ORIGINAL RESEARCH PAPER

Volume-8 | Issue-11 | November - 2019 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

THE EFFECT OF ACTION OBSERVATION TRAINING VERSUS MOTOR IMAGERY TRAINING TO PROMOTE UPPER LIMB FUNCTION IN SUB-ACUTE STROKE SUBJECTS: A RANDOMIZED CLINICAL TRIAL.

Physiotherapy

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ABSTRACT

Background and Objectives: The paretic upper limb is a common and undesirable consequence of stroke that increases activity limitation. In recent decades, many stroke rehabilitation methods have been developed. Action Observation Training (AOT) and Motor Imagery (MI) are two techniques which have proved its effectiveness in treatment of stroke subjects. The majority of evidence focuses on chronic stroke and supports its use at this stage of recovery. Although the studies are fewer in number, the evidence also supports MI as an effective intervention for the UE post stroke in the sub acute stage of recovery. Previous literature has also suggested for its comparison and best can be recommended for clinical practice. So, the aim of this study was to compare the effect of AOT and MI on upper extremity motor recovery and functional status in sub acute stroke subjects.

Materials and methods: Total of 45 stroke subjects who is having minimal motor criterion and met other inclusion criteria were recruited from department of physiotherapy, central referral hospital. Subjects were randomized into two groups i.e. AOT (Group A) and MI (Group B). Pre and post intervention outcome measures were taken using Action research arm test, Fugl-Meyer assessment test and Box and Block test.

Result: At baseline subjects of both group showed no significant differences regarding ARAT, FMA-UE and BBT scores but after 3 weeks of intervention, subjects of both group showed statistically significant improvements in all the variables measured ($p<0{\cdot}05$). In this study had shown significant improvements in the AOT group when compared to the MI group.

Conclusion: The present study confirms that AOT is an effective treatment technique to improve upper extremity motor recovery, hand manual dexterity and motor function in stroke subjects compare to MI. It is cost effective, easy and safe method for rehabilitation and most important can be easily administered at home by the subjects. Overall, clinicians will consider their stroke subjects stage of recovery and AOT protocol to implement for their particular practice setting, in the context of the evidence supporting.

KEYWORDS

Action Observation Training, Rehabilitation, Stroke, Upper Extremity, Motor Imagery

INTRODUCTION

Stroke is one of the major causes for physical and functional disability in adult population globally and also the third most common cause of death.[1] It is the fifth leading cause of disability internationally[2] and it is likely that this is an underestimate of the absolute level of functioning that is lost, especially in low income countries.[3] Upper limb impairment are very common and challenging problem of stroke that leads to difficulty moving or coordinating the arms, hands and fingers often resulting in difficulty carrying out daily activities such as eating, dressing and washing.[4] More than half of the people with upper limb impairment will still have problems many months to years after stroke.[5]

Many possible interventions have been suggested such as motor rehabilitation program, NDT, resistance training, constraint induced movement therapy.[12] To improve upper limb (UL) function after stroke and reduce the long-term disability related to poor functional recovery, effective evidence-based therapeutic interventions are still needed.[6] Previous literature have suggested two well assessed strategies for motor learning are action observation and motor imagery, both of which believed to share the same neural mechanism in the brain.[17]

Action observation training (AOT) is a novel neurological rehabilitation approach where the observation of actions performed by others activates the same neural structure responsible for the actual execution of those same actions, thus while observing other people doing everyday actions, neural structure involved in the actual execution of those actions are recruited in the observer's brain as if he/she actually performed the observed action.[6] The phenomena is suppose to occur via the activation of the mirror neuron system (involving the inferior parietal lobule, the pre-motor cortex, and the superior frontal lobe).[7] Mirror neurons (MN) were described for the first time in the nineties by a group of researcher at the university of Parma and localized in ventral pre-motor cortex F5 area of monkeys.[8] The MN revealed a mechanism in the brain which allows one to match an observed action with its motor counterpart in the observer's brain. In fact the neurons discharge when an animal performs an object directed action or a motor action performed by other individual. 9

