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The effect of Constraint-Induced Movement Therapy in the upper limb motor recovery and Functional Independence Measure scores among stroke survivors

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Abstract

Background

The word `Stroke` means an act of striking/hitting someone or something. Stroke is a sudden neurological deficit due to vascular pathology. Strokes are now the second most important cause of death above 60 years and the fourth leading cause of lost productivity, as measured by disability-adjusted life years.[1] Stroke is a leading cause of serious long-term disability. According to the World Health Organization, 15 million people suffer stroke worldwide each year.[2] In India, stroke is one of the leading causes of death and disability. The estimated adjusted prevalence rate of stroke range, 84-262/100,000 in rural and 334-424/ 100,000 in urban areas. The incidence rate is 119-145/100,000 based on the recent population based studies.[3] Stroke rehabilitation is not well developed in India due to scarcity of rehabilitation specialists. Stroke is becoming an important cause of premature death and disability in low-income and middle-income countries like India, largely driven by demographic changes and enhanced by the increasing prevalence of the key modifiable risk factors. According to Trivandrum stroke registry 2005, adjusted annual incidence rates of stroke per 100,000 were 135 in Trivandrum, Kerala.[4] Stroke rehabilitation has been proved effective in functional improvement, prevention of complications and reduction of disability and mortality.[5] As many basic self-care activities depends upon the upper limb, the rehabilitation strategies aiming upper limb recovery in stroke is very important.

Constraint-induced movement therapy (CIMT) is one of the recent rehabilitation interventions in patients with stroke to improve upper limb motor recovery. CIMT is based on the concepts of neuroplasticity. It is used to overcome the learned non use which is seen in patients with upper limb motor impairment after stroke. By restraining the unaffected limb and through forced use of the impaired limb, augmented use of the affected limb can be achieved. Studies revealing the effectiveness of CIMT in Indian population are very limited. One such study was conducted by Singh and Pradhan using m-CIMT in sub-acute stroke patients in 2011. Since the data regarding the effectiveness of Constraint Induced Movement Therapy is lacking, the investigator decided to conduct this study.

Mechanism of Neurological Recovery in stroke

Neurological improvement begins immediately after the stroke. Improvement seen in the first days to weeks after stroke is mainly due to recovery of function in portions of the ischemic penumbra and resolution of oedema and mass effect. The process of cerebral plasticity and functional reorganization of the cerebral cortex happens together with the early resolution and continues for at least several months.[6]

Neuroplasticity and Neurological Recovery

Human brain has the ability to reorganize and remodel. Neuro plasticity refers to changes in neural pathways and synapses due to changes in behaviour, environment, neural processes, thinking, emotions, as well as changes resulting from bodily injury. It is the ability of the CNS to re-organize and remodel after CNS injury.

Constraint-induced movement therapy (CIMT)

Constraint-induced movement therapy (CIMT) is based on the current concepts of neuroplasticity. CIMT was developed by Edward Taub of the University of Alabama at Birmingham. It is one of the more recently developed therapies in neuro rehabilitation. .

Edward Taub proposed a theory that patients with motor impairment in an upper limb after stroke learn to depend more on the unaffected limb for performing functional tasks because attempts to use the affected arm often result in failure and frustration. This is explained through the principles of operant conditioning, where failed attempts to use the upper limb produce a kind of negative feedback.[7] This was demonstrated by Taub in studies of primates who underwent dorsal root lesions that led to a deafferentation of an upper limb. Even with the preservation of motor control, there is a tendency to avoid using the affected arm in functional tasks. The use of the affected limb can be augmented by forced use of the impaired limb through a process of restraining the intact upper limb in a body jacket. Subjects may be trained to perform tasks with the affected limb through successive approximations of the desired task, which is the behavioural technique known as shaping. CIMT requires attention because it is safe, no added technology is needed.

