. GMI is also helpful in the treatment of conditions like carpal tunnel syndrome, osteoarthritis, chronic neck and back pain. [16]

In neurological conditions like stroke, GMI is considered as a “backdoor” to accessing the motor system and rehabilitation at all stages of stroke recovery because “it is not dependent on residual functions yet still incorporates voluntary drive.” [17]

De vries and Mulder gave the concept that in stroke patient’s motor system can also be activated “offline” by motor imagery or observing movements. [5] The presence of mirror neurons goes hand in hand with this concept. These are neurons which fire both when we perceive (observe and imagine) the action as well as perform the action. [18]

The above-mentioned concept shows that motor imagery, observation and execution are closely related phenomena sharing neural control processes. [5]

Motor impairment after stroke is a major cause of permanent disability. Recovery of upper extremity is crucial in order to perform activities of daily living but is often variable and incomplete. It is proven that prolonged passive movement therapy in stroke patients neither improves performance nor induces cortical plasticity. And an early initiation of active movement becomes difficult due to lack of motor performance. Graded motor imagery (GMI) can be used to bridge this gap between passive therapy and active therapy. [17]

Unlike active and passive motor therapies, graded motor imagery, in principle, is not dependent on residual function but still incorporates voluntary drive. Importantly, in the primate, primary motor cortex (M1) is directly involved in motor imagery as suggested by direct cellular recordings. In patients with stroke, motor imagery may therefore provide a substitute for executed movement as a means to activate the motor network. [19]

Many studies have been performed using motor imagery, mirror therapy and hand laterality recognition separately, but a few studies have been performed using all three together.

2. CASE DESCRIPTION

Subject 1-The subject was a 55-year-old male who suffered from a left cerebrovascular accident with subsequent right hemiparesis and non-fluent aphasia one month before the study began. He had a history of hypertension since 10 years. A month ago the patient experienced headache, giddiness and heaviness in the right side of his body followed by loss of consciousness while he was working. He was immediately brought to the emergency department of a nearby hospital where he gained consciousness after he was given the required medical intervention. An MRI report was performed on the same day which revealed an acute left PCA infarct. Since then he is admitted in the in-patient department of the same hospital with the complaints of inability to move the right upper and lower limbs, inability to walk or use right upper and lower limbs during ADLs and inability to speak fluently. Currently the patient requires assistance during ADLs like bathing, grooming, dressing eating etc. He also requires moderate to maximal assistance for transfers. Patient is an electrician with right as the dominant side. He resides with his wife in a rural environment on the ground floor of a building. His job demands coordinated fine as well as gross motor activities, maintaining a position for a long period, and physically challenging activities like squatting, heavy lifting, climbing up on a chair/stool, overhead activities.

Subject 2-the subject was a 60-year-old male who suffered from a right cerebrovascular accident with subsequent left hemiparesis 15 days before the study began. The patient had a history of hypertension since 15 years and diabetes myelitis since 5 years. 15 days ago the patient experienced heaviness in his left upper and lower extremities while he was sitting in his house. He was immediately brought to the nearby hospital where he was admitted to the in-patient department and given medical intervention. MRI done on the next day revealed acute non-haemorrhagic infarct of the right PCA. He has been admitted in the same hospital since then with the following complaints- difficulty in moving the left upper extremity and using it in ADLs and difficulty in walking with loss of balance while walking. Currently the patient requires assistance during ADLs like bathing, grooming, dressing eating etc. and requires a walker during ambulation. He resides in a rural environment with his wife and children. By occupation he is a farmer with right as his dominant side. His job demands coordinated gross as well as fine motor activities, occasional squatting and overhead activities.

3. METHODOLOGY

Study design-descriptive study

Sampling technique-purposive sampling with chits

Materials- Laptop

- Mouse attached to laptop
- Mirror box
- Pen paper
- Fugl Meyer scale [FMAS]
- Chedoke arm and hand activity inventory. [CAAHAI]
- Movement imagery questionnaire [MIQ-R]
- And materials required in performing the scale

Inclusion Criteria-Subjects between age 35 to 65.

Who have experienced one episode of unilateral stroke only.

Gender -Both males and females.