Several studies have reported that similar system has been found in human brain in the rostral part of the inferior parietal lobe whose properties are similar to those of neuron in pre motor cortex.[10] Studies have also showed that object directed and non object directed actions modulates the action of those motor areas normally involved in the actual execution of the observed action recruiting different sectors of pre-motor and parietal cortex.[11] The discovery that MN are involved in motor learning has allowed the development of a new rehabilitation approach, called AOT, during which the patient is asked to carefully observe actions presented through a video-clip or performed by an operator, in order to try and imitate them after the observation. The purpose of AOT in the rehabilitation of individuals with lesions of the central nervous system (CNS) is to provide a tool to recover damaged cerebral networks and take advantage to rebuild motor function despite impairments.[12]

Motor imagery (MI) is considered to be one of the latest rehabilitation strategies to treat post stroke impairments.[18] It is defined as the covert cognitive process of imagining a movement of one's own body without actually moving it i.e. ability to mentally rehearse motor acts that may or may not accompanied by overt body mvements.[19] MI is used in learning motor tasks, especially in sports, to complement physical training or to improve motor performance. It has been shown to enhance motor performance and learning in various tasks and over different time scales. The central brain region in motor execution (ME) is the primary motor cortex (M1) for which structural and functional changes during learning have been reported. MI and ME are behaviorally closely related and share similar neural networks.[34]

Numerous studies have shown an increase in excitability in contralateral M1 (cM1) during MI using transcranial magnetic stimulation. In a recent brain imaging metaanalysis, Hétu et al (2013) confirmed that in most studies MI is activated a large number of primary and secondary motor areas in both hemispheres, including supplementary motor area (SMA), dorsal premotor cortex, as well as regions in the parietal lobe, basal ganglia and cerebellum. However, primary cortical activation was infrequent during MI (i.e., only 22% of the 75 experiments). This suggests strong inter-individual variability in MI ability and possibly differences in experimental procedures instructions given, imagery training length, level of motor expertise in the task to be imagined, inability to objectively measure compliance.[33]

All of these facets could explain the inconsistent outcomes of MI in neurorehabilitation. Therefore, the neural underpinnings of MI have not yet been fully unraveled.[32] Instead of simply performing mental imagery, recent work has guided imagery via online feedback of metabolic correlates of neural activity from a desired brain region or network. This process is known as real-time functional magnetic resonance imaging neurofeedback. In the motor domain, experiments have repeatedly shown that MRI-enhanced motor imagery can be used to successfully self-regulate primary and secondary sensorimotor areas. As such, the use of neurofeedback can make activation of primary motor cortex more consistent during MI.[35]

In 1996, Jean Decty suggested that imagined and executed movements were found to activate similar region of the pre-motor cortex, basal ganglia and cerebellum that are associated with movement planning association and modulation. In 1999 Jeannerod et al. provided evidence that the prefrontal cortex, pre SMA and the parietal cortex might be involved in mental imagery.[21] At the beginning of the 21st century, attempts were made to transfer the concept of MI from sports psychology to stroke rehabilitation.[22] Page et al. and Liu et al tried to combine occupational therapy and MI to improve motor recovery in subjects after stroke.[23,24,25]

Most of the studies have been done on effectiveness of AOT in stroke subjects focusing more on recovery of upper extremity (UE) function and presents evidence attesting to the benefits conferred on stroke subjects resulting from the participation in AOT, and few studies are available for acute as well as sub acute stroke subjects addressing balance training and lower limb function. Many of the previous literature have suggested that MI intervention is more effective on acute stroke rehabilitation to improve upper and lower extremity function and studies have also said that MI or mental practice is effective when combined with conventional therapy. Thus, the individual application of AOT and MI training proved to be very effective in recovery of stroke subjects however there is need of direct comparison between the effectiveness of these two techniques. So the aim of this study was to compare the effectiveness of AOT versus MI training to promote upper limb function in sub-acute stroke subjects.

