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A study of constraint-induced movement therapy in subacute stroke patients in Hong Kong

Jennifer Ma Wai Wai Myint, **Grace Fung Chi Yuen**, **Teresa Kim Kam Yu**, **Carolyn Poey Lyn Kng**, **Amy Mei Yee Wong**, **Keith Kit Chi Chow**, **Hercy Chi Kong Li** and **Chun Por Wong** Department of Geriatrics, Ruttonjee Tang Shiu Kin Hospitals, Hong Kong

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Objective: To investigate the beneficial effect of constraint-induced movement therapy in improving the function of hemiplegic upper extremity in the early subacute stroke patients.
Design: A prospective, single-blinded, randomized controlled study comparing the effectiveness of constraint-induced movement therapy or control treatment at post intervention and 12 weeks follow-up.
Subjects: The inclusion criteria were 2–16 weeks after stroke, hemiparesis of the affected limb, minimal function of ≥20 degrees wrist extension and ≥10 degrees extension of all digits and Mini-Mental State Examination score ≥17.
Interventions: The intervention group underwent a programme of 10 days upper extremity training (4 hours per day) with the unaffected limb being restrained in a shoulder sling and the control group received an equivalent duration of conventional rehabilitation therapy.
Main measures: Functional level for hemiparetic upper extremity, Motor Activity Log, Action Research Arm Test and modified Barthel Index.
Results: There were 23 and 20 subjects respectively in the constraint-induced movement therapy and control groups. Significant improvements were seen at post intervention and 12 weeks after constraint-induced movement therapy in functional level for hemiparetic upper extremity ($P = 0.001$), and in the 'amount of use' ($P = 0.001$) and 'how well' ($P = 0.021$) subscales of the Motor Activity Log. The total Action Research Arm Test score, grasp ($P = 0.004$), grip ($P = 0.004$), pinch ($P = 0.032$) and gross ($P = 0.006$) components showed significant improvement over the control group at post intervention. The grip component ($P = 0.019$) and the total Action Research Arm Test score ($P = 0.009$) were superior to the control group at 12 weeks.
Conclusion: Significant improvement in hand function could be achieved with constraint-induced movement therapy in subacute stroke patients, which was maintained up to 12 week follow-up.

Introduction

Stroke is the most common cause of disability in the adult and elderly population and one of the major causes of hospitalization. Although most stroke survivors recover to some degree, more

Address for correspondence: Jennifer Ma Wai Wai Myint, Department of Rehabilitation, Kowloon Hospital, 147A Argyle Street, Kowloon, Hong Kong.
e-mail: jmyint@graduate.hku.hk

Los Angeles, London, New Delhi and Singapore

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than 50% of survivors are left with significant sensorimotor and cognitive deficits.[1] These deficits produce long-term need for assistance from caregivers and society and impaired upper extremity function is associated with poorer health-related quality of life.[2]

Long-term motor deficits in stroke patients may be due to 'learned non-use', a process enhanced by the teaching of compensatory activity during rehabilitation. Recovery may be improved by constraint-induced movement therapy,[3,4] which involves the restraining of the unaffected upper limb and intensively training the affected side with a technique called 'shaping'.

A series of animal studies have shown that the reduced motor activity associated with cortical lesions can be overcome by restraining the unaffected limb to force the animal to use the affected limb.[5–7] Lesioned animals treated with constraint-induced movement therapy incorporate these motor gains into functional activities, such as feeding and grooming. A number of studies of constraint-induced movement therapy in people with chronic hemiplegia of variable duration[8–12] reported that this treatment improves objective measures of dexterity and motor function. Subsequently various modifications of the original protocol by Taub have been introduced successfully.[13,14] In addition, functional imaging studies have shown recovery to be associated with shifts of activation during motor tasks involving the affected hand to ipsilateral secondary and tertiary motor areas and to contralateral homologous motor areas.[15–17]

