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Effectiveness of Mirror Therapy in Rehabilitation of Hand Function in Sub-Acute Stroke

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Abstract

Aim: Three quarters of strokes occur in the region supplied by the middle cerebral artery. As a consequence, the upper limb will be affected in a large number of patients. Purpose of the study is to examine the effectiveness of mirror therapy in rehabilitation of hand function in sub-acute stroke.

Methodology: An experimental study design, 30 subjects with sub-acute stroke with impaired hand function randomly allocated 15 subjects into each experimental group and conventional group. Both groups received conventional physiotherapy. The experimental group in addition, received Mirror Therapy program of 30 repetition of each exercises per day for 5 days in a week for 4 weeks (total = 20 sessions). Hand functions were measured using Upper extremity motor activity log (UE MAL) and Action research arm test (ARAT) before and after 4 week of intervention.

Results: Results of the study suggested that both the experimental and conventional group had a significant improvement in hand function (AROM, functional task with objects, object manipulation), however experimental group showed significantly more improvement than conventional group, providing Mirror Therapy with conventional treatment is more effective than conventional treatment alone.

Conclusion: Mirror therapy with conventional physiotherapy brings more improvement in hand function than conventional physiotherapy alone.

Keywords: Mirror therapy; Hand function; Motor imagery; Feedback; Hemiplegia.

Introduction

World Health Organization [WHO; Stroke; 1989] defines the clinical syndrome of stroke as 'rapidly developed clinical signs of focal (or global) distribution of cerebral function with symptoms lasting more than 24 hours or longer or leading to death, with no apparent cause other than vascular origin'.

Prevalence rates reported for stroke or CerebroVascular Accident (CVA) worldwide vary between 500 to 800 per 100,000 population [N.K. Sehi et al 2007] with about 20 million people suffer from stroke each year; out of that 5 million will die as a consequences and 15 million will survive with long term disabilities of varied spectrum. Many surviving stroke patients will often depends on other people's continuous support to survive.

Stroke is the most common cause of chronic disability [1]. Of survivors, an estimated one third will be functionally dependent after 1 year experiencing difficulty with activities of daily living (ADL), ambulation, speech, and so forth [2]. Cognitive impairment occurs frequently after stroke, commonly involving memory, orientation, language, and attention. The presence of cognitive impairment in patients with stroke has important functional consequences, independent of the effects of physical impairment (T K Tatemichi et al 1994).

Recovery of function after stroke may occur, but it is unclear whether interventions can improve function beyond the spontaneous process. In particular, recovery of hand function plateaus in about 1 year, and common knowledge is that the patient will remain at that level for the rest of his or her life [3,4]. Typically in such situations, upper arm function is better than that in the hand [5]. An emerging concept in neural plasticity is that there is competition among body parts for territory in the brain [6-11].

Several studies have been conducted to examine the recovery of the hemiplegic arm in stroke patients. Up to 85% of patients show an initial deficit in the arm. Three to six months later, problems remain in 55% to 75% of patients [12-15]. While recovery of arm function is poor in a significant number of patients. Three quarters of strokes occur in the region supplied by the middle cerebral artery [16]. As a consequence, the upper limb will be affected in a large number of patients. Functional

recovery of the arm includes grasping, holding, and manipulating objects, which requires the recruitment and complex integration of muscle activity from shoulder to fingers.

Functional brain imaging studies of healthy subjects suggest that excitability of the primary motor cortex ipsilateral to a unilateral hand movement is facilitated by viewing a mirror reflection of the moving hand [17]. Reorganization of motor functions immediately around the stroke site (ipsilesional) is likely to be important in motor recovery after stroke, and a contribution of other brain areas in the affected hemisphere is also possible. Activation when a subject is doing motor tasks can also occur in the bilateral inferior parietal area, the supplementary motor area, and in the premotor cortex. Furthermore, central adaptations occur in networks controlling the paretic as well as the nonparetic lower limb after stroke [18].

The aim of this study is to find the effect of mirror therapy in rehabilitation of hand function in sub-acute stroke.

Methodology

Study Design

Two group, pre-test post-test structured, experimental study design. A total of 30 subjects with hemiplegia due to stroke were randomly selected and were recruited from physiotherapy department of Swami Vivekananda National Institute of Rehabilitation Training and those who matched inclusion and exclusion criteria were randomly assigned to the two groups.