Normal and injured primate brain is capable of cortical reorganization in response to behavioural interventions.[8] Along with repetitive movements, new skill acquisition or reacquisition of lost skills after stroke is required to induce cortical reorganization and promote recovery of motor function. The neuroplastic changes in the structure and function of relevant brain areas are induced primarily by specific rehabilitation methods. The therapeutic method which induces neuroplastic changes, leads to greater motor and functional recovery than traditional methods. Further, the recovery is permanent in nature. A review focusing on the methods that have evidence of associated cortical level reorganization, namely task-specific training, constraint-induced movement therapy, robotic training, mental imaging, and virtual training was conducted[9] and the findings demonstrated convincing evidence both at the neural and functional level in response to such therapies. The protocol has evolved to specifically include repetitive and adaptive task practice under clinical supervision. These additional structured elements collectively define the current concept of CIMT.

Repetitive Task Practice (RTP) is continuous blocked practice of a specific functional task, usually for a period of 15–20 minutes. Adaptive Task Practice (ATP), or shaping, uses a step-wise approximation method, breaking down tasks into successive manageable components to improve overall proficiency.[10] Based upon the underlying operant conditioning through provision of therapist feedback, shaping fosters patient problem solving, resulting in self motivation to use the affected limb. This intensive practice fosters motor relearning and has been shown to promote neural plasticity in the CNS.[11] Successful application of CIMT is thought to induce a use-dependent increase in cortical reorganization of the areas of the brain controlling the most affected limb.[12,13] Several studies, primarily in mild to moderately impaired survivors of stroke, have demonstrated clinically relevant results.[14,15] Practitioners say that stroke victims disabled for many years have recovered the use of their limbs using CIMT.

Steven L. Wolf and colleagues carried out a multisite clinical trial -Effect of Constraint-Induced Movement Therapy on Upper Extremity Function 3 to 9 Months. After Stroke - The EXCITE Randomized Clinical Trial in 2006.[16] They included 222 individuals with stroke of 3 to 9 months duration. The outcome measures were The Wolf Motor Function Test (WMFT), a measure of laboratory time and strength-based ability and quality of movement (functional ability), and the Motor Activity Log (MAL), a measure of how well and how often 30 common daily activities are performed. The results from baseline to 12 months, the CIMT group showed greater improvements than the control group in both the WMFT Performance Time. They concluded as, among patients who had a stroke within the previous 3 to 9 months, CIMT produced statistically significant and clinically relevant improvements in arm motor function that persisted for at least 1 year.

A randomized controlled trial of constraint-induced movement therapy after stroke conducted by Lin KC and group using 22 chronic stroke patients.[17] Motor performances was evaluated using the Fugl-Myer Assessment and the Motor Activity Log. Functional outcomes were evaluated using the Functional Independence Measure and the Nottingham extended activities of daily living scale. The CIMT group showed significantly greater improvements in motor performance, level of functional independence and the mobility domain of extended activities of daily living.

Wolfgang H.R. Miltner and associates studied Effects of Constraint-Induced Movement Therapy on patients with chronic motor deficits after Stroke.[18] The outcome was measured using WMFT, MAL and Arm Motor Ability Test. The study indicates that CIMT is a powerful treatment for improving the rehabilitation of movement of the affected upper extremity in chronic stroke patients.

Gyrd Thrane and colleagues conducted a meta-analysis of constraint- induced movement therapy after stroke in November 2012 to evaluate the effect of constraint induced movement therapy in adult stroke patients and to examine the impact of time since stroke and various treatment modalities.[19]They concluded that Constraint-induced movement therapy can improve arm motor function and improve arm motor activities and may have a lasting effect on arm motor activity.

Priyanka Singh and Bijayetta Pradhan in India conducted a randomized control trial to assess the effectiveness of modified CIMT in sub-acute stroke patients in 2011.[20] A total of forty sub-acute stroke subjects were randomly assigned to both m-CIMT and a control group. The outcome measures were evaluated at pre- and post-intervention by using the Wolf Motor Function Test (WMFT) and Fugl-Meyer assessment (FMA) of motor recovery after stroke. After intervention significant effects were observed in m-CIMT group and there was a significant improvement in upper extremity function which indicated that m-CIMT was effective in improving the motor function of the affected arm in stroke subjects. However, its long-term effect has not proved since there was no follow-up after intervention.

