A Study to Analyze the Effectiveness of Constraint Induced Movement Therapy and Robot Assisted Therapy in Improving Upper Limb Function of Patients with Hemiplegia

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Abstract: ***The study intended to ascertain the effectiveness of Constraint Induced Movement Therapy and Robot Assisted Therapy in Improving Upper Limb Function of Patients with Hemiplegia on sixty hemiplegic patients with limited upper extremity function who fulfilled inclusion and exclusion criteria were selected by Non probability purposive sampling technique and 30 were assigned to interventional group that received Constrained Induced Movement therapy with routine rehabilitation program and 30 were assigned as control group that received Robot Assisted Therapy with routine rehabilitation program. Pre-test level of upper extremity function was assessed through motor activity log and modified Sollerman hand grip function scale with observation checklist, among study groups on first day of the study and post-test was conducted on 14th day. The non-affected arm of the patients was restrained with splint for 4 hours and affected arm was practiced with repeated activities such as peg board, transferring jelly with spoon, picking and transferring the nuts, grasping the smiley ball for 4 hours under the supervision of the researcher.***

Keywords: Constrained Induced Movement; Robot Assisted Therapy, Strength Training; hemiplegia

1. Introduction

Stroke is a medical emergency which can cause permanent neurological damage or death. Human functions such as movement, sensation or emotions that were controlled by the affected area of the brain are lost or impaired. The severity of the loss of function varies according to the location and extent of the brain involved.

The World Health Organization (2005) defines stroke as the rapid development of clinical signs and symptoms of a focal neurological disturbance lasting more than 24 hours or leading to death with no apparent cause other than vascular origin. A stroke is the disturbance in blood supply, when blood vessel ruptured or blocked by a clot, which cuts off the oxygen supply and nutrients to the brain, causing damage to the brain tissue. Stroke is a clinical syndrome divided into two broad classifications such as ischemic stroke which is caused by sudden occlusion of arteries supplying the brain, either due to a thrombus at the site of occlusion or formed in another part of the circulation. It accounts for 50% to 85% of all strokes worldwide. A hemorrhagic stroke occurs due to injury to a blood vessel wall and formation of clot. It accounts for 15% of all strokes worldwide.

In 2013, stroke was the second most frequent cause of death after heart diseases, accounting for 6.4 million deaths, in which ischemic stroke resulted in 3.3 million deaths and hemorrhagic stroke resulted in 3.2 million deaths. Almost half of the stroke patients live less than one year and two thirds of strokes occurred in those over 65 years old.

Worldwide stroke is the fourth leading cause of disability. According to the WHO (2015), each year 15 million people worldwide suffer from stroke. In that nearly 5 million people die and another 5 million people are left permanently disabled. It forecasts that disability-adjusted life years (DALYs) lost to stroke will rise from 38 million in 1990 to 61 million in 2020. The prevalence of new or recurrent stroke is nearly 750,000 in each year and above 4 million is living with the residual effects of stroke which includes paralysis and disability. In India, stroke is one of the leading causes of death and disability. The prevalence rate ranges from 84-262/100,000 in rural areas and 334-424/100,000 in urban areas. Stroke signified 1.2% of total deaths in India.

Stroke risk increases with various risk factors such as age, sex, race, family history, hypertension, extreme alcohol consumption, smoking, tobacco, lack of physical exercise, obesity, high blood cholesterol level, diabetes mellitus, earlier TIA and heart diseases. The aged population has less chance of recovering from paralysis and disability; males are more at risk than females and ratio in India is 7:1. The prevalence of stroke among men may be due to smoking and drinking as well as higher among menopausal women in India.

The stroke cause sudden death depends on the site and severity of brain injury. The common symptoms are sudden weakness or numbness, confusion, aphasia, dysphasia, dysarthria, vision changes, altered motor function and unconsciousness. In worldwide, almost 85% of stroke survivors experience upper extremity hemiparesis immediately after stroke and between 55% and 75% of survivors continue to experience upper extremity functional limitations and diminished quality of life. Treatment to recover from lost function is called stroke rehabilitation and ideally takes place in a stroke rehabilitation units through the interdisciplinary team.