Inclusion Criteria

Subjects had first episode of unilateral stroke with hemiparesis, aged between 35 and 55 year, Brunnstorm stage between II and IV for upper extremity, Able to understand and follow simple verbal instruction with no cognitive disorder, Patient having stroke upto 1 year of post-stroke.

Exclusion Criteria

Patient with second episode of unilateral stroke. Brunnstrom score <II and > IV, Inability to understand and follow simple verbal command, Poor cognitive function as assessed Mini Mental Status Examination (MMSE) < 24, With uncontrolled hypertension, Visual deficit such as Homonymous Hemianopsia, reflex sympathetic dystrophy, severe shoulder subluxation, contracture in the upper limb, Patient who have received Botox injection or acupuncture within past 6 months to the affected upper limb.

Procedure

All the stroke persons who were willing to participate, and the subjects who met the inclusion and exclusion criteria signed the informed consent. Then subjects were assessed and randomly allocated into two groups Experimental group and Conventional therapy group by picking up chits marked 1 and 2. All participants underwent an initial baseline assessment of *Upper Extremity Motor Activity Log (UE MAL)* and *Action Research Arm Test (ARAT).* Both groups received conventional physiotherapy [stretching and strengthening exercises, active range of motion exercises and ADL training (Functional tasks with objects and object manipulation]. The experimental group in addition, received Mirror Therapy including forearm supination and pronation, wrist flexion and extension, finger flexion and extension, fanning of fingers, counting fingers with conventional therapy.

Upper Extremity Motor Activity Log (UE MAL): This instrument is a structured interview intended to examine how much and how well the subject uses their more-affected arm outside of the laboratory setting. Participants were asked standardized questions about the amount of use of their more-affected arm (Amount Scale or AS) and the quality of their movement (How Well Scale or HW) during the functional activities indicated. Score was calculated for both scales by adding the rating scores for each scale and dividing by the number of items asked. Inter-test reliability for the 2 MAL scales = .99 and .96; correlation of the scales of the MAL with the Abilhand Test - .88 and .71. **(Johnson A, Judson L, Morris D, Uswatte G, Taub E).**

Action Research Arm Test (ARAT): The ARAT is an observer-rated, performance-based assessment of upper extremity function and dexterity. It consisted of 19 items designed to assess four areas of function; grasp, grip, pinch, and gross movement. Each question was scored on an ordinal scale ranging from 0 (no movement) to 3 (normal performance of task). Score ranges from 0 – 57, with lower scores indicating greater level of impairment. Action research arm test (ARAT) has been found to have excellent Interrater Reliability **(Nijland et al, 2010; Van der Lee et al, 2001).**

During the **Mirror therapy** patient were seated close to a table on which a mirror was placed vertically. The involved hand was placed behind the Mirror and the non-involved hand in front of the Mirror. During exercise patient looked into the Mirror, watching the mirror image of non-involved hand. Patients involved hand was hidden from sight. During the session patient was instructed to imagine the reflected image as the involved hand. Patients were also instructed to try to do the same movements with the paretic hand while they watched only the mirror image of the non-paretic hand. The group received Mirror therapy program of 30 repetition of each exercises per day for 5 days in a week for 4 weeks (total = 20 sessions).

Data Collection

Measurements were taken prior to the beginning of the treatment (pre-test) and were repeated after completion of 4 weeks (post-test).

Data Analysis

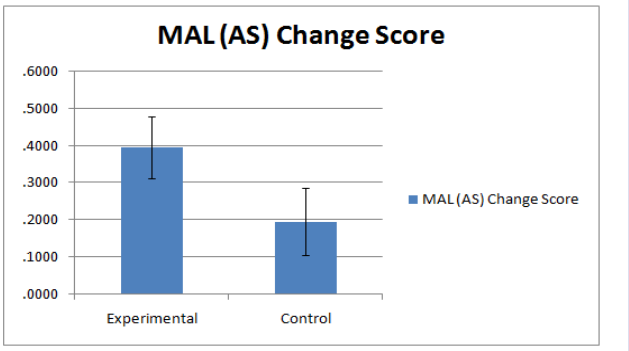
Analysis was performed using SPSS version 23.0 package

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.

Wilcoxon Signed Rank Sum test is used to test the within group difference in pre and post intervention scores. 0.05 level of significance was used for hypothesis testing.