Aims and objectives

Constraint-induced movement therapy (CIMT) is a current approach to stroke rehabilitation that implies the forced use and the massed practice of the affected arm by restraining the unaffected arm. CIMT is found to be a useful intervention to improve the motor recovery and the functional outcome without any added technology, with lack of adequate evidence in the Indian scenario. Presently, constraint-induced movement therapy (CIMT) has not been incorporated as part of standard practice for the rehabilitation of the hemiplegic upper extremity. Aim of the study is to evaluate the effect of Constraint-Induced Movement Therapy in stroke patients in a Physical Medicine and Rehabilitation of a tertiary centre in India.

The objectives are to find out if there is any significant difference between stroke survivors undergoing standard rehabilitation techniques and those receiving a combined CIMT and standard rehabilitation techniques in the following parameters:

1. Power of upper limb

3 Functional Independence Measure (FIM) scores

Materials and Methods

The study was conducted at the Department of Physical Medicine and Rehabilitation, Government Medical College, Kottayam, a tertiary care centre in Kerala after getting ethical committee clearance and consent. 35 persons between the age group of 18 to 75 with stroke of 4 to 28 weeks duration, who came to the Department during December 2012 to December 2013 and fulfilled the inclusion criteria, was enrolled into the study.

Inclusion Criteria

1. Unilateral ischemic or haemorrhagic stroke (confirmed with neuroimaging) of 4 weeks to 28 weeks duration
2. Patients having a motor power of grade 2 or more of the biceps and first dorsal interosseous as per the Medical Research Council scale
3. Patients without significant cognitive impairment as assessed by a score of >/=24 of MMSE (Mini Mental Status Examination)
4. Patients between the age group of 18-75years
5. Adequate vision as assessed by the clinical method of counting fingers at a 3 meter distance.

Exclusion Criteria

1. Patients having hemi-neglect as assessed by star cancellation test
2. Patients having associated severe co morbid conditions such as severe Cardiopulmonary and renal disease
3. Patients with upper extremity injury or conditions that limited the use of the affected upper limb prior to the stroke
4. Patients who refuse to give informed consent

Sampling Technique

Patients were selected consecutively from those coming to department till the required sample size is obtained. Both groups were studied as inpatients for a minimum period of 2 weeks. After allocating the group, the patients were evaluated in muscle power, muscle tone, activities of daily living and motor function and physical impairment rating of upper limbs.

Group A or the intervention group comprised of 19 patients, who were given the intervention namely Constraint-Induced Movement Therapy (CIMT), along with the standard rehabilitation interventions routinely given in stroke patients namely basic sensorimotor techniques used to promote motor recovery such as strengthening and range of motion exercises and task-oriented approach advocated by Carr &Shepherd which includes standing up and sitting down, balancing, walking training and training in reaching and manipulating objects. Group B or the control group comprised of 16 patients who were given only the standard rehabilitation intervention given in stroke as detailed above.

In the intervention group, the intervention CIMT was applied by restraining the unaffected upper limb in an arm sling for a total of 6 hours during the day, providing 1 hour of rest or freedom from constraint at intervals of every 2 hours, over a 2 weeks period. During the periods of constraint the affected upper limb was given concentrated repetitive training including attempting to eat, putting blocks into a box, and spooning beans.

Follow up:

The tools were reapplied at 4 weeks and 12 weeks and scoring done.

Assessment

Motor impairment is assessed by power, motor control and co-ordination, muscle tone and balance. Power is assessed by Medical Research Council's (MRC) 6 point scale. The grading is between 0-5.