Rehabilitation programs are different in worldwide that most commonly, certain types like inpatient rehabilitation centers with acute care facilities, outpatient & home rehabilitation. In those rehabilitation programs they practice mobility, communication, ADLs and normal bowel and bladder patterns. Recent research has focused on techniques using robotics and constraint induced movement therapy.

Constraint Induced Movement Therapy (CIMT) is a form of rehabilitation therapy that improves upper extremity function in stroke and other central nervous system damage victim by increasing the practice of their affected upper limb. CIMT has been shown to be an effective method of stroke rehabilitation irrespective of the level of initial motor ability, amount of chronicity, amount of previous therapy, affected side of hemiparesis or infarct site. A consistent exclusion criterion for CIMT has been less voluntary wrist and finger extension in the affected hand. Constraint Induced Movement Therapy (CIMT) is now being implemented by therapists to promote better compliance. IulyTreger, Lena Aidinof et al (2012) conducted a single-blinded randomized controlled trail study among 28 samples to assess the effectiveness of constraint induced movement therapy (CIMT) at loewenstein rehabilitation hospital, Israel. The CIMT group received 1 hour daily physical rehabilitation session and unaffected arm was restrained for 4 hours for 2 weeks. The control group received routine physical rehabilitation. The subjects were requested to perform the following tasks such as transfer pegs from a saucer to a pegboard, grasp, carry, and release a hard rubber ball and eating using a spoon to remove the jelly from the plate, bring it towards the mouth, and then place it on another plate with the affected hand for 30 seconds. The number of repetitions in each test was recorded as an outcome. Study results revealed that CIMT therapy group showed significantly greater changes in all 3 tests than control group.

Many researchers used constraint induced movement therapy (CIMT) program to recover upper extremity function. CIMT is an evidence- based program in an enriched environment to increase the use of the affected upper extremity. Many results recommended that CIMT may be a successful method of improving function and use of the affected arms of patients exhibiting learned non-use.

Rehabilitation robots can be divided into therapeutic and assistive robots. The purpose of assistive robots is compensation, whereas therapeutic robots provide task-specific training (Lum PS et al 2012). The types of robotic devices used for motor training are end-effector-type devices and exoskeleton-type devices. End-effector devices work by applying mechanical forces to the distal segments of limbs. End-effector type robots offer the advantage of easy set-up but suffer from limited control of the proximal joints of the limb, which could result in abnormal movement patterns. In contrast, exoskeleton-type robotic devices have robot axes aligned with the anatomical axes of the wearer. These robots provide direct control of individual joints, which can minimize abnormal posture or movement.

Robot-assisted therapy (RAT) offers intensive, repetitive, and goal-oriented training to help hemiplegic patients recover upper limb function by promoting neuroplasticity and improving motor control. While some studies show mixed results compared to conventional therapy, particularly in chronic stroke patients, RAT can enhance compliance and motivation through engaging, game-like interfaces. The effectiveness can depend on factors like robot intensity, training specifics, and the patient's stage of recovery, with some evidence suggesting greater gains over longer periods or with higher intensity (He Wang et al 2025). Robots provide consistent, high-repetition movement practice that is often difficult to achieve with manual therapy alone (He Wang et al 2025). Robotic devices to provide assistance or resistance during repetitive arm movements (Alex Pollock et al 2014); Allows for high-intensity, repetitive training, which is crucial for motor learning and recovery; It be customized to provide different levels of assistance and track performance and can incorporate virtual reality and gaming to improve motivation (Gert Kwakkel et al 2007).

A study by Fasoli et al. 2004 comprising 56 patients with sub acute stroke reported that patients who received conventional therapy alone showed little improvement, whereas patients who received robotic training plus conventional therapy continued to improve in the latter half of the inpatient rehabilitation period. This means that robot-assisted therapy is effective for improving upper limb motor function in patients with sub acute stroke. A study by Lo et al. 2010 recruited 127 chronic stroke patients reported that robot-assisted therapy and conventional therapy produced similar amounts of improvement after 12 weeks of treatment. However, after 36 weeks of therapy, the robot-assisted therapy achieved greater motor improvement than did conventional therapy. A study in patients with chronic stroke by Hsief et al. 2012 also found significantly greater improvement in upper limb motor function in the higher-intensity robot-assisted training group than in the control treatment group. In contrast, upper limb motor recovery did not differ significantly between the lower-intensity training group and the control group. These findings suggest that the intensity is the most important parameter of robot-assisted therapy for upper limb motor recovery in patients with chronic stroke.