Type-Both ischemic and haemorrhagic strokes

Duration from episode-between 1 to 6 months

Mini mental state examination score >23

A score of 25 and above on Movement imagery questionnaire [MIQ-R]

Exclusion Criteria-Individuals with musculoskeletal disorder

Neurological disorder other than stroke

Visual impairment

Systemic diseases

Patient who is non cooperative

Patients with psychological problems

Outcome measures-

- Fugl Meyer scale [FMAS]-Time frame-before and after 4 weeks

The upper extremity section of this scale was used. (24)

- Chedoke arm and hand activity inventory. [CAAHAI] (25)

Time frame-before and after 4 weeks

Intervention-(20)

Duration-Total number of weeks-4 weeks

Sessions per week-5 sessions

Total number of sessions-20 sessions

Time allotted to each session-90min-60min of GMI 30min for conventional therapy

Conventional therapy-Passive range of motion exercises for upper limb, weight bearing exercises for upper limb, task oriented exercises for upper limb, positioning of upper limb, lower extremity conventional exercises, functional mobility training, balance and gait training.

Fig-1 Conventional Therapy-Passive Range of Motion Exercises

Graded motor imagery

Graded motor imagery (GMI) has 3 steps

- Implicit motor imagery(IMI)
- Explicit motor imagery(EMI)
- Mirror therapy(MT)

Each step was introduced to the patients in a graded manner. Each step was progressed from easy to difficult level gradually. Steps 2 and 3 were introduced to the patient in the last two sessions of the preceding step.

➢ IMI included a training based on hand discrimination task. An online software was used called as “orientate”. It is a laterality recognition program which displays pictures of left and right hands randomly. It calculated the time consumed by the patient to guess the answer as well as recorded the progress of the patient over time.

60 pictures were displayed on a laptop screen and the patient had to identify whether the picture is of the right and or left hand.

A total of 7 sessions were conducted of which 5 were purely of IMI last two consisted of IMI and EMI.

Following target was aimed to be achieved at the end of this step-

- Accuracy of 80% and above.
- Similar results of left and right hands.
- Response time of 2 seconds +/- 0.5 seconds.

➢ EMI Training consisted of imagining movements without actually performing it. It was introduced in last two sessions of IMI.

Standardized scripts were used to explain the task to the patient in detail.

The scripts were translated to the language the patient was comfortable with by a professional.

Initially easy tasks were asked to be imagined and then gradually the complexity of skill was enhanced.

List of tasks to be imagined-

To lift the arm

To open a jar

To pour a glass of water

Draw a line with a ruler

To button up a shirt

Carry a bag up the stairs

- Mirror therapy MT-using mirror box [13]

Is a technique that uses visual feedback about motor performance to improve rehabilitation outcomes?

It was introduced in the last two sessions of EMI.

It involved the patient placing their affected hand and forearm inside the mirror box and their unaffected arm and forearm in front of the mirror

The patients were then instructed to perform a movement with their unaffected arm and to simultaneously attempt to copy the movement with their hidden affected arm [8, 10]