Studies in acute patients recruited within 1–2 weeks of stroke[18,19] using a modified protocol of constraint-induced movement therapy demonstrated promising results and showed no adverse effects. Although animal studies of constraint-induced movement therapy in the very early stage caused enlarged lesion volume in the rat brain[20] and impeded motor recovery of the affected limb, constraining the intact limb seven days after the onset of stroke did not have adverse outcome.[21,22]

However, there have been few published results of constraint-induced movement therapy in Chinese patients especially in this early subacute phase of stroke. At this juncture, intensive rehabilitation is still in progress and constraint-induced movement therapy may be incorporated into the outpatient or day hospital programmes to enhance recovery. Acceptance and compliance may be a problem as traditional Chinese culture encourages rest and recuperation after an acute illness rather than intensive procedures with risk of injury and fall. The aim of this pilot study is to investigate the beneficial effect and feasibility of implementing constraint-induced movement therapy in improving the function of hemiplegic upper limb in the early subacute period after stroke, in an outpatient day hospital setting.

Method

This was a randomized controlled clinical trial to compare upper extremity functional outcomes between a modified constraint-induced movement therapy protocol group and a dose-equivalent control group immediately after the intervention and at three-month follow-up. The observer was blinded and the subjects were randomized by drawing sealed envelopes which were filled at random with indication of which intervention group the patient was allocated to. Subjects were drawn from consecutively admitted patients of a regional hospital with acute and stroke rehabilitation service. Suitable subjects were also referred from two other hospitals with rehabilitation facilities. This project was approved by the ethics committee of the investigating hospital and was funded by a Government-sponsored health care research fund.

Patients received conventional rehabilitation therapy as inpatients in the first 14 days after acute stroke and were initially screened by the physician in charge according to recruitment criteria. They were then referred to the investigators for further physical examination and randomization. If patients did not fit all the inclusion criteria at the time of initial screening, for example not being able to walk safely, they were followed up regularly for up to 16 weeks after stroke in the inpatient or outpatient setting. After randomization, the allocated intervention was explained in detail to the patient. The baseline assessment was performed after informed consent (within five days before starting intervention) and the post-treatment assessments were performed within five days after completion of the constraint-induced movement therapy and after 12-week follow-up.

The inclusion criteria were 2–16 weeks after an ischaemic or haemorrhagic stroke, hemiparesis of the affected limb at least functional level 3 (functional test for hemiparetic upper extremity[23]), minimal movement of $\geq$20 degrees wrist extension and $\geq$10 degrees extension of all digits and the Cantonese version of Mini-Mental State Examination (MMSE)[24] score of 17 or above (the cut-off score for Hong Kong Chinese elderly who are illiterate is 18 out of maximum of 30). The subjects should be able to walk with or without aid. The exclusion criteria were assessed clinically and they included severe aphasia, high risk of fall, cerebellar stroke and severe shoulder pain affecting therapy.

Intervention programme

The constraint-induced movement therapy group underwent a programme of 10 days of hemiplegic upper extremity training by a designated occupational therapist with the unaffected limb being restrained in a shoulder sling and the control group received conventional therapy in the same period. Both groups received 4 hours of therapy each day for five days per week for two consecutive weeks. There was a slight modification from the original protocol[3] by reducing the therapy period from 6 to 4 hours per day to allow for local service structure. Both groups were trained in the geriatric day hospital setting although some patients remained in hospital overnight due to transport problem or lack of social support at home.

The constraint-induced movement therapy subjects signed a contract to wear a padded shoulder sling for 90% of waking hours during the 10-day treatment period. The subjects were treated with 4 hours of supervised activities which included shaping[25] which is a behavioural method to improve motor performance in small steps and encouraged with positive feedback and increasing level of difficulty. Error information was provided after each shaping trial and the therapist increased the level of difficulty of each set of tasks after the subject could complete the preceding ones. Training did not follow a strict algorithm of tasks with increasing level of difficulty. Rather, the therapist trained the patient with sets of tasks, and items relevant to the patient's activities of daily living which were appropriate to the functional level of upper extremity. The subject was instructed to wear the sling outside therapy during waking hours except when toileting, bathing and engaging in activities with potential risk of fall. A log book was given for the patient or carer to record the use of the sling hourly over 10 days and the percentage of compliance to the sling during waking hours was calculated.