MATERIALS AND METHOD

Study population

Stroke subjects were recruited from Central Referral Hospital in Sikkim, India by simple random sampling method. SMIMS Institutional ethics committee approved the study on 27th May 2017 with IEC registration number IEC/504/17-035. This study was not register for clinical trial registry in INDIA. Stroke was defined as an acute event of cerebrovascular origin causing focal or global neurologic dysfunction lasting more than 24 hours, as diagnosed by a neurologist and confirmed by computed tomography or magnetic resonance imaging. Subjects were included in the study if they (1) had a first episode of unilateral stroke with hemiparesis from 8 to 90 days (2) had a Brunnstrom score stages III and IV for the upper extremity, (3) Both gender of 30-80 years of age, (4) Mini-Mental State Examination score (MMSE) ≥ to 24 (21 for illiterate). (5) Able to sit independently for 30 minutes. We also applied the following exclusion criteria: Subjects with severe aphasia, Perceptual impairment, visual or hearing impairment and uncooperative subjects.

Recruitment and randomization

We used a randomized controlled design in which the assessor was blinded to the group allocation of each subject. All assessments were performed by the same investigator who was blinded to the treatment assignment. The baseline data regarding name, age, sex, hospital number, post stroke duration, the side of involvement, MMSE and brunnstorm recovery stage was taken after informed consent for all subjects. Subjects were individually randomized into AOT with conventional therapy (CT) and MI with CT groups by using computer generated random numbers (fig.3). Blocks were numbered, after which we used a random-number generator program to select numbers that established the sequence in which blocks were allocated to one or the other group. A physical therapist who was blinded to the research protocol and was not otherwise involved in the trial conducted the random-number program. There was total number of 45 subjects out of which 23 were in AOT group and 22 were in MI group. Both the AOT group and MI group received the CT programs for thirty minutes additionally and had each of their own therapies for thirty minutes per session, five days a week for three weeks. The CT was subject-specific and consists of Rood's facilitation techniques, Bobath techniques and Motor relearning program.

Intervention and conventional therapy group

AOT group i.e. Group A subjects made to sit on a chair, feet were firmly positioned on the floor, the trunk was erect and positioned against the chair back. All subjects received individually tailored AOT program for affected UE in the morning time. The entire training phase was divided into observation phase and execution phase. The observation phase was of 3 minutes where subjects observed the pre-recorded videos and execution phase was for 2 minutes where subjects performed the observed tasks and 1 minute of rest after practice of each activity. Each session was comprised of five functional tasks using upper limb for 30 minutes (fig.1). During the training period of three weeks, tasks progress from simple to complex.

Fig.1: The list of task for AOT Group

1st week	2nd week	3rd week
1.Making fist and open	1. Opening and closing a jar	1.Holding a spoon and taking to mouth
2.Grasping and moving a cup in horizontal plane	2.Picking up a cup, taking to the mouth and keeping it back to the starting position	2. Drink water from cup
3.Grasping and moving a cup in vertical plane	3. Touch head and reversing back to the initial position	3. Button/ unbutton clothes
4.Holding and rolling a cube	4. Folding the towel	4. Folding the paper
5.Hold small cube between two fingers and transfer it to the other hand	5 Stacking of blocks(vertical)	5.Opening and closing of lock

MI group i.e. group B subjects made to sit on a chair for 30 minutes. Out of 30 minutes, initial 5 min. was given as relaxation, discussion to make the subject feel relaxed and confident. Next 20 min. MI exercises. Out of those 20 min. initial 5 minutes, videos of the tasks were shown where the subject is asked to observe the tasks successfully, next five minute was analysis and correction phase where the subject was asked to correct the inadequate execution mentally and last 10 minutes the subject rehearsed the corrected movement physically several times while being helped. The subject ends up with 5 minutes of auto evaluation based on movement accuracy and general feelings. During the training period of three weeks tasks progress from simple to complex that is from one week to another, the difficulty, speed, size and weight of an object was modulated as soon as the subject improves his/her performances (fig.2).