In addition, studies in patients with sub acute stroke suggested that patients who received additional robotic therapy showed greater improvements in ADL (Susan E Fasoli et al 2004 & Stefano Masiero et al 2007). However, trials in patients with chronic stroke demonstrated no additional improvement in ADL over conventional therapy. In summary, robot-assisted therapy for upper limb motor function provides an additional effect on ADL function only in patients with sub acute stroke. Further studies may be needed to draw a definite conclusion about the effect of robot-assisted training on ADL in patients with chronic stroke (E Fasoli et al 2004).

Hwang et al.2012 demonstrated that robot-assisted therapy provided dose-dependent improvement in hand function. However, all three trials were single-centre studies with relatively small numbers of participants, all in the chronic stage of stroke, and there was no randomized controlled trial that included sub acute stroke patients as participants Furthermore, there was no assessment of ADL function after robot-assisted therapy for hand motor function. Therefore, these results suggest that robot-assisted therapy with end-effector devices may yield similar or greater improvement in hand motor function in patients with chronic stroke, but there is insufficient research to support an effect in patients with sub acute stroke. Therefore, well-designed studies are needed to draw clear conclusions regarding the effect of robot-assisted therapy that use end-effector-type devices on improvement of the hand motor function of patients in both the sub acute and chronic stages of stroke.

2. Material and Methods

In this study, quasi experimental pre-test post-test control group design was selected to evaluate the effectiveness of Constraint Induced Movement Therapy and Robot Assisted Therapy in Improving Upper Limb Function of Patients with Hemiplegia.60 subjects who fulfilled the inclusion and exclusion criteria were selected by Non probability purposive sampling technique. The sample size for the study was 60 hemiplegic patients with limited upper extremity function in which 30 subjects were assigned in Group A and treated with Robot Assisted Therapy and 30 subjects were assigned to Group B and they are treated with Constraint Induced Movement Therapy. The study was conducted at Physiotherapy outpatient department Sarada College of Physiotherapy, Ongole. Study duration is 2 weeks. Sixty hemiplegic patients with limited upper extremity function who fulfilled inclusion and exclusion criteria were selected by Non probability purposive sampling technique and 30 were assigned to interventional group that received Constrained Induced Movement therapy with routine rehabilitation program and 30 were assigned as control group that received Robot Assisted Therapy with routine rehabilitation program. Pre-test level of upper extremity function was assessed through motor activity log and modified Sollerman hand grip function scale with observation checklist, among study groups on first day of the study and post-test was conducted on 14th day. The non-affected arm of the patients was restrained with splint for 4 hours and affected arm was practiced with repeated activities such as peg board transferring jelly with spoon, picking and transferring the nuts, grasping the smiley ball for 4 hours under the supervision of the researcher. Measurement tools were Demographic variables, Clinical variables, Motor Activity Log (MAL). The minimum and maximum scores were 0 and 150 respectively. The scores were interpreted as follows,

Description	Scores
No motor arm function	0
Very poor motor arm function	1 ± 30
Poor motor arm function	31 ± 60
Fair motor arm function	61 ± 90
Almost normal motor arm function	91 ± 120
Normal motor arm function	121 ± 150

Modified Sollerman hand grip function scale with observation check list which consists of 10 items was used to assess hand grip function. The answers were interpreted based on 5-point rating scale (0-4). The minimum and maximum scores were 0 and 40 respectively. The scores were interpreted as follows

No hand grip function	0
Very poor hand grip function	1 ± 9
Poor hand grip function	10-19
Fair hand grip function	20 - 29
Almost normal hand grip function	30 - 39
Normal hand grip function	40

3. Procedure

Ethical clearance was obtained from the ethical committee of The Medicina Alternativa, The open International University for Complimentary Medicines (OIUCM) – Colombo, Sri Lanka and prior to the commencement of the study the purpose of the study was explained and a written informed consent was taken from all the participants. 60 Hemiplegic subjects who fulfilled the inclusion criteria were selected for the study through a Non probability purposive sampling technique and 30 subjects were assigned in Group A and were treated with Robot Assisted Therapy; and 30 subjects were assigned to Group B are treated with Constraint Induced Movement Therapy. The demographic and clinical variables were collected from the patients.