The control group received 4 hours of conventional occupational therapy and physical therapy using a combination of neurodevelopmental techniques in the geriatric day hospital that included bimanual tasks for the upper limbs, compensatory techniques for activities of daily living, strength and range of motion, positioning and mobility training. Both groups continued outpatient therapy as needed after the 10-day programme and were discharged when clinically static progression was reached.

Outcome measurements

The functional test for hemiparetic upper extremity was used as a screening tool for inclusion and also one of the primary outcome measures. This tool is based on the Brunnstrom's seven levels of recovery and grading is on a pass–fail basis of activities within each level and has been validated for use in Hong Kong.[26] At functional level 3, the subject is able to abduct the shoulder, hold a pouch and stabilize a pillow. At functional level 7, key turning, usage of chopsticks and clipping cloth pegs are all achieved.

The primary end points for this study include the Action Research Arm Test and the Motor Activity Log score with two subscales of 'amount of use' and 'how well' the upper limb was used. The secondary outcomes were the modified Barthel Index score and the ability to complete the Nine-hole Peg Test. The blinded assessors were also occupational therapists trained specifically to use the above tools for this trial.

Reliability, construct validity, and predictive validity of the Action Research Arm Test (which is a laboratory-based motor function test) are well established.[27,28] Derived from the Fugl-Meyer scale, the Action Research Arm Test includes 19 items divided into four subscales: grasp, grip, pinch and gross movement. The performance of each motor task is rated on a 4-point hierarchical scale, ranging from 0 (no movement possible) to 3 (movement performed normally). Scores on individual items are added, with a maximum score per arm of 57.

The Motor Activity Log[3] is a structured interview with 30 standardized questions on various activities of daily living which evaluates how much and how well the affected extremity was used in specific daily activities during the past week. The quality ('how well') subscale consists of scores from 0 to 5 (not used at all to normal use) and the quantity ('amount of use') subscale consists of scores 0 to 5 (not used at all to used as much as prestroke). The Motor Activity Log is stable over a two-week waiting period[9] and has a high internal consistency (Cronbach's alpha 0.88–0.95), high inter-rater reliability and high test–retest reliability ($r = 0.94$, $P < 0.01$).[10] This tool is a real world measure used extensively in many previous constraint-induced movement therapy studies and correlated favourably with computerized activity monitors worn on a patient's wrist.[29]

The Nine-hole Peg Test[30] measures finger–hand coordination in terms of the time it takes a patient to place nine pegs in a 5-in by 5-in board and then remove them. Normal values are available for males and females using left or right hand. In this study, only the ability to complete the Nine-hole Peg Test regardless of the time taken to complete it were recorded and the number of patients who were able to complete the test in each group were compared. The modified Barthel Index,[31] a well-established scoring system for global measure of ADL was used.

Analysis

All data analyses were computed with SPSS version 10 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were computed for each of the baseline variables included in the study. For between-group comparisons of variables, *t*-tests, *U*-test, χ^2 and Fisher analyses were used when appropriate. A modified intention-to-treat analysis was implemented because not all subjects who were randomized received the baseline assessment. Mean scores and standard deviations (±SD) for baseline, post intervention and 12 weeks after intervention were calculated. ANCOVA was computed to test the study hypothesis for the outcome measures of the functional test for hemiparetic upper extremity, Motor Activity Log, total Action Research Arm Test and total modified Barthel Index. Kruskal–Wallis test for ordinal variables or non-parametric variables was used for the subscores of Action Research Arm Test.

Results

One hundred and twenty-two patients were screened for possible recruitment from October 2004 to December 2005 and 28 patients were recruited into the intervention group and 20 enrolled in the control group. Five patients refused to begin assessment or therapy after randomization and three patients dropped out from the intervention group after giving consent but before completing the 10-day therapy. The patient flow is shown in Figure 1.

