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Efficacy of Constrained Induced Movement Therapy Versus Bilateral Arm Training on Upper Extremity Functional Outcomes in Stroke Patients

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Abstract

Background and Purpose: Recovery of motor function after stroke may depend on balance of activity of neural network involving the affected and the unaffected motor cortices. Modified constrained induced movement therapy and bilateral arm training share similar key therapeutic elements (mass and repetitive practice with specific techniques), and both target to improvement of the affected upper limb. The aim of the study was to compare the effect of these two techniques on improving upper extremity function in stroke patients.

Patients and Methods: Thirty male ischemic stroke patients with age ranged between 45-55 years. Patients were divided randomly into three equal groups. Group I received modified constrained induced movement therapy in addition to a selected physical therapy program. Group II received bilateral arm training in addition to a selected physical therapy program. Group III received the selected physical therapy program. Motor function of the upper extremity and gross manual dexterity were recorded using action research arm test and box and blocks test respectively.

Results: The results showed statistically very highly significant increase of the mean value of the action research arm test score of the affected upper limb post treatment within each group. ($p < 0.0001$ in GI, $p = 0.0001$ in GII and $p = 0.007$ in GIII) and Comparing between each pair of the three groups post treatment revealed that there was a statistically non-significant difference between GI and GII ($p = 0.143$) while a very highly significant difference between GI and GIII ($p = 0.0001$) and a highly significant difference between GII and GIII ($p = 0.008$) post treatment. Also, there was a statistically very highly significant increase in BBT score post treatment within each group. ($p < 0.0001$ in GI, $p = 0.0001$ and $p = 0.0018$ in GIII) and comparing between each pair of the three groups post treatment revealed that there was a statistically very highly significant difference in the mean value of BBT score between GI and GII ($p = 0.001$) and between GI and GIII ($p = 0.0001$) while there was a statistically highly significant difference between GII and GIII ($p = 0.006$) post treatment.

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Conclusion: Both modified constrained induced movement therapy and bilateral arm training improves upper extremity function in hemiparetic patients with more superiority of modified constrained induced movement therapy on improving hand dexterity.

Key Words: Stroke – Neural network – Constrained induced movement therapy – Bilateral arm training – Action research arm test – Box and block tests.

Introduction

STROKE is the most common cause of permanent disability worldwide. Patients with stroke complain with complex neurologic deficits, leading to poor movement quality, muscle weakness, sensory dysfunction, and cognitive impairments [1]. Almost 80% of stroke patients experience upper extremity (UE) paresis, causing deficits in motor control consequently, has limitations in daily function [2].

Two available Neurorehabilitation concepts figure prominently that stand in stark contrast. On the one hand, there are therapies that prevent the use of the non-paretic UL, such as constraint-induced movement therapy (CIMT) [4]. On the other hand, there are therapies that dictate utilization of the non-paretic UL to enhance motor function in the paretic limb, such as bilateral arm training (BAT) [5].

Constraint induced movement therapy (CIMT) is a family of techniques that have been implemented to increase the amount and quality of function of an affected upper limb [6]. These techniques involve restraint of the intact limb over an extended period, in combination with a large number of repetitions of task-specific training of the affected limb so overcoming learned nonuse phenomenon [7].

Studies revealed that functional gains were accompanied by increased activation in the bilateral hemispheres after CIT/mCIT. Increased use of the affected hand in CIT/mCIT may increase ipsilesional activation, enlarge cortical representation of the affected hand and facilitate eipsilateral pathways in the contralesional hemisphere. CIT/mCIT there by resulted in use-dependent brain reorganization [8].

Bilateral arm training and CIT share similar therapeutic elements of task-specific and repetitive exercise. BAT emphasizes both UEs, which simultaneously practice functional tasks. Possible rationales include interhemispheric coupling and neural cross-talk. CIT and its distributed form (dCIT), an alternate form of the original CIT in which treatment is done for a longer period with fewer training hours per day, involve restriction of the unaffected UE and intensive training of the affected UE to overcome learned nonuse [9].