Study subjects in Group A was treated by Robot assisted therapy through active-assistive therapy to perform everyday tasks like grasping objects; and the training session last between 20 to 30 minutes with 30 repetitions, 3 sets, daily 2 sessions for 2 weeks

Subject performing upper limb activity

Study subject in Group B was treated with repeated activities such as peg board, transferring jelly with spoon, building block on each other and placing ring in cone, picking and transferring the nuts, grasping the smiley ball under the supervision of the researcher with the affected limb by wearing glove to the unaffected limb with 2-3 hours per session, 2 sessions daily for 2weeks.

Pre-test level of upper extremity function was assessed through motor activity log and modified Sollerman hand grip function scale with observation checklist, among both the groups on first subject performing upper limb activity using RAT day of the study. Followed by, Robot Assisted Therapy was demonstrated in Group A patients and the patients were made to practice the same for14 consecutive days and post-test was conducted on 14th day; and constraint induced movement therapy was demonstrated in Group B patients and the patients were made to practice the same for14 consecutive days and post-test was conducted on 14th day. The non-affected arm of the patients of both the Groups was restrained with splint for 4 hours. Both the Groups received routine rehabilitation program.

4. Results and Discussion

Table 1: Mean, Standard Deviation and Mean difference in Pre and Post-test scores among Patients in RAT and CMIT group

Groups	Level of Upper Extremity Function	Pre test		Post test		Mean difference
		Mean	SD	Mean	SD	
RAT group n=30	Motor arm function	21.80	13.38	32.83	15.77	11.03
	Hand grip function	6.20	4.80	10.87	4.78	4.67
CMIT group n=30	Motor arm function	19.33	10.45	22.93	10.37	3.60
	Hand grip function	5.43	7.04	7.76	6.77	2.33

Table 2: Paired 't' test value of pretest and post test score on level of upper extremity function among RAT group

RAT group		Mean	SD	Paired 't' value	Df
Motor Arm function	Pre-test	21.80	13.38	**12.67	29
	Post-test	32.83	15.77		
Hand Grip function	Pre-test	6.20	4.80	**16.62	
	Post-test	10.87	4.78		
Table value = 2.46		** Highly significant at ≤0.01			

Table 3: Un paired 't' test value of pot scores on level of upper extremity function among RAT and CMIT group

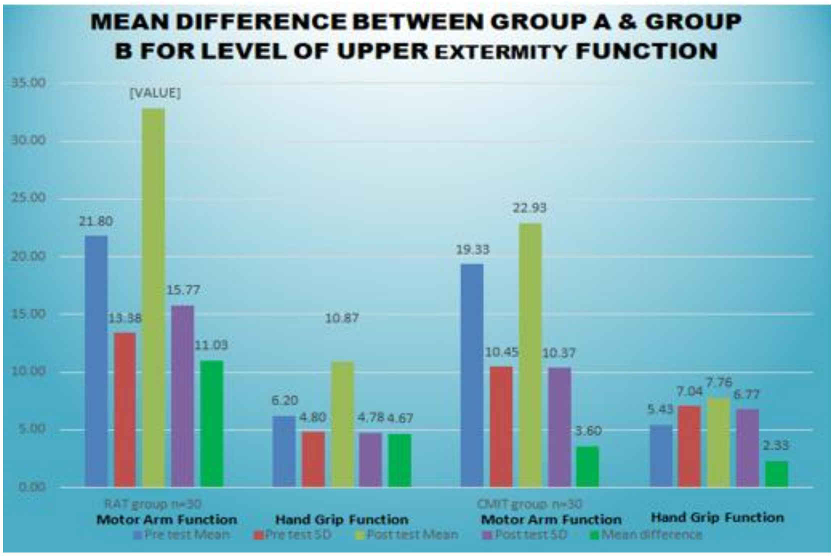
Level of upper extremity function	Groups	Mean	SD	Unpaired 't' value	df
Motor Arm function	RAT group	32.83	15.77	**2.82	58
	CMIT group	22.93	10.37		
Hand Grip function	RAT group	10.87	4.78	**4.18	
	CMIT group	7.76	6.77		

Table value =2.39 **Highly Significant p” 0.01

Table 4: Association between the pre and post-test scores on level of upper extremity function among patients and their selected variables in the RAT group.