The constraint-induced movement therapy subjects were recruited at a mean interval of 38.2 (±20.4) days from the onset of stroke. All the subjects could be assessed at post-intervention follow-up, but two patients from the constraint-induced movement therapy group could not be assessed after 12 weeks as one died of liver malignancy and one was lost to follow-up. The patients in the control group were recruited at a mean interval of 44.9 (±28.6) days from onset of stroke. One patient suffered a recurrent stroke and could not be assessed at 12-week follow-up.

The baseline characteristics (Table 1) including age, sex, type of stroke, laterality, interval between onset of stroke and therapy, presence of hemi-anaesthesia (by clinical

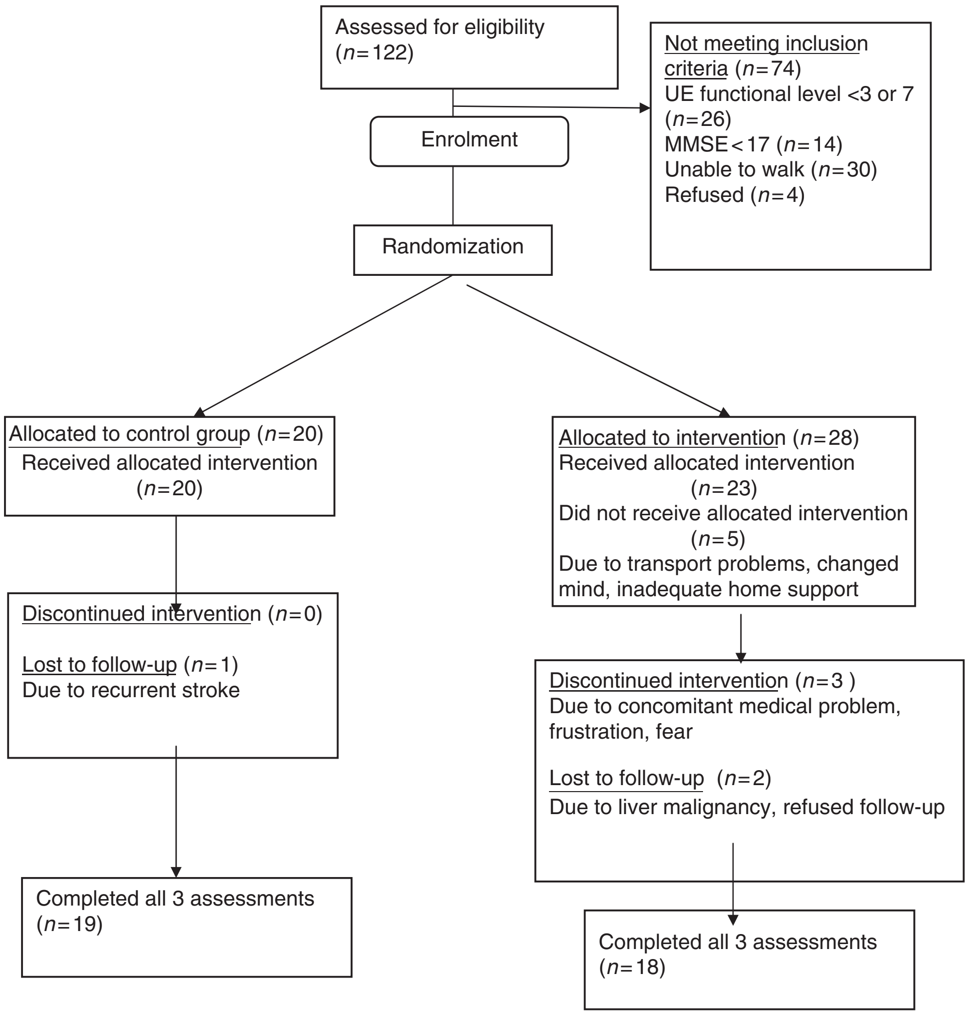

Figure 1 Patient flow.

assessment), presence of hemi-neglect (by clinical assessment and line bisection test) and the level of functional return at the baseline did not show statistically significant difference. Baseline variables such as MMSE, functional test for hemiparetic upper extremity, Motor Activity Log which consists of the 'amount of use' scale and the 'how well' scale, Action Research Arm Test, Nine-hole Peg Test and modified Barthel Index showed no statistically significant difference between the control group and constraint-induced movement therapy group.