Simultaneous activation of both hands may have rebalanced inter hemispheric activation and inhibition. It causes an additional facilitation in the affected hemisphere and positive after effects of reducing the motor impairment of the affected UE [10].

This study was designed to investigate the effect of modified constrained induced therapy versus bilateral arm training on upper extremity functional outcomes in stroke patients.

Patients and Methods

Patients:

Thirty male ischemic stroke patients aged from 45 to 55 years were enrolled in this study. Patients were selected from the outpatient clinic of the Faculty of Physical Therapy, Cairo University in the period from September 2014 to April 2015. Patients were divided randomly into three equal groups. Group I received modified constrained induced movement therapy in addition to a selected physical therapy program. Group II received bilateral arm training in addition to a selected physical therapy program. Group III received the selected physical therapy program.

The patients were diagnosed as having stroke in the domain of carotid system based on careful clinical assessment by a neurologist and radiological investigations including computed axial tomography or magnetic resonance imaging of the brain. Patients participated after signing a written consent forms approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University.

Participants met the following inclusion criteria: (1) Male ischemic stroke, (2) Their duration of illness from 6 months to one year, (3) Motor deficit involving one arm with the ability to perform at least 20° wrist extension and 10° finger extension, (4) No serious cognitive deficits (score ≥ 24 on the Mini-Mental State examination), (5) Muscle tone of affected upper limb ranged from 1 to 1+ according to Modified Asworth Scale (MAS) [1], (6) Moderate arm motor impairment (between 30 and 49 scores) on the Fugl-Meyer (FM) arm section scale according to Michaelsen et al. [11] and Patients had the ability to understand and follow simple instructions and two step commands.

Exclusion criteria include patients who had recurrent stroke, moderate and severe spasticity, apraxia, unilateral spatial neglect, visual or auditory defects, other neurological or orthopedic disorders affecting the reaching to grasping ability such as ataxia, joints stiffness or subluxation, deep sensory loss, diabetic polyneuropathy and peripheral nerve injuries.

Instrumentation:

- 1- Modified Asworth Scale for assessment of muscle tone is a 6-point scale. Scores range from 0 to 4, where lower scores represent normal muscle tone and higher scores represent spasticity or increased resistance to passive movement [9].
- 2- The arm section of the FM Scale was used to evaluate upper extremity impairment as inclusion criteria. This scale includes 4 motor sub-items. Each item was rated on a 3-point scale (0=Cannot perform; 1=Partially performs; 2=Performs fully) for a 66-point maximum.
- 3- The Action Research Arm Test (ARAT) is an evaluative measure to assess specific changes in limb function among individuals who sustained cortical damage resulting in hemiplegia. It assesses a client's ability to handle objects differing in size, weight and shape and therefore can be considered to be an arm-specific measure of activity limitation. The total score on the ARAT ranges from 0 to 57, with the lowest score indicating that no movements can be performed, and the upper score indicating normal performance. Thus, higher scores will indicate better performance [12].
- 4- Box and Block Test for assessment of gross manual dexterity. This test was made up of a box with a partition directly in the Centre creating two equal sides. Subjects would be instructed to move as many blocks as possible

from one side of the container to the other for a period of one minute by using stop watch. It measures the number of cubes transported in 1 minute from one side of a box to another [13].

5- Stop watch. It was used during assessment of box and blocks test.

Procedure:

A- Evaluation session:

Assessment of arm motor impairment and function using the FM arm section scale and ARAT respectively, assessment of muscle tone using modified ashworth scale and assessment of gross manual dexterity was done by using BBT. The arm motor impairment by FM scale and muscle tone by MAS were done pretreatment only while ARAT and BBT test done pre and post treatment.