Results

The extent of improvement in MAL (AS) score in experimental group is more as compared to conventional group from pre test measurement to post test measurement as depicted in [Graph-1].

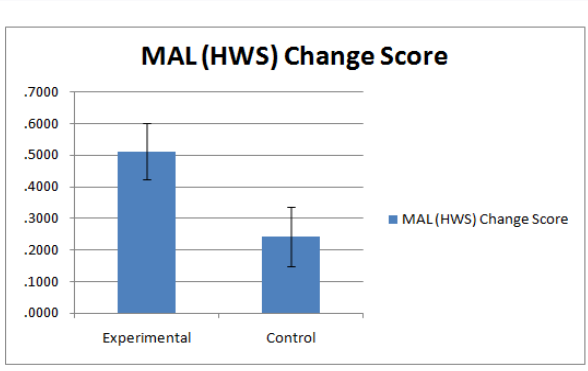


Graph 1: Mean change in MAL (AS) score between groups

Improvement in hand function was significant in both experimental and conventional groups; however experimental group showed significant more improvement than conventional group. Wilcoxon Signed Rank test showed that there was significant change from pre to post score of MAL (AS) in conventional group – (p = 0.003, z = -2.936) and in experimental group (p= 0.001, z = -3.409).

Mann-Whitney U test showed that there is statistically significant difference in the change score of MAL (AS) between the group (p= 0.003, z= -2.972).

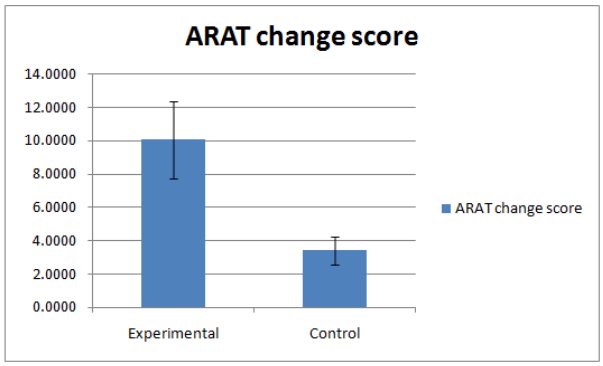
The extent of improvement in MAL (HWS) score in experimental group is more as compared to conventional group from pre test measurement to post test measurement as depicted in [Graph-2].



Graph 2: Mean change in MAL (HWS) score between groups

There was a significant difference in score of MAL (HWS) from pre to post in conventional group (p= 0.002, z = -3.062) and in experimental group (p= 0.001, z= -3.408).

There was statistically significant difference in the change score in MAL (HWS) between the groups (p= 0.005, z= -2.825). The extent of improvement in ARAT score in experimental group is more as compared to conventional group from pre test measurement to post test measurement as depicted in [Graph- 3].



Graph 3: Mean change in ARAT score between

There was significant change from pre to post score of ARAT in conventional group (p= 0.001, z= -3.190) and in experimental group (p= 0.001, z= -3.411).

Mann-Whitney U test showed that there is statistically significant difference in the change score in ARAT between the groups (p= 0.001, z= -3.371).

Discussion

Overall result of the study shows that improvement in hand function was found in both experimental and conventional group as measured by Motor Activity Log (MAL) and Action Research Arm Test (ARAT), however experimental group showed significantly more improvement than conventional group, providing Mirror Therapy with conventional treatment is more effective than conventional treatment alone. Both the groups (experimental group and conventional group) participated in the conventional stroke rehabilitation program.

In this study there was improvement in MAL from pre to post measurement after 4 weeks of intervention in both experimental and conventional group. The Motor Activity Log (MAL) consisted of Amount Scale (AS) which represents the amount of use of the affected upper extremity and How Well Scale (HWS) represents the quality of movement of the affected extremity during the functional activity. The conventional group showed 98.54% increase in Amount Scale (AS) scale and 26.24% increase in How Well Scale (HWS).

There was improvement in object manipulation and task related hand function. The improvement in conventional group could be due to improved motor conventional and functional recovery as Conventional exercises are linked to improve ***cortical reorganization.*** **Nudo RJ and Plautz EJ et al** 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 [19,20]. Using focal transcranial magnetic stimulation (TMS) has shown that TSE, in comparison to traditional stroke rehabilitation, yields long-lasting cortical reorganization specific to the corresponding areas being used [21]. Patients in this group practiced ***repeated meaningful tasks*** by affected UL. Some

researcher like **Bayona NA and Byl et al** has demonstrated that rehabilitation may be more successful if the tasks and stimuli are important and meaningful to the person [22,23].