The Functional Independence Measure (FIM) instrument is more recently developed and most commonly used measure in medical rehabilitation, [22] which measures the degree of dependency. Loss of function related to chronic diseases like stroke are more persistent but are potentially reversible with proper timing and type of intervention. A single disease process may cause multiple disabilities e.g., a stroke may result in impairments in mobility, language, self-care ability and /or continence. The activities of daily living are assessed using FIM7 in 18 parameters, including feeding, grooming, bathing, dressing, toileting, sphincter control, transfer activities, locomotion, social cognition and communication. There are motor and cognitive components. The functional dependency due to the motor impairment is assessed by the motor subtotal.

Statistical Analysis

The data collected was coded and entered into Microsoft Excel and analysed using the software SPSS Version 16.0. Data summary is described as means and standard deviations for quantitative variables and as counts and percentages for qualitative variables.

The independent t-test is used to find out the significant difference between means. The level of significance is taken as a p value of <0.05 and that of highly significant as <0.01.

Results

Among the 35 patients, 27 were males and 8 were females. There were 11 males below 50 years and 16 were 50 years or above. There were 4 female patients below 50 years and 4 were 50 years or above. A total of 15 patients were below 50 years.

The minimum age was 26 and the maximum age was 67 in the study population. The mean age of intervention group was 51.95 years and control group was 55.06 years.

18 (51.42%) were suffering from stroke affecting the right side of the hemisphere and remaining 17 (48.57%) were affected with left hemisphere stroke.

According to etiology, in 71.42% (25 patients) strokes were ischemic and only in 28.57% (10 patients) it was haemorrhagic.

Comparison of parameters at first follow up (4 weeks)

All the shoulder muscle groups show some improvement in power in both the intervention and control groups. However, the mean difference in power in the intervention group is higher than that of the control group. The power of shoulder flexion, a mean difference of 1.05 and 0.69 are found in intervention and control group respectively. By applying independent sample t- test it is found to be statistically significant also (P value=0.040). In shoulder extensors, shoulder abductors and adductors the mean difference in intervention group is higher than in the control group, but this is not found to be statistically significant.

In the elbow muscle groups, the mean difference in power is higher in intervention group for elbow extension and that is statistically significant (P value 0.021). In supination, the mean difference was higher in the intervention group and this is also found to be statistically significant (p value= 0.020). In pronators also, there is a higher mean difference in the intervention group and it is found to be statistically significant (p value=0.020). In elbow flexion, even though there was a good mean difference with more improvement in intervention group, the P value is not statistically significant.

In the wrist muscle groups, both wrist flexion and extension have a higher mean difference for the intervention group and it is highly significant in wrist extension group (p value=0.007)

Similar result is found in both finger flexors and finger extensors with higher mean difference in the intervention group and it is statistically significant with p values 0.034 and 0.006 respectively.

Observing the degree of dependency, using the FIM score, it was seen a mean value of 23.89 and 21.44 in the intervention and control group respectively. Even though the mean difference is higher in intervention group it is not statistically significant (p value= 0.324).

Comparison of parameters between first and second follow up (at 4 weeks and 12 weeks)

Among the shoulder group; Shoulder flexors and extensors showed a better improvement in the control group. Shoulder abductors and adductors improved better in intervention group. In both, the difference is not statistically significant.

In the elbow muscle groups, the mean difference in power is higher in intervention group, but the difference is not statistically significant.

Observing power in the wrist groups, wrist flexors have a higher mean difference for the intervention group; even though this is not statistically significant. The mean difference in power of wrist extensors is higher for control group, but not statistically significant.

The finger flexors showed more improvement in the intervention group even though this is not statistically significant. In finger extensors the higher mean difference is seen in the control group but it is not statistically significant.

Observing the degree of dependency using FIM score, though the mean difference is higher in the intervention group, (improvement is 75.42+10.16 in the intervention and 65.75+9.75 in the control group) this is not statistically significant (p value 0.884).

Discussion

This study was conducted to know the effectiveness of Constraint-Induced Movement Therapy in stroke patients in our population. The investigator used two outcome measures, namely, power and Functional Independence Measure score.