Fig.2: The list of task for MI Group

1st week	2nd week	3rd week
1.Making fist and open	1. Opening and closing a jar	1.Holding a spoon and taking to mouth
2.Grasping and moving a cup in horizontal plane	2.Picking up a cup, taking to the mouth and keeping it back to the starting position	2. Drink water from cup
3.Grasping and moving a cup in vertical plane	3. Touch head and reversing back to the initial position	3. Button/ unbutton clothes
4.Holding and rolling a cube	4. Folding the towel	4. Folding the paper
5.Hold small cube between two fingers transfer it to the other hand	5.Stacking of blocks(vertical)	5.Opening and closing of lock

Outcome measures

To measure improvement in motor recovery of UE the Action research arm test (ARAT), for motor functioning Fugl-Meyer assessment (FMA-UE), for gross manual dexterity Box and Block test (BBT) was administered. Outcome measures were performed at 0 months (pretreatment) and at 3 weeks (post-treatment). The ARAT is a standardized ordinal scale that measures UE (arm and hand) function. It is a 19-item measure divided into 4 basic movements: grasp, grip, pinch, and gross movements of extension and flexion at the elbow and shoulder which assesses the ability to handle smaller and larger objects with a variety of qualitatively rated items. It is reliable and valid measure to assess upper limb functions in stroke subjects.[25]

PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

The FMA-UE is 3 point ordinal scale to measure impairments of volitional movements. Its motor score includes 33 items related to movements of the proximal and distal parts of the upper extremity. The total score ranges from 0 to 66. It has good validity and high reliability. It is having 4 components: shoulder/elbow/wrist, wrist, hand and co-ordination/speed.[26] The BBT was devised to assess unilateral gross manual dexterity in stroke subjects. It requests subjects to seat at a table, facing a rectangular box that is divided into two square compartments of equal dimension by means of a partition: one of the two compartments contains one hundred and fifty, 2.5 cm, colored, wooden cubes. The individual is instructed to move as many blocks as possible, one at a time, from one compartment to the other for a period of 60 seconds. The final score is computed by counting the number of blocks moved during the one-minute trial period. The inter-rater reliability and validity of BBT are excellent.[27]

Statistical analysis

The data was statistically analyzed using SPSS 22.0 version. All statistical analysis was performed on the final 40 subjects because 3 drop outs were in AOT group and 2 were in MI group. 3 subjects stopped coming for AOT at 2nd week of intervention and 2 subjects discontinued due to ill health at 3rd week for MI. The mean and standard deviation of the data were obtained through descriptive statistics. Data were normally distributed. Post hoc analysis with Bon- Feronni test was used to see the changes in the group and between the groups. The main effect and interaction effect i.e. F value was computed with level of significance fixed at <0.05 ($P<0.05$).

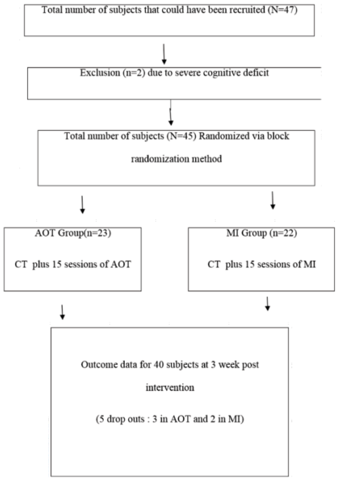

Fig 3: Flow diagram for randomized subject assignment in this study

RESULTS

Demographic and clinical characteristics of the 40 subjects, as well as baseline comparisons of the groups, are presented in table 1. Baseline comparisons revealed that age, sex, duration, type, side of involvement, MMSE scores did not differ between the groups. At baseline subjects of both groups showed no significant differences regarding ARAT, FMA, and BBT (Table 2 and 3). Data given in the Table 2 shows the changes in baseline variables in AOT and MI group. After 3 weeks of intervention, subjects of both groups showed statistically significant improvements in all the variables measured (Table 3). No relevant adverse event was noted during the study in both groups. Table 4 presents the between-group comparisons of the change score for ARAT, FMA, and BBT from baseline to post intervention i.e. interaction effect of different outcome measures used in both the group. ANOVA test was performed to analyse the change within group.