B- Training session:

Patients of Group I received modified constrained induced movement therapy were expected to wear a mitt on the less affected hand for at least 4 hours a day. The patients could choose when they wore the mitt, but were requested to wear it during periods of activity. The participants in mCIMT focused on restriction of the unaffected hand with a mitt and intensive training of the affected UE with functional activities and behavioral shaping for 2-hour per day, 5 days per week, for 3 weeks. The functional tasks included: Reaching forward or upward to move, Box and blocks training, Picking up a utensil to take food, Manipulating cards, Grasping and releasing various blocks, Pouring from glass to another, Changing paper in a book, throwing a ball in a basket. The level of challenge was adapted based on patient ability and improvement during training in addition to the selected physical therapy program.

The second group received training matched to them CIMT in duration and intensity of bilateral activities. During each 2-hour per day, 5 days per week, for 3 weeks. The participants concentrated on simultaneous movement of the ULs in functional tasks in symmetric or alternating patterns that emphasized both ULs moving synchronously, such as Grasping and folding a towel, unscrewing a bottle, where the non-affected hand stabilizes the bottle and the affected hand manipulates the

cover, Lifting 2 cups, Reaching forward or upward to move blocks, Alternative movements included exercises such as Alternative reaching forward or upward, The patients were especially reminded of the importance of not letting the less-affected arm compensate too much for the weaker arm and the focus was to allow the participation from the affected arm in addition to the selected physical therapy program.

The third group received the selected physical therapy program only. This include Postural control and balance activities, Upper extremity control as the patient held the arm with the extended elbow then eccentric and finally concentric, Proprioceptive Neuromuscular Facilitation (PNF), Weight bearing and weight shift exercises as modified plantigrade, Lower limb control and Gait training. It was given for patients in three groups.

Statistical analysis:

Descriptive statistics were done in the form of mean and standard deviation for age, duration of illness, arm impairment, function and gross manual dexterity. Paired *t*-test was used to assess changes within groups and One-way ANOVA test was used to compare between the means of three groups followed by post hoc Tukey test to know which of three groups are different from each other for each of the research variables. Analysis was done using SPSS version 18. The alpha point of 0.05 was used as a level of statistical significance (when $p \leq 0.05$ is usually classed as "significant", $p \leq 0.01$ as "highly significant" and $p \leq 0.001$ as "very highly significant") [15].

Results

I- General demographic data and patients characteristics in the three groups (GI, GII and GIII):

The mean values of age in GI, GII and GIII were 51.33 ± 2.41 , 50.67 ± 2.89 and 51.07 ± 2.84 years respectively. The mean values of stroke duration in GI, GII and GIII were 8.73 ± 1.83 , 8.64 ± 2.51 and 8.27 ± 2.282 months respectively. The mean values of FM score in GI, GII and GIII were 40.40 ± 4.27 , 39.53 ± 6.29 and 41.20 ± 7.20 respectively. Comparison of the mean values of age, stroke duration and FM score between the three groups revealed no significant differences (Table 1).

Table (1): Mean values of the age, stroke duration and MMSE score between the three patients groups.

Characteristics	GI Mean \pm SD	GII Mean \pm SD	GIII Mean \pm SD	F-value	<i>p</i> -value
Age (years)	51.33 \pm 2.41	50.67 \pm 2.89	51.07 \pm 2.84	0.228	0.768
Stroke duration (months)	8.73 \pm 1.83	8.64 \pm 2.511	8.27 \pm .282	0.184	0.516
FMscore (points)	40.40 \pm 4.27	39.53 \pm 6.29	41.20 \pm 7.20	1.504	0.165

II- Comparison of ARAT scores within groups:

The mean value of ARAT score pre-treatment in GI, GII and GIII were 29.20 ± 8.11 , 32.33 ± 9.45 and 31.93 ± 9.64 respectively. The mean value of ARAT score post-treatment in GI, GII and GIII

were 43.07 ± 7.02 , 41.00 ± 8.30 and 33.87 ± 8.28 respectively. Comparison of the mean values of the ARAT score pre and post treatment within each group being significantly higher post treatment. Table (2) and Fig. (1).

Table (2): Comparison of the mean values of the ARAT score within each group pre and post treatment.