It has been shown in various studies previously that task-oriented training can result in improved hand function after stroke.

Chanuk Yoo et al (2015) examined the improvement of hand function and activities of daily living in stroke patients after carrying out task-oriented training for 30 min per day for 4 weeks. Their hand function and activities of daily living were evaluated before and after the training. They found that the task oriented training had a significant impact in terms of improving hand function and activities of daily living [24].

Jang, Sung Ho et al (2003) investigated the effect of task oriented training on cortical activation pattern in 4 chronic hemiparetic stroke patients. The functional status of the affected hand and functional Magnetic Resonance Imaging (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 [25].

In experimental group of Motor Activity Log (MAL), there was 138.70% increase in Amount Scale (AS) scale and 56.93% increase in How Well Scale (HWS). The subjects in experimental group received an additional Mirror therapy program. During the session subjects were asked to try to do the same movements with the paretic hand while they were moving the non-paretic hand. The subjects had done several exercises of forearm, wrist and fingers.

There was improvement in object manipulation and hand function with improved activity of daily living. The improvement in experimental group could be due to the mirror illusion. The experimental group received Mirror Visual Feedback (MVF). ***Mirror visual feedback (MVF)*** might accelerate recovery from hemiparesis by activating Mirror neurons found in frontal as well as parietal lobe. The effect of mirror visual illusions on brain activity investigated. Mirror neurons discharge with both action observation and action execution. It has been proposed that the mirror neuron system is instrumental in motor learning. The human primary motor cortex (M1) displayed mirror activity in response to movement observation, and is capable of forming motor memories, and is involved in motor learning **Katja Stefan et al (2005).** Another researcher also performed TMS during mirror illusions in healthy subjects and found increased excitability of primary motor cortex (M1) of the hand behind the mirror [26].

It has been shown in various studies previously that Mirror therapy can result in improved hand function after stroke.

Provided a case report using mirror therapy (MT) in the home environment [27]. A home-based MT program was practiced over 5 week. An independent evaluator administered three outcome measures pre- and post intervention: Upper Extremity Sensory and Pain sections of the Fugl-Meyer Assessment; Jebsen–Taylor Test of Hand Function, and the Manual Ability Measure–20. Change scores indicated improvement on all of the included outcome measures. Hence they concluded that a predominantly self-administered home-based MT program is feasible and effective at improving function after stroke.

Used Transcranial Magnetic Stimulation (TMS) to look at excitability of the motor cortex ipsilateral to a moving hand in Motor Activity Log (MAL) subjects [28]. They studied four conditions: (i) subjects watching the hand they were moving; (ii) subjects watching their inactive hand; (iii) subjects watching a marked position between the moving and inactive hand; and (iv) subjects watching the reflection of the moving hand in a plane reflecting mirror. They found a significant increase in motor cortex excitability in the mirror viewing condition compared with the other conditions consistent with the mirror reflection exciting the motor cortex corresponding to the reflection of the moving hand.

In experimental group of Motor Activity Log (MAL), there was 40.16 % more increase in Amount Scale (AS) scale and 30.69% more increase in How Well Scale (HWS) than conventional group. Following may be the reasons why experimental group showed more improvement than the conventional group. Suggested that the mirror illusion of a normal movement of the affected hand may substitute for decreased proprioceptive information, thereby helping to recruit the premotor cortex and assisting rehabilitation through an intimate connection between visual input and premotor areas [29]. This mirror illusion was absent in conventional group of our study and therefore showed less improvement as compared to experimental.

Results similar to the present study were reported by **Gunes Yavuzer et al [29].** They found that hand function improved more after MT in addition to a conventional rehabilitation program as compared with a conventional treatment immediately after 4 weeks of treatment.