Fig-2 Mirror Box Therapy

4. GRAPHICAL ANALYSIS

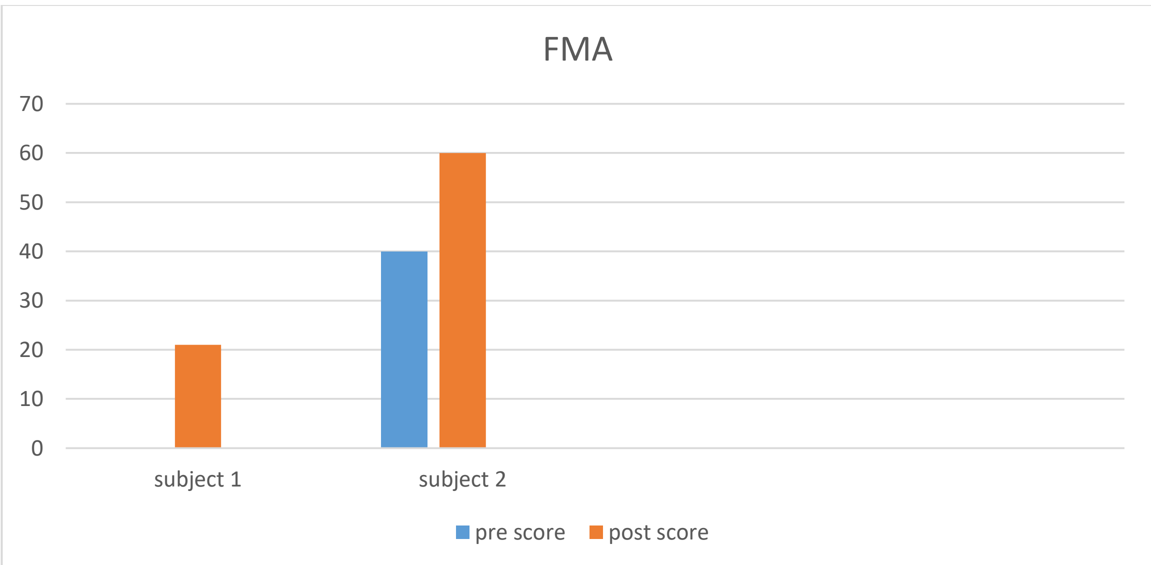

Chart -1 pre and post scores of FMA scale

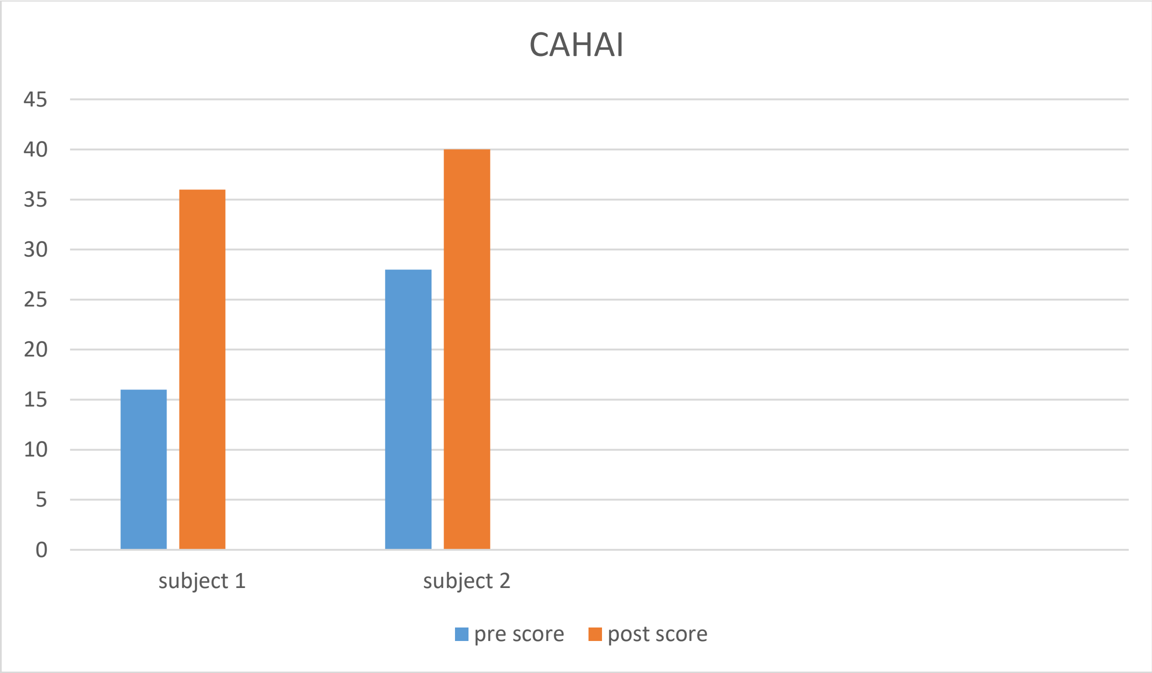

Chart-2 pre and post scores of CAHAI scale

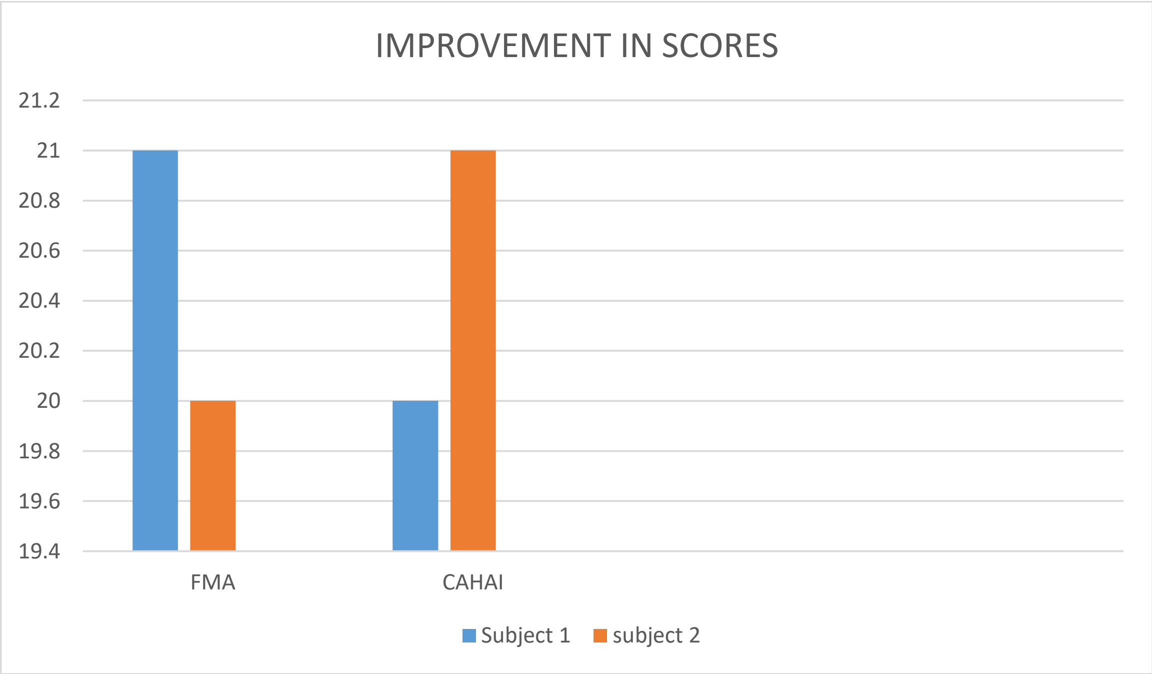

Chart-3 improvement in scores on both scales

Chart 1 shows the pre and post scores of subject 1 and subject 2 on FMA scale.

Chart 2 shows the pre and post scores of subject 1 and subject 2 on CAHAI scale.

Chart 3 shows the improvement in scores on both scales. 21 for subject 1 and 20 for subject 2 on FMA while 20 for subject 1 and 21 for subject 2 on CAHAI.

5. RESULTS-paired t test was used for statistical analysis.

	p-value	t-value	significance
FMA	0.0155	41	**SIGNIFICANT**
CAHAI	0.0155	41	**SIGNIFICANT**

The one tailed t value for both the scales was 41 hence the p-value was 0.0155 which is significant at 95% confidence limit.

6. DISCUSSION

This descriptive study was conducted to see the effect of graded motor imagery on upper limb function in stroke patients.

Based on the statistical analysis mentioned in the result above, current study showed statistically significant improvement in upper limb function on FMA and CAHAI after the treatment compared to the pre-treatment scores.

Subject 1 with a pre-treatment score of 0 on FMA and 16 on CAHAI showed drastic improvement in following components on FMA-development of flexor synergy, movements combining synergies and hand function. While on CAHAI following components showed significant improvement-buttoning up a shirt, opening a jar and cutting a medium resistance putty. At the end of the treatment duration the patient became less dependent on family members for performing ADLs.

Subject 2 with a pre-treatment score of 40 on FMA and 28 on CAHAI showed drastic improvement in following components on FMA-development of flexor synergy, movements out of synergies and hand function. While on CAHAI following components showed significant improvement-buttoning up a shirt, putting on a zipper, drawing a straight with a ruler, and applying paste in a toothbrush. At the end of the treatment duration the patient could perform some of the ADLs independently like grooming eating, while other ADLs he could complete with minimal assistance.