The outcome measurements for pre-intervention, post-intervention and 12-week follow-up assessments are presented in Table 2. Using the baseline score of each variable as a covariate, ANCOVA was computed for the two follow-up measurements of the functional test for hemiparetic upper extremity, Motor Activity

Table 1 Baseline characteristics

Baseline variable	CIMT $N=23$ (mean ± SD)	Control $N=20$ (mean ± SD)	*P*-value
Age (years)	63.4 ± 13.6	63.9 ± 12.2	0.900
Interval (days)	38.2 ± 20.4	44.9 ± 28.6	0.383
Female:male	13:10	12:8	0.818
LACI	14	8	0.369
PACI	2	5	
POCI	2	1	
TACI	0	0	
ICH	5	6	
Affected side R:L	11:12	14:6	0.142
Dominant hand R:L	22:1	19:1	0.720
Affected hand dominant	11	14	0.216
Hemi-anaesthesia	5	7	0.334
Hemi-neglect	1	2	0.446
Old stroke	4	4	0.566
MMSE (maximum = 30)	25.6 ± 4.2	24.1 ± 5.5	0.300

Types of stroke: LACI, lacunar infarct; PACI, partial anterior circulation infarct; POCI, posterior circulation infarct; TACI, total anterior circulation infarct; ICH, intracerebral haemorrhage
R, right side; L, left side; MMSE, Mini-Mental State Examination (Cantonese version); CIMT, constraint-induced movement therapy.

Log scores and total Action Research Arm Test scores (Figures 2–5, Table 3).

Serial assessment of the functional test for hemiparetic upper extremity showed significant superiority ($F=14.08$, $P=0.001$) in the intervention group as compared to control group over the two follow-up observation points. After intervention, the mean Motor Activity Log scores comprising of 'amount of use' and 'how well' scales also improved significantly ($F=12.673$, $P=0.001$ for 'amount of use' and $F=5.816$ $P=0.021$ for 'how well').

The subcomponents of Action Research Arm Test were compared by using Kruskal–Wallis test. The grasp ($P=0.004$), grip ($P=0.004$), pinch ($P=0.032$) and gross movement ($P=0.006$) components were found to have significant improvement in the constraint-induced movement therapy group over the control group at post intervention. The grip component ($P=0.019$) and the total score of the Action Research Arm Test in the constraint-induced movement therapy group (ANCOVA, $F=7.601$, $P=0.009$) were superior to the control group at 12-week follow-up. For the grasp, pinch and gross movement components, there was no significant difference at 12 weeks although there was a favourable trend for constraint-induced movement therapy intervention. This early plateau of the functional aspect of upper extremity function is illustrated in Figure 5.

The Nine-hole Peg Test is a further measure of dexterity for patients with more advanced hand function (level 7 of the functional test for hemiparetic upper extremity). The number of patients who could perform this test at baseline was not significantly different, 8 (34.8%) in intervention group and 6 (30%) in control group. After constraint-induced movement therapy at post intervention, 16 study patients (69.6%) were able to perform the test, as compared to the control group where only 9 patients (45%) could do so ($P=0.022$). A similar trend was also evident at 12-week follow-up ($P=0.029$), which demonstrates that constraint-induced movement therapy resulted in more patients with return of fine hand function.