Other similar study was done by **Ertelt et al., 2007** who worked on stroke recovery using Mirror Visual Feedback (MVF), except they had patients watch videos of movements performed by healthy individuals presented via a screen in frontal view, and then have the subjects try to use their paretic arm to make similar movements [30]. This method of therapy was found in a Motor Activity Log (MAL) trial to be superior to a conventional group of subjects who received conventional physical therapy and watched videos of geometric symbols. Many groups have also employed virtual reality technology to create the visual feedback— instead of using mirrors **(Eng et al., 2007).**

This result similar to our study showing that Mirror therapy is helpful in improvement of hand function as assessed by using MAL.

Conducted a randomized conventional trial to evaluate the effects of mirror therapy on upper-extremity' motor recovery, spasticity, and hand-related functioning of inpatients with subacute stroke [31]. The scores of the Brunnstrom stages for the

hand and upper extremity and the FIM self-care score improved more in the mirror group than in the conventional group. Hence, they concluded that the group of subacute stroke patients, hand functioning improved more after mirror therapy in addition to a conventional rehabilitation program compared with a conventional treatment immediately after 4 weeks of treatment and at the 6-month follow-up.

Our result similar to their study showed that Mirror therapy in conjunction with conventional physiotherapy was more helpful in improvement of hand function as compared to conventional physiotherapy alone as assessed by using MAL.

Action Research Arm Test (ARAT)

The Action Research Arm Test (ARAT) is an assessment tool used to identify the functional improvement of an upper limb's performance ability. It sub-items include holding (six items), grasping (four items), picking up (six items), and total movements (three items). The total score for these 19 items is 57, and a higher score is associated with a higher performance level. In this study there was improvement in ARAT from pre to post measurement after 4 weeks of intervention in both experimental and conventional group. The conventional group showed 56.01% improvement in ARAT.

The subjects in conventional group received conventional therapy consisted of similar exercise as described earlier. Each task was practiced for 30 repetitions for 5 days in a week for 4 weeks. There was improvement in object manipulation of different shapes and sized objects. The result could be due to improved motor conventional (due to repetitive task training) and functional recovery as Conventional exercises are linked to improve cortical reorganization.

Most researchers recommend that the more the task is practiced, the better the overall performance [31,32].

According to ***Kilgard and Merzenich repetition*** plays a major role in inducing and maintaining brain changes [33].

In another study by ***Richards LG et al*** who demonstrated Neural plastic changes in the human brain following stroke and task specific intervention [34]. Another scientist **Jang SH et al.** noted decrease in the unaffected and an increase in the affected primary sensorimotor cortex activities along with functional recovery in stroke patients who received TSE [35]. It has been shown in various studies previously that task-oriented training can result in improved hand function after stroke.

Neural plastic changes have been demonstrated in human brain following stroke and task related training. **Richards LG et al (2008)** indicated that experience-dependent cortical plasticity underlies post-stroke motor recovery of the impaired upper extremity [34]. They conducted a meta-analysis on stroke studies examining changes in neural representations following therapy specifically targeting the upper extremity to determine if rehabilitation-related motor recovery is associated with neural plasticity in the sensorimotor cortex of the lesioned hemisphere. Twenty-eight studies investigating upper extremity neural representations (e.g., Transcranial Magnetic Stimulation [TMS], fMRI, PET, or SPECT) were identified, and 13 met inclusion criteria as upper extremity intervention training studies. Results indicated that neural changes in the sensorimotor cortex of the lesioned hemisphere accompany functional paretic upper extremity motor gains achieved with targeted rehabilitation interventions.

Examined the improvement of hand function and activities of daily living in stroke patients after carrying out task oriented training [24]. Their hand function and activities of daily living were evaluated before and after the training. They found that the task-oriented training had a significant impact in terms of improving hand function and activities of daily living.

In experimental group there was 124.6% increase from pre to post measurement in Action Research Arm Test (ARAT).

The subjects in experimental group received Mirror therapy. The subjects done similar exercises of forearm, wrist and fingers as mentioned above. There was improvement in object manipulation of different sized objects (blocks, ball) and hand function with improved activity of daily living. The improvement in experimental group could be due to activation of **mirror neuron system** triggered by the observation of mirror illusion explained by ***Franceschini M , Dushanova J et al .*** Mirror neurons discharge not only during action execution but also during action observation [36-38]. The discharge of these neurons is associated with object-oriented hand actions such as grasping, holding, tearing, and manipulating [39,40]. These areas are rich in motor command neurons each of which fires to orchestrate a sequence of muscle twitches to produce simple skilled movements [41]. These cortical areas are supposed to be activated by MT which suggests that they might be involved in the efficacy of MT in stroke [39,42]. It has been shown in various studies previously that Mirror therapy can result in improved hand function after stroke.