According to past studies the estimated clinically important difference of the upper extremity FMA score is ranged from 4.25-7.25 points. Both the patients showed a difference that was higher than this range.[25]

The results obtained are similar to that of a study conducted by By Decety and colleagues. They revealed that there is involvement of the premotor area, supplementary motor area, cingulate area and parietal cortical area as well as basal ganglia and cerebellum not only during actual movement but also during imagination of movement. They proposed that graded motor imagery shares neural mechanism with processes used in motor control. They emphasized the importance of activation of the pre-frontal cortex during GMI and stated that this helps in maintaining dynamic motor representations in working memory. Thus they gave a general idea that prefrontal cortex is responsible for the creation and maintenance of explicit representations that guides action. This might have been one of the reasons for the improvement in upper limb function seen in our study. [13]

According to a systemic review conducted by Katleho Limakasto and colleagues in 2016 in south Africa Laterality recognition/implicit motor imagery tasks activate premotor and supplementary motor areas, with an exception of the primary motor cortex (M1) cortex. IMI is therefore fundamental in the preparation for subsequent phases of GMI programme. Thus this could have been one of the mechanisms how IMI contributed for the improvement of upper limb function in our study. [15]

In a study on motor imagery by Devries and Mulder it was explained that Explicit motor imagery activates the somatosensory (S1), premotor and M1 cortices contralateral to the paretic extremity. Over the past decade, neuroimaging and psychophysical research on motor control has shown that there are striking similarities between real and imagined movements. These findings have led to a theoretical term called" the simulation hypothesis". This hypothesis states that overt movement and motor imagery (covert movement) are essentially based on the same processes. Movement execution, motor imagery and action observation are all driven by the same basic mechanism. Motor imagery and action observation are conceived as" offline" operations of the motor areas in the brain. The simulation hypothesis is based on 2 different lines of evidence.