S. No	Variables	Motor Arm Function: Pre Test df	Pre Test Z value	Pre Test Table value	Motor Arm Function: Post Test df	Post Test Z value	Post Test Table value	Hand Grip Function: Pre Test df	Pre Test Z value	Pre Test Table value	Hand Grip Function: Post Test df	Post Test Z value	Post Test Table value
	Interventional Group												
1	Age	4	1.09	9.49	6	4	12.6	4	2.82	9.49	4	6.01	9.49
2	Sex	2	0.46	5.99	3	2.6	7.82	2	1.4	5.99	2	0.71	5.99
3	Education	8	6.68	15.51	12	9.8	21	8	6.54	15.51	8	6.74	15.51
4	Working status	4	13.23*	9.49	6	17.41	12.6	4	10.23*	9.49	4	11.05*	9.49
5	Social habit	6	4.05	12.59	9	8.3	16.9	6	4.03	12.59	6	8.5	12.59
6	Food habit	2	0.33	5.99	3	0.4	7.82	2	0.33	5.99	2	2.78	5.99
7	Prestroke exercise	2	0.84	5.99	3	1.1	7.82	2	0.83	5.99	2	3.09	5.99
8	Supportive members in family	6	10.25*	12.59	9	17.56	16.9	6	7.74	12.59	6	12.2	12.59
9	Type of stroke	2	1.33	5.99	3	4.5	7.81	2	1.33	5.99	2	2.14	5.99
10	Duration of stroke	4	3.77	9.49	6	16.5	12.6	4	3.77	9.49	4	11.06*	9.49
11	Affected arm	2	1.49	5.99	3	2.4	7.81	2	1.49	5.99	2	2.27	5.99
12	Prestroke dominant side	2	0.15	5.99	3	2.1	7.81	2	0.15	5.99	2	1.37	5.99
13	Duration of rehabilitation	4	5.04	9.49	6	14.1	12.6	4					

*Significant **$p < 0.05$**



The Mean, Standard Deviation and Mean difference in Pre and Post-test scores among patients in RAT and CMIT group in Pre-test, the mean and standard deviation of motor arm function was 21.80 ± 13.38 in RAT group and 19.33 ± 10.45 in the CMIT group, whereas the mean and standard deviation of hand grip function was 6.20 ± 4.80 in RAT group and 5.43 ± 7.04 in the CMIT group. In Post-test, the mean and standard deviation of motor arm function was 32.83 ± 15.77 in the RAT group and 22.93 ± 10.37 in the CMIT group, whereas the mean and standard deviation of hand grip function was 10.87 ± 4.78 in the RAT group and 7.76 ± 6.77 in the CMIT group. The mean difference of motor arm function was 11.03 and 3.60 and hand grip function was 4.67 and 2.33 in RAT and CMIT group respectively. The results of the Paired 't' test value of pretest and post test score on level of upper extremity function among RAT group – the calculated paired "t' test value of motor arm function 12.67 was greater than the table value 2.46 at p<0.01 the calculated paired "t' test value of hand grip function 16.62 was greater than the table value 2.46 which was highly significant at p<0.01. It reveals that the Robot Assisted therapy was effective in improving upper extremity function among hemiplegic patients. Hence, the hypothesis is retained.