ARAT score	Group I		Group II		Group III	
	Pre	Post	Pre	Post	Pre	Post
Mean (SD)	29.20 ± 8.11	43.07 ± 7.02	32.33 ± 9.45	41.00 ± 8.30	31.93 ± 9.64	33.87 ± 8.28
Mean Difference	13.87		8.67		1.93	
t-value	$t=11.10$		$t=10.01$		$t=3.11$	
p-value	<0.0001 ****		0.0001 ***		0.007 **	

*** Very highly significant at $p \leq 0.001$. SD: Standard deviation. ARAT: Action research arm test.

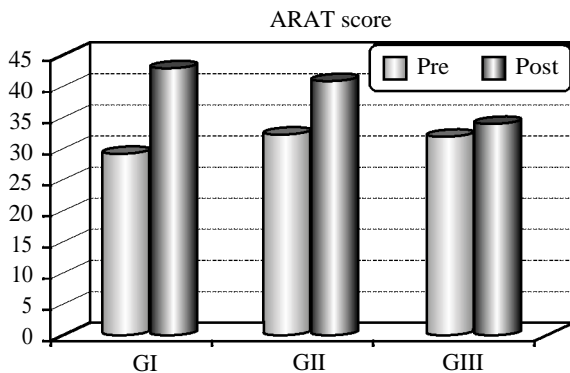


Fig. (1): Comparison of the mean values of the ARAT scores within each group pre and post treatment.

Post Hoc Tukey Test was used for comparison of the mean value of ARAT score between each pair of the three groups post treatment. The test revealed that there was a statistically non-significant difference in the mean value of ARAT score between GI and GII ($p=0.143$) while a very highly significant difference between GI and GIII ($p=0.0001$) and a highly significant difference between GII and GIII ($p=0.008$) post treatment (Table 3).

Table (3): Post Hoc Tukey Test for comparison of the mean values of ARAT score between each pair of the three groups post treatment.

ARAT	GI & GII	GI & GIII	GII & GIII
	Post-treatment	Post-treatment	Post-treatment
Mean Difference	3.20	9.80	6.60
p-value	0.143ns	0.0001 ***	0.008 **

*** Very highly significant at $p \leq 0.01$. ARAT: Action research arm test.

III- Comparison of BBT scores within groups:

The mean value of BBT score pre-treatment in GI, GII and GIII were 21.47 ± 4.76 , 18.60 ± 5.37 and 19.67 ± 3.87 respectively. The mean value of FM score post-treatment in in GI, GII and GIII were

40.53 ± 9.79 , 29.67 ± 5.96 and 21.33 ± 3.56 respectively. Comparison of the mean values of the BBT score pre-treatment and post treatment within each group revealed very highly significant differences (Table 4, Figs. 1,2).

Table (4): Comparison of the mean value of the BBT score within each group.

BBT score	Group I		Group II		Group III	
	Pre	Post	Pre	Post	Pre	Post
Mean (SD)	21.47 ± 4.76	40.53 ± 9.79	18.60 ± 5.37	29.67 ± 5.96	19.67 ± 3.87	21.33 ± 3.56
Mean Difference	19.07		11.20		2.53	
t-value	$t=9.98$		$t=12.34$		$t=3.85$	
p-value	<0.0001 ****		0.0001 ***		0.0018 **	

*** Very highly significant at $p \leq 0.001$. SD: Standard deviation. BBT: Box and blocks test.

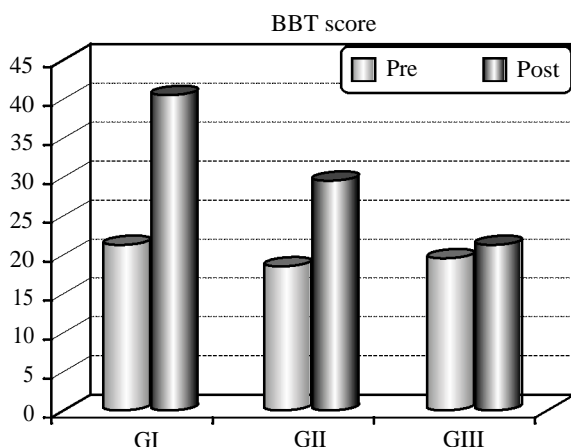


Fig. (2): Comparison of the mean value of the BBT scores within each group pre and post treatment.