First, it has been shown that there are similarities in the behavioural domain. For instance, the time to complete an imagined movement is known to be similar to the time needed for actual execution of that movement; this phenomenon is known as mental isochrony. Parsons showed that the time needed to judge whether a rotated picture of a hand is a left or a right hand is related to the degree of the rotation of that picture.

A second line of evidence for the simulation hypothesis shows that the neural system, used for action control is, indeed, activated during imagination of these actions. An increasing number of brain imaging studies have shown this similarity at the neural level. [5]

Moseley in the year 2004 conducted a study using GMI on patients with chronic CRPS1 and concluded that GMI reduced pain by 20 points on Numerical pain rating scale in the chronic CRPS1 population. Moseley conclude that patients in GMI group did better than patients in other group and the treatment components were only effective when they followed the sequential pattern. Moseley stated that CRPS1 involves cortical abnormalities similar to those observed in phantom limb pain and that after stroke. He thought that the possible explanations for the results obtained were sequential activation of cortical pre-motor and motor networks or sustained and focused attention on the affected limb, or both. Moseley made major contribution towards the development of GMI intervention strategy. There are many studies that look at the provision of one component of GMI process, but limited research is there looking at the whole process.[14]

On similar lines Manisha Uttam and colleagues hypothesised that even though CRPS1, Phantom limb pain and stroke are different conditions originating from distinct mechanisms of peripheral trauma, deafferentation and cortical damage respectively, they share identical aspects of symptomatic presentation and pattern of cortical reorganisation. Thus, based on these common findings the established mechanisms of GMI on CRPS1 and phantom limb pain can also be applicable to Stroke. [21]

Ramachandra was the first to study about mirror therapy. According to him mirror therapy works on the principle of mirror visual feedback(MVF). MVF addresses changes in the S1 and M1 cortices. In addition, it provides visual input to the brain, that movement is executed normally without inhibition. The therapeutic effect associated with mirror visual feedback may be due to activation of mirror neurons in the brain hemisphere contralateral to the paretic limb. These mirror neurons have been shown to fire during observation and execution of movement. Mirror neurons accounts for about 20% of all neurons present in a human brain. These neurons are capable of laterality reconstruction i.e., ability to differentiate between the left and right sides. When using a mirror box, it is found that these mirror neurons get activated and helps in recovery of affected parts. This system is thought to use the observation of movement to stimulate the motor process which would be involved in the movement. [22]

According to a study done by Rizzolatti and his colleagues in 2010 using mirror therapy on stroke patients, motor command neurons are found in abundance in the frontal lobes as well as the parietal lobes. These neurons fire to orchestrate a sequence of muscle twitches to produce skilled movement. According to Rizzolatti "mirror neurons" a subset of motor command neurons also fire when a person merely WATCHES another individual perform the same movement or IMAGINES the movement. Mirror neurons necessarily involve interactions between multiple modalities—vision, motor commands, proprioception—which suggest that they might be involved in the efficacy of MVF in stroke. An additional possibility is that lesion is not always complete; there may be a residue of mirror neurons that have survived but are 'dormant' or whose activity is inhibited and does not reach threshold. (And, indeed, motor areas may have become temporarily inactive as a result of the same mechanism as learned.

7. CONCLUSION

Thus we conclude that GMI is effective in improving the upper limb function in stroke patients. It should be included in the standard rehabilitation protocol post stroke.

8. SCOPE OF STUDY

- The study can be performed on a large scale using a larger sample size.
- Longer application and its effect can be seen.
- Independent effect of GMI can be studied without combining it with conventional therapy.

9. CLINICAL IMPLICATON

GMI is non-invasive, extremely feasible and easy intervention, which can be used as an adjunct to conventional therapy.

It can also be used in any kind of therapeutic set-up and can also be recommended as home program.

Lastly it can be used by patients irrespective of residual limb function.

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