Muscle power at first follow-up showed improvement in shoulder flexors by a grade of 1.05 (21%) in the intervention group and found to be statistically significant (p value= 0.040), as compared to the control group (improvement was only by 13.8%). In the second follow-up however, there was no statistically significant difference between the two groups observed. In the shoulder extensors, abductors and adductors, even though there was an improvement in power in the first follow-up after intervention, this was not statistically significant. At the second follow-up, the shoulder abductors and adductors showed better improvement in the intervention group and the flexors and extensors showed a better improvement in the control group though this difference was not statistically significant.

The muscle power in the elbow extensors showed improvement by 1.42 grade at the first follow-up in the intervention group. This was statistically significant with p value=0.021. This improvement persisted at the second follow-up but did not exhibit any statistical significance in the difference with the control group. The forearm supinators showed a 24.2% improvement in motor power following CIMT at the first follow-up which was statistically significant (p value= 0.020), which however could not be extrapolated to the second follow-up (p value=1.883). Pronators also showed a similar improvement pattern in motor power in the first follow-up which was also found to be statistically significant (p value =0.020). Even though the improvement continued into the second follow-up, it was not found to have statistical significance (p value>0.05).

The power of the wrist extensors improved by 1.47 grade from the initial score according to MRC scale at the first follow-up, in the intervention group. This was of high statistical significance (p value=0.007). At the second follow-up the wrist extensors showed better improvement in the control group which however, was not of statistical significance. Both finger flexors (improved by 1.58 grade) and extensors (+1.26) showed significant improvement in motor power in the intervention group at first follow-up (p value 0.034 and 0.006 respectively) when compared to control group (+1.06 and +0.62 respectively). At the second follow-up, the finger flexors showed improvement in the intervention group which was not statistically significant, however. The finger extensors showed better improvement in the control group at the second follow-up. This was not statistically significant.

Even though the functional independence improved at first and second follow ups, in the intervention group more than in the control group, this improvement was minimal (+23.89 in intervention group when compared to +21.44 in the control at first follow up and +10.16 against +9.75 in the second). This was not statistically significant.

Even though positive results in the outcome measures showing the effectiveness of CIMT were seen during the first and second follow-ups, none of these changes were found to be statistically significant at the second follow-up. This is probably because the intervention was applied only for 2 weeks which means that the time given for the patient for cortical reorganization was a mere 2 weeks. However, studies published earlier also showed that only a 2 weeks program of CIMT was given to every study population. Hence, keeping the concept of neuroplasticity in mind, it is suggested that further studies incorporating longer periods of CIMT intervention such as 6 months or more may be carried out in order to come to reliable conclusions. Even though this may be impractical in an institutional set-up, this intervention being relatively simple may be carried out at home by the patient, after taking the patient and caregiver into confidence.

Tables

Table 1: Comparison of power in shoulder muscle groups before intervention and at first follow up

Power	Group	Mean difference	Standard Deviation	P value
Shoulder flexion	Intervention group(19)	1.05	0.524	0. 040
	Control (16)	0.69	0.479	
Shoulder extension	Intervention group(19)	1.16	0.602	0.059
	Control (16)	0.81	0..403	
Shoulder abduction	Intervention group(19)	1.26	0.653	0.159
	Control (16)	0.94	0.680	
Shoulder adduction	Intervention group(19)	1.32	0.671	
	Control (16)	1.00	0.632	0.164

Table 2: Comparison of parameters between first and second follow up (at 4 weeks and 12 weeks)

Power	Group	Mean difference	Standard Deviation	P value
Shoulder flexion	Intervention group(19)	0.47	0.772	0. 908
	Control (16)	0.50	0.516	
Shoulder extension	Intervention group(19)	0.47	0.697	0.901
	Control (16)	0.50	0..516	
Shoulder abduction	Intervention group(19)	0.47	0.772	0.474
	Control (16)	0.31	0.479	
Shoulder adduction	Intervention group(19)	0.47	0.697	
	Control (16)	0.25	0.447	0.277