Post Hoc Tukey Test was used for comparison of the mean value of BBT score between each pair of the three groups post treatment. The test revealed that there was a statistically very highly significant difference in the mean value of BBT score between GI and GII ($p=0.001$) and between GI and GIII ($p=0.0001$) while there was a statistically highly significant difference between GII and GIII ($p=0.006$) post treatment (Table 5).

Table (5): Post Hoc Tukey Test for comparison of the mean value of BBT score between each pair of the three groups post treatment.

FM score	GI & GII	GI & GIII	GII & GIII
	Post-treatment	Post-treatment	Post-treatment
Mean Difference	10.87	19.20	8.33
<i>p</i> -value	0.001***	0.0001***	0.006**

*** Very highly significant at $p \leq 0.01$.
BBT: Box and blocks test

Discussion

In this study the statistical analysis revealed that there were highly significance differences in ARAT score before and after treatment within the three groups. The increase is non-significant between group I and II while significant between group I and III and between group II and III. Also, there were highly significance differences in BBT score before and after treatment in the three groups. Also, there were highly significance differences in BBT score before and after treatment within the three groups. The increase is highly significant between group I, II and III while significant between group II and III.

The results came in agreement with Winstein et al., [16], who suggested that training specificity is thought to be critical to training effect, tasks involving fine finger control are most commonly performed unilaterally or with hands performing bimanually different but coordinated tasks (eg, when tying shoelaces or typing) while bilateral practice of dexterity tasks in which both arms perform identical movement may be some what artificial and probably insufficiently related to everyday life dexterity requirements to provide a training effects as in mCIMT group.

Also, the results of the study came in agreement with the studies done by Atteya, [6], Jin et al., 2014; Wang et al., [18] and Page et al., [19]. Atteya, [6] concluded that increases in arm function as measured by the ARAT and reduction in arm impairment as measured by the FM. In addition, considerable changes were also observed among CIT subjects between pre-testing and post-testing sessions on the Wolf Motor Function Test, both in terms of rating of arm use, and in terms of time taken to complete the task.

The possible explanation for the improvement of the BAT group was to the concept of interhemispheric disinhibition triggered by bilateral movements. When the intact arm was resting during the unilateral task, the undamaged hemisphere was not activated to generate the template of firing organization to guide the affected arm during skilled actions [10].

Page et al., [19] found significant changes in ARAT scores after CIMT without corresponding changes in FM-UE scores and speculated that their results were a result of the greater reliance of the ARAT on distal upper-extremity function, which may be emphasized more heavily than the proximal arm in activities practiced during CIMT.

These results came in agreement Morris et al. [20] who found no superiority of bilateral training on arm function as assessed using ARAT, but rather an advantage for unilateral training with regard to dexterity as assessed by the Nine Hole Peg Test (NHPT).

The more improvement in hand dexterity after mCIMT than both groups was largely consistent with Wolf et al. [21] and Wu et al. [22] studies that reported the benefits of mCIMT for improving the overall or physical domains of quality of life. Because the mCIMT program focused on the repeated practice of functional tasks, patients may be more able to improve on physical performance and daily function. In contrast, the change in hand

function was small in the BAT group, and this may be associated with the restricted effects of BAT on use of the affected UL and daily function.

On the contrast of the results of this study, French et al. [23] Revealed that there was non-significant difference for hand/arm functional activity, after repetitive task training in stroke patients. But in this study the highly significant difference because mCIMT and BAT were considered a subtype of repetitive task training. The contrast between results may be attributed to different methodology and training methods used.