Table 1: Demographic Characteristics of the Action Observation Training and Motor Imagery Training and its Baseline Measurements

	AOT with CT	MI with CT	
Age (years)	57.5 ± 13.74	61.5 ± 10.68	p=0.311
MMSE	26.4 ± 2.25	26.35 ± 2.56	p=0.948
Gender (male: female)	15 : 5	11 : 9	
Side of involvement(right: left)	13 : 7	11 : 9	
Duration (in days)	15.4 ± 7.57	16.3 ± 9.58	
Brunnstorm recovery stage 3:4	9 : 11	8 : 12	

Table 2: Baseline comparison of variables in both the groups

	Baseline comparison		
Variables	**AOT (n=20)**	**MI (n=20)**	**t, p value**
FMA	29.05±10.46	29.65±9.25	- .066, .948
ARAT	30.75±13.41	28.20±10.13	- .192, .849
BBT	20.35±9.47	26.35±8.91	.678, .502

Table 3: Variables of both the groups with Mean and Standard Error

Variables	Group		Mean ± SE	95% Confidence Interval
FMA	**MI**	**Baseline**	29.650±2.20	25.18-34.12
		After 3 weeks	47.400±2.14	43.06-51.73
	AOT	**Baseline**	29.050±2.20	24.58-33.52
		After 3 weeks	50.200±2.14	45.86-54.53
ARAT	**MI**	**Baseline**	28.20±2.65	22.81-33.58
		After 3 weeks	46.00±1.72	42.51-49.48
	AOT	**Baseline**	30.75±2.65	25.36-36.13
		After 3 weeks	46.20±1.72	42.71-49.68
BBT	**MI**	**Baseline**	26.35±2.05	22.18-30.51
		After 3 weeks	52.40±2.54	47.24-57.55
	AOT	**Baseline**	20.35±2.05	16.18-24.51
		After 3 weeks	50.20±2.54	45.04-55.35

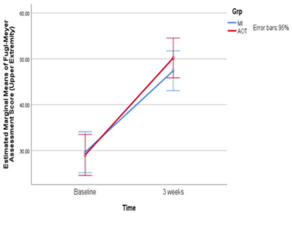

Fig. 4: Shows group x Time effect for FMA- UE between both the groups.

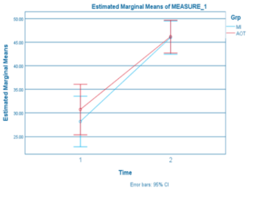

Fig.5: Shows group x time effect for ARAT between both the groups

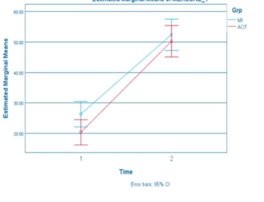

Fig. 6: Shows group x time effect of BBT between both the group.

Table 4: Summary table of interaction effect of different outcome measures used in both the group

	After 3 weeks Mean ± SD				
Variables	**AOT**	**MI**	**Effect**	**F**	**P**
FMA	50.20±9.51	47.4±9.64	Group x time effect	8.887	0.005
ARAT	46.20±8.10	46.00±7.26	Time	1.338	.255
BBT	50.20±12.28	52.40±10.41	Group x time effect	7.543	0.009

DISCUSSION

The present study demonstrated that 3 weeks of AOT and MI can safely improve the motor recovery, motor function and gross hand dexterity in sub- acute stroke subjects. The result has shown more significant improvement in ARAT, FMA-UE and BBT, in AOT group compared to

MI group. Greater improvement in AOT group can be explained by the following mechanism: According to Brunner et al during AOT the improvement in motor performance was related to activation of inferior temporal gyrus, thalamus and also other movement related areas such as premotor, supplementary and motor cortex. Gonzalez-roza et al reported AOT was associated with greater beta synchronization over bilateral parietal regions, compared with MI.[30] A. Tettamanti et al did a study to see the effect of AOT and MI in learning a complex motor task and they revealed that AOT has a more physiological approach for motor learning and through AOT MN is triggered in more ecological manner due to direct activation of the ventral pre motor cortex receiving visual inputs.

Christen Dettmers et al found promotion in hand function after stroke by AOT and suggested that training for 1 hour a day over a period of 3 weeks caused an improvement of hand function. They found that AOT supports motor memory formation and possibly the memory learning. Harsmen et al also explained about the activation of cerebellar and premotor area correlated with improvement in UE function during AOT.[31] The similar finding was also noted by Gatti et al where AOT was combined with task oriented training and greater improvements in motor performance was observed in AOT compared to control group.[32] Thus our study findings are also in accordance with the above study findings where similar improvement was found in AOT compared to MI after 3 weeks of intervention.