Table 3 - Comparison of power in elbow muscle groups before intervention and at first follow up

Power	Group	Mean difference	Standard Deviation	P value
Elbow flexion	Intervention group(19)	1.05	0.621	0. 040
	Control (16)	0.81	0.403	
Elbow extension	Intervention group(19)	1.42	0.607	0.059
	Control (16)	1.00	0.365	
Supination	Intervention group(19)	1.21	0.631	0.159
	Control (16)	0.75	0.447	
Pronation	Intervention group(19)	1.21	0.631	0.164
	Control (16)	0.75	0.447	

Table 4 - Comparison of power in elbow group at first and second follow up

Power	Group	Mean difference	Standard Deviation	P value
Elbow flexion	Intervention group(19)	0.47	0.612	0. 852
	Control (16)	0.44	0.512	
Elbow extension	Intervention group(19)	0.32	0.671	0.311
	Control (16)	0.12	0.342	
Supination	Intervention group(19)	0.47	0.841	0.069
	Control (16)	0.06	0.250	
Pronation	Intervention group(19)	0.53	0.772	0.743
	Control (16)	0.44	0.814	

Table 5. Comparison of power of wrist and finger muscle groups before intervention and at first follow up

Power	Group	Mean difference	Standard Deviation	P value
Wrist flexion	Intervention group(19)	1.32	0.671	0. 355
	Control (16)	1.12	0.500	
Wrist extension	Intervention group(19)	1.47	0.697	0.007
	Control (16)	0.81	0.655	
Finger flexion	Intervention group(19)	1.58	0.769	0.034
	Control (16)	1.06	0.574	
Finger Extension	Intervention group(19)	1.26	0.653	0.006
	Control (16)	0.62	0.629	

Table 6. Comparison of power in wrist and finger groups at first and second follow up

Power	Group	Mean difference	Standard Deviation	P value
Wrist flexion	Intervention group(19)	0.37	0.761	0. 246
	Control (16)	0.12	0.342	
Wrist extension	Intervention group(19)	0.42	0.838	0.946
	Control (16)	0.44	0.512	
Finger flexion	Intervention group(19)	0.26	0.806	0.528
	Control (16)	0.12	0.342	
Finger Extension	Intervention group(19)	1.26	0.769	0.729
	Control (16)	0.62	0.516	

Functional Independence Measure (FIM)

Table 7: Comparison of FIM scores before intervention and first follow up Group

Group	Mean difference	Standard Deviation	P value
Intervention group (19)	23.89	8.299	0.324
Control (16)	21.44	5.715	

Table 8- Comparison of FIM at first and second follow ups

Group	Mean difference	Standard Deviation	P value
Intervention group (19)	10.16	9.29	0.884
Control (16)	9.75	6.598	

Conclusions

1. CIMT was found to be effective in improving the motor power of shoulder flexors, elbow extensors, forearm supinators and pronators, wrist extensors, finger flexors and extensors at 4 weeks follow up.

2. The FIM score also was also higher in intervention group at 4 weeks.

3. None of these changes were found to be statistically significant at the second follow-up at 12 weeks.

4. This is probably because the intervention was applied only for 2 weeks which means that the time given for the patient for cortical reorganization was a mere 2 weeks.

Limitations of the study

1. The study is a non-blinded one.
2. This study was conducted only for a period of 12 weeks. Long term follow- up is recommended as the intervention is based on neuroplasticity. Further studies are therefore required.
3. At the time of enrolment into the study, the two groups may have had dissimilar impairments in muscle power.