Conducted a study on 36 stroke subjects and were divided into MT and conventional group [43]. The main outcome measures were the Fugl-Meyer sub scores for the upper extremity, FIM and ARAT. This study demonstrated that application of MT in the early phase after stroke resulted in functionally relevant improvements in motor, sensory and attentional deficits and to support motor recovery in a distal plegic limb.

Evaluated the effect of MT on upper limb motor recovery and motor function in 26 subacute stroke subjects [44]. The FMA, Brunnstrom motor recovery stage, manual function test were used as an outcome measures. They found that there were great improvement in the score of Brunnstrom recovery stage, manual function test of hand in experimental group and also there was no significant difference in coordination items of FMA.

Studied to evaluate for any clinical effects of home based mirror therapy and subsequent cortical reorganization in patients with chronic stroke with moderate upper extremity paresis [45]. The primary outcome measure was the Fugl-Meyer Motor Assessment (FMA). Changes in neural activation patterns

were assessed with functional Magnetic Resonance Imaging (fMRI). Result showed Post treatment, the FMA improved more in the mirror than in the conventional group fMRI results showed a shift in activation balance within the primary motor cortex toward the affected hemisphere in the mirror group only.

In experimental group there was 67.99% more increase in Action Research Arm Test (ARAT) as compared to conventional group.

Following may be the reasons why experimental group showed more improvement than the conventional group. Within stroke patients, the sensomotoric coupling is often disturbed, which might compromise task-intrinsic feedback [46]. Therefore, to recover motor function stroke patients may be more dependent on augmented feedback [47]. This augmented feedback might be delivered in the form of visual feedback through MT [48]. This augmented feedback was absent in conventional group of our study because they did not practice with the mirror. This might have contributed to more improvement in experimental group as compared to the conventional group.

Another possible mechanism for effectiveness of mirror therapy might be bilateral arm training. Bilateral arm training was not practiced by subjects of conventional group as they performed exercise by using unilateral hand **(Muzaffar Tufail et al).**

Results similar to the present study were reported by Sneha **S. Khandare et al** [49]. They found that hand function improved more after MT in addition to a conventional rehabilitation program as compared with a conventional treatment immediately after 4 weeks of treatment.

Kyunghoon Kim et al (2016) investigated the effects of mirror therapy combined with exercise tasks on the function of the upper limbs and activities of daily living [50]. Upper limb function was measured with the Action Research Arm Test (ARAT), the Fugl-Meyer Assessment, and the Box and Block test and activities of daily living were measured with the Functional Independence Measure (FIM). They found that in the intragroup comparison, both groups showed significant differences between measurements taken before and after four weeks of therapy. In the intergroup comparison, the mirror therapy group showed significant improvements compared with the conventional therapy group, both in upper limb function and activities of daily living. Hence, concluded that the mirror therapy is more effective than conventional therapy for the training of stroke patients to improve their upper limb function and activities of daily living.

Invernizzi M et al (2013) did a randomized conventional trial to evaluate adding mirror therapy (MT) to conventional therapy (CT) can improve motor recovery of the upper limb in subacute stroke patients [51]. Action Research Arm Test (ARAT) was the primary outcome measures. Motricity Index (MI) and the Functional Independence Measure (FIM) were the secondary outcome measure. After one month of treatment patients of both groups showed statistically significant improvements in all the variables ($P<0.05$). Moreover patients of the MT group had greater improvements in the ARAT, MI and FIM values compared to CT group ($P<0.01$, Glass's.

Our result similar to their study showed that Mirror therapy in conjunction with conventional physiotherapy was more helpful in improvement of hand function as compared to conventional physiotherapy alone as assessed by using ARAT.

Conclusion

Mirror therapy with conventional physiotherapy (AROM, functional task with objects, object manipulation) brings about more improvement in hand function than conventional physiotherapy alone.

Limitations

Small sample size, No follow-up study was performed, Participants of single geographic location.

Clinical Utility

Mirror therapy can be used simultaneously in clinical as well as home based setting to bring about improvement in hand function. Also, the cost effectiveness and easy applicability seems to make mirror therapy a useful adjunct to conventional physiotherapy.

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