The results of the Un paired 't' test value of pot scores on level of upper extremity function among RAT and CMIT group shows that the calculated unpaired 't' test value of motor arm function 2.82 was greater than the table value 2.39 at p<o.01. The calculated unpaired 't' value of hand grip function 4.18 was greater than the table value 2.39 which was highly significant at p<0.01. Hence it shows that Robot Assisted therapy was effective in improving level of upper extremity function for hemiplegic patients. Hence, the hypothesis is retained. The results of the association between the pre and post-test scores on level of upper extremity function among patients and their selected variables in the RAT group show that in the RAT group, with regard to motor arm function there was a significant association found between working status and supportive members in the family whereas age, sex, education, social habit, food habit and pre stroke exercise were not associated at p< 0.05.

In hand grip function, working status was found to be associated in post test score. Age, sex, education, social habit, food habit, pre stroke exercise and supportive members in family were not associated at p< 0.05. In the RAT group, with regard to motor arm function there was a significant association found between duration of stroke and duration of rehabilitation whereas type of stroke, affected arm and pre stroke dominant side were not associated at p< 0.05. In hand grip function duration of stroke and duration of rehabilitation was found to be associated in post test score. Type of stroke, affected arm and pre stroke dominant side were not associated at p< 0.05.

Chengzhu Jin et al 2025 conducted a study to determine the intervention effects of robot-assisted task-oriented training on enhancing the upper limb function and daily living skills of stroke patients through a systematic search conducted across PubMed, China National Knowledge Infrastructure, Web of Science, Cochrane Library, Embase, and Scopus databases through March 1, 2024.The results indicated that robot-assisted task-oriented training significantly improved Fugl-Meyer Assessment-Upper Extremity scores compared to the control group [SMD = 1.01, 95% CI (0.57, 1.45)]. Similarly, robot-assisted task-oriented training demonstrated a significant effect on the Modified Barthel Index scores [SMD = 0.61, 95% CI (0.41, 0.82)]. Subgroup and regression analyses revealed that the use of combined interventions, the geographical region of the first author, and the age of the subjects did not appear to be sources of high heterogeneity. Publication bias tests using the FMA-UE as an outcome measure yielded Begg's test (p = 0.76) and Egger's test (p = 0.93), suggesting no significant publication bias. Sensitivity analyses confirmed the robustness of the study findings. The study concluded that the Robot-assisted task-oriented training significantly enhances the rehabilitation of upper limb function and the recovery of daily living skills in stroke patients.

He Wang et al 2025 evaluated the efficacy of robot-assisted training (RAT) in the treatment of upper limb motor function in patients with stroke, and to compare the efficacy of different types of RAT through PubMed, Web of Science, Embase, Cochrane Library, and Scopus, China National Knowledge Infrastructure [CNKI], SinoMed [CBM], VIP, and Wanfang. The study concluded that RAT combined with routine rehabilitation therapy can effectively improve the upper limb motor function and activities of daily life of patients with stroke. Among them, the EE-RAT had the best effect in improving the upper limb motor function of patients with stroke, and the Exo-RAT had the best effect in improving the ability of daily life of patients with stroke. Hwang CH et al 2022 evaluated individual finger synchronized robot-assisted hand rehabilitation in stroke patients through a prospective parallel group randomized controlled clinical trial on patients who were ≥18 years old, more than three months post stroke, showed limited index finger movement and had weakened and impaired hand function. Patients with severe sensory loss, spasticity, apraxia, aphasia, disabling hand disease, impaired consciousness or depression were excluded. Patients received either four weeks (20 sessions) of active robot-assisted intervention (the FTI (full-term intervention) group, 9 patients) or two weeks (10 sessions) of early passive therapy followed by two weeks (10 sessions) of active robot-assisted intervention (the HTI (half-term intervention) group, 8 patients).The study concluded that a four-week rehabilitation using a novel robot that provides individual finger synchronization resulted in a dose-dependent improvement in hand function in sub acute to chronic stroke patients.

5. Conclusion

In conclusion, the present statistical analysis of the randomized study showed that there was an improvement in level of upper extremity function after implementation of RAT in hemiplegic patients in Group A when compared to pre-test. Also, there was a difference in the post test scores on level of upper extremity function among ART Group and the CMIT Group. Thus, the results of the study concludes that Robot Assisted Therapy is effective in Improving Upper Limb Function of Patients with Hemiplegia compared to patients treated with CMIT.

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