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References

1. Mukherjee D, Patil CG. Epidemiology and the Global Burden of Stroke. World Neurosurg. 2011 Dec; 76 (6, Supplement):S85–90.
2. Stroke | World Heart Federation [Internet]. [cited 2015 Apr 29]. Available from: http://www.world-heart-federation.org/cardiovascular-health/stroke/
3. Pandian JD, Sudhan P. Stroke Epidemiology and Stroke Care Services in India. J Stroke. 2013 Sep;15(3):128–34.
4. Sridharan SE, Unnikrishnan JP, Sukumaran S, Sylaja PN, Nayak SD, Sarma PS, et al. Incidence, types, risk factors, and outcome of stroke in a developing country: the Trivandrum Stroke Registry. Stroke J Cereb Circ. 2009 Apr; 40(4):1212–8.
5. Strand T, Asplund K, Eriksson S, Hägg E, Lithner F, Wester PO. A non intensive stroke unit reduces functional disability and the need for long-term hospitalization. Stroke J Cereb Circ. 1985 Feb;16(1):29–34.
6. Walter R Frontera JAD. DeLlisa’S Physical Medicine & Rehabilitation; Principles and Practice. 5th ed. Wolters kluwer/ Lippincott Williams & wilkins; 2010. 2264 p.
7. Taub E, Crago JE, Burgio LD, Groomes TE, Cook EW, DeLuca SC, et al. An operant approach to rehabilitation medicine: overcoming learned non-use by shaping. J Exp Anal Behav. 1994 Mar; 61(2):281–93.
8. Calautti C, Baron J-C. Functional neuroimaging studies of motor recovery after stroke in adults: a review. Stroke J Cereb Circ. 2003 Jun; 34(6):1553–66.
9. Arya KN, Pandian S, Verma R, Garg RK. Movement therapy induced neural reorganization and motor recovery in stroke: A review. J BodywMovTher. 2011 Oct; 15(4): 528–37.

10. Reiss AP, Wolf SL, Hammel EA, McLeod EL, Williams EA. Constraint- Induced Movement Therapy (CIMT): Current Perspectives and Future Directions. Stroke Res Treat [Internet]. 2012 [cited 2015 May 3]; 2012.

11. Wolf SL, Blanton S, Baer H, Breshears J, Butler AJ. Repetitive Task Practice: A Critical Review of Constraint-Induced Movement Therapy in Stroke. The Neurologist. 2002 Nov;8 (6):325–38.

12. Taub E, Uswatte G. Constraint-induced movement therapy: bridging from the primate laboratory to the stroke rehabilitation laboratory. J Rehabil Med. 2003 May; (41 Suppl):34–40.

13. Liepert J, Miltner WH, Bauder H, Sommer M, Dettmers C, Taub E, et al. Motor cortex plasticity during constraint-induced movement therapy in stroke patients. NeurosciLett. 1998 Jun 26; 250(1):5–8.

14. Page SJ, Sisto SA, Levine P, Johnston MV, Hughes M. Modified constraint induced therapy: a randomized feasibility and efficacy study. J Rehabil Res Dev. 2001 Oct; 38(5):583–90.

15. Wittenberg GF, Chen R, Ishii K, Bushara KO, Eckloff S, Croarkin E, et al. Constraint-induced therapy in stroke: magnetic-stimulation motor maps and cerebral activation. Neurorehabil Neural Repair. 2003 Mar; 17(1):48–57.

16. Wolf SL, Winstein CJ, Miller JP, Taub E, Uswatte G, Morris D, et al. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial. JAMA. 2006 Nov 1; 296(17):2095–104.

17. Lin K-C, Wu C-Y, Liu J-S. A randomized controlled trial of Constraint-induced movement therapy after stroke.ActaNeurochir Suppl. 2008;101:61–4.

18. Miltner WH, Bauder H, Sommer M, Dettmers C, Taub E. Effects of Constraint-induced Movement therapy on patients with chronic motor deficits after stroke: a replication. Stroke J Cereb Circ. 1999 Mar;30(3):586–92.

19. Thrane G, Friborg O, Anke A, Indredavik B. A meta-analysis of Constraint-induced movement therapy after stroke. J Rehabil Med. 2014 Oct; 46(9):833–42.

20. Singh P, Pradhan B. Study to assess the effectiveness of modified Constraint-induced Movement therapy in stroke subjects: A randomized controlled trial. Ann Indian Acad Neurol. 2013;16(2):180–4.