In agreement with the study results of Carey et al. [24] who reported that a statistically significant increase of the mean value of the BBT scores post treatment in three groups. The more increase in mCIMT and BAT groups than group three may be explained in view that the excitability of the representation of the paretic hand in ipsilesional motor cortex is affected by the efficacy of motor training of a paretic hand.

This explanation was also postulated by Muellbacher et al. [25] who suggested that improved hand grasp and release function produced by task-specific rehabilitation in chronic stroke patients are associated with normalization of sensorimotor cortex laterality, a shift in the laterality of activation in sensorimotor cortex (primary motor cortex, primary somatosensory cortex, premotor cortex) from largely contralesional to largely ipsilesional, detected by using functional magnetic resonance image (fMRI) during paretic index finger tracking.

The contradiction between results of this study and results of Higgins et al. [13] who indicated that a task-oriented intervention did not improve gross manual dexterity of the affected arm in people with chronic stroke in which only two blocks increased post treatment. This may be attributed to different methodology and training methods used as in this study, BBT was used not only as assessment method but also as a training method.

Conclusion:

The present study revealed that mCIMT and BAT improved upper extremity function in stroke patients with the superiority of mCIMT than BAT in improving gross manual dexterity.

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الملخص العربي

خلفية: استرداد الوظيفة الحركية بعد السكتة الدماغية يعتمد على نشاط الشبكات العصبية المصابة والغير مصابة بالمخ الحركي. العلاج الحركي المستحث بالتقييد المعدل والتمرين الثنائي للذراعين يتشاركان عناصر علاجية متماثلة (الممارسة الجماعية والمنكررة مع تقنية محددة) وكلاهما يستهدف تحسين وظيفة الطرف العلوي في مرضى السكتة الدماغية.

الهدف من الدراسة: مقارنة تأثير هاتان التقنيتان على تحسين وظيفة الطرف العلوي في مرضى السكتة الدماغية.

المرضى وطريقة البحث: اشتملت هذه الدراسة على ثلاثون مريضاً بالسكتة الدماغية تراوحت اعمارهم ما بين ٥٤ و ٥٥ سنة. تم تقسيمهم عشوائياً إلى ثلاث مجموعات متساوية. المجموعة الأولى تلقت العلاج الحركي المستحث بالتقييد المعدل بالإضافة الى برنامج علاج طبيعي مختار. المجموعة الثانية تلقت التمرين الثنائي للذراعين بالإضافة الى برنامج علاج طبيعي مختار والمجموعة الثالثة تلقت برنامج علاج طبيعي مختار فقط. وظيفة الطرف العلوي والبراعة اليدوية تم قياسهم عن طريق عمل اختبار الذراع البحثي واختبار الصندوق والكتلة بالترتيب.

النتائج: اوضحت المعالجه الاحصائية للنتائج وجود زيادة واضحة ذات دلالة احصائية في اختبار الذراع البحثي في المجموعات الثلاثة قبل وبعد العلاج. وعند المقارنة ما بين المجموعات وبعضها تبين وجود زياده ذات دلالة احصائية واضح ما بين المجموعة الاولى والثالثة وما بين المجموعه الثانية والثالثة ولا يوجد فارق ذو دلالة احصائية بين الاولى والثانية بعد العلاج. أيضا وجود زيادة واضحة ذي دلالة احصائية في اختبار الصندوق والكتلة في المجموعات الثلاثة قبل وبعد العلاج. وعند المقارنة ما بين المجموعات وبعضها تبين وجود زياده ذات دلالة احصائية واضح ما بين المجموعة الاولى وكلتا المجموعتين الثانية والثالثة ووجود زيادة ذي دلالة احصائية ما بين المجموعه الثانية والثالثة بعد العلاج.

الخلاصة: العلاج الحركي المستحث بالتقييد المعدل والتمرين الثنائي للذراعين كلاهما يزيد التحسن في وظيفة الطرف العلوي في مرضى السكتة الدماغية مع تفوق العلاج الحركي المستحث بالتقييد المعدل في تحسين البراعة اليدوية