In present study we found that all variables have significant change in AOT group for UE function compared to MI. These findings are in lined with Sugg et al where they reported a greater improvement in recovery of UE function following AOT plus physical training, in comparison to sham relaxation plus physical training. Participants in their study had a moderate impairment of UE functioning, and they have also used FMA, ARAT as an outcome measures. They have suggested that implementation of AOT combined with physical practice, may be associated with additional improvements in terms of UE motor function in stroke subjects.

In this study the mean change and interaction effect i.e. (group x time) of FMA-UE in the AOT was found to be significantly improved over time with F and p value 8.887 and 0.005 respectively at the end of 3 weeks. Similarly Page et al indicated that the addition of AOT and change in FMA score of more than 6-8 points is associated with clinically meaningful improvement and may be helpful in improving UE function in stroke subjects. The present study also shows significant improvement in FMA-UE score stating that treatment duration of AOT has provided an added benefit in comparison to MI.

Our study has also shown significant improvement in gross hand dexterity on BBT with F and p value 7.543 and 0.009 respectively for AOT compared to MI which is in accordance with the study done by Franceschini et al who revealed that AOT can facilitate better training effects compared with control group. They have also showed significant changes in BBT score showing improvement in gross hand dexterity.[33] Similarly Sale et al did a study on sub acute stroke subjects to see the effect of AOT using FMA, BBT as an outcome measure where they have found that hand dexterity on BBT has improved significantly.[34]

Buccino et al suggested the use of AOT in comparison to simple task specific training in improving the grip strength of stroke subjects.[35] De varies et al explained the significant improvement of ARAT on chronic stroke subjects. So, our study finding is also in line with the above study findings where grip strength was improved significantly.
In the present study significant improvement was also observed in the MI group which can be well understood by these findings. Confalonierri et al reported impact of MI in sub acute stroke subjects and explained that MI stimulates sensorimotor, pre motor areas including the cingulate gyrus and the parietal cortex. Another study done by Liepert J. et al suggested that MI shares cortical circuitry with the preparation and execution of motor tasks and motor excitability thereby inclusion of MI with physical practice help promote learning by reinforcing process at the cortical level.[36]

The improvement in all variables in MI group was observed in this study which is in accordance with a study by Liu et al where they suggested the better improvement in FMA and ARAT for chronic stroke subjects.[37] Kim et al stated that mental practice is able to increase the use of affected arm and also causes brain reorganization or new cortical areas are recruited to assist in moving the affected arm.[38] Malouin et al revealed that stroke subjects engaging in mental practice showed significantly better improvement in function and were more able to transfer learned skills to other tasks in new environment.[39]

The improvement of ARAT and BBT in this study at the grip strength in MI group which can be explained by Riccio et al where they found that MI in sub acute stroke subjects achieved improvement in strength, grip quality and performance speed.[40] Page et al revealed that mental practice helps to improve function in impaired limb by developing new motor schemes when it is combined with CT. The outcome measures used in their study were FMA, ARAT, Nine Hole peg test and BBT. The increase in ability to perform tasks better and improvement in grip strength was confirmed by subjects.[41] So, overall in present study there was greater improvement in AOT group in all variables compared to MI group on UE function in sub acute stroke subjects after 3 weeks of intervention.

Study limitations

A potential limitation of this study is the generalizability of the results that these findings may not be applicable to chronic stroke subjects with severe cognitive deficits. Other possible limitations could be lack of follow up at post intervention. The functional improvement of the paretic arm cannot be explained from cortical activation patterns. Therefore, further studies using non-invasive brain imaging technology should be conducted to observe the cortical reorganization corresponding to improved paretic UE function after AOT in subacute stroke subjects and also follow up subjects to know its long term effect. Lastly, it should also be compared with other stroke rehabilitation technique.

CONCLUSION

In conclusion, this study found impressive positive effects of AOT compared with MI on motor recovery, especially manual dexterity, grasping performance, as well as gross motor recoveries and motor functioning in stroke subjects. This study is important to help to inform the health professionals about the AOT in treatment for sub acute stroke subjects. It also provides benefits on the prognosis of stroke subjects.

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