There were no significant differences in modified Barthel Index ($F=1.083$, $P=0.305$) between the constraint-induced movement therapy group and the control group at the two follow-ups. No major complications occurred, except one patient with exacerbation of shoulder pain in the affected upper extremity which was reported one month after the end of the intervention period. There were no fall episodes documented in all 23 constraint-induced movement therapy patients. Subgroup analysis did not show significant superiority of constraint-induced movement therapy in neglect patients, sensory-impaired patients or dominant limb-affected patients.

The compliance of patients to the sling during waking hours in the constraint-induced movement therapy group was 87.3 ± 12.9% with a range of 57.7 to 100%. There was no significant difference between males versus females or younger (less than 70 years of age) versus older patients for the compliance. MMSE, side of hemiplegia and interval between stroke and onset of treatment were also not significantly related to compliance.

Table 2 Outcome parameters

Outcome	CIMT (mean ± SD)	Control (mean ± SD)	Test for between group differences	*P*-value
Functional test for hemiparetic upper extremity (maximum = 7)				
Baseline	4.4 ± 1.3	4.3 ± 1.1		
Post intervention	6.7 ± 0.5	5.4 ± 1.3		
12-week follow-up	6.8 ± 0.5	6.1 ± 1.2	*F* = 14.08	0.001*
MAL – AU (maximum = 5)				
Baseline	1.01 ± 0.76	0.60 ± 0.59		
Post intervention	2.54 ± 1.10	1.14 ± 0.72		
12-week follow-up	3.42 ± 1.15	2.20 ± 1.31	*F* = 12.67	0.001*
MAL – HW (maximum = 5)				
Baseline	2.08 ± 0.94	1.74 ± 0.92		
Post intervention	3.41 ± 0.81	2.63 ± 1.05		
12-week follow-up	3.91 ± 0.75	3.25 ± 0.93	*F* = 5.82	0.021*
ARAT – grasp (maximum = 18)				
Baseline	10.3 ± 5.2	9.6 ± 5.3	*U* = 205.50	0.548
Post intervention	16.1 ± 3.9	12.8 ± 4.8	KW	0.004*
12-week follow-up	16.0 ± 3.8	14.2 ± 5.2	KW	0.130
ARAT – grip (maximum = 12)				
Baseline	5.7 ± 3.7	5.2 ± 4.3	*U* = 196.50	0.640
Post intervention	10.4 ± 2.9	8.2 ± 3.1	KW	0.004*
12-week follow-up	11.0 ± 2.0	9.5 ± 2.9	KW	0.019*
ARAT – pinch (maximum = 18)				
Baseline	4.0 ± 4.0	2.7 ± 3.6	*U* = 172.50	0.155
Post intervention	10.4 ± 6.3	6.0 ± 5.3	KW	0.032*
12-week follow-up	11.6 ± 6.4	8.3 ± 5.8	KW	0.096
ARAT – gross (maximum = 9)				
Baseline	6.9 ± 2.2	6.6 ± 2.3	*U* = 209.50	0.608
Post intervention	8.8 ± 1.1	7.7 ± 1.9	KW	0.006*
12-week follow-up	8.6 ± 1.1	7.9 ± 1.7	KW	0.121
ARAT – total (maximum = 57)				
Baseline	27.0 ± 13.4	24.0 ± 13.2		
Post intervention	47.1 ± 10.2	33.6 ± 12.5		
12-week follow-up	49.6 ± 9.9	39.9 ± 14.1	*F* = 7.601	0.009*
MBI (maximum = 100)				
Baseline	86.7 ± 12.4	79.5 ± 15.3		0.305
Post intervention	92.6 ± 8.5	85.3 ± 13.6		
12-week follow-up	97.6 ± 4.2	93.4 ± 7.7	*F* = 1.08	
Nine-hole Peg Test				
Able to complete at baseline	9 (34.8%)	6 (30%)	Chi-square = 0.111	0.739
Able to complete at post intervention	16 (69.6%)	9 (45%)	Chi-square = 5.223	0.022*
Able to complete at 12-week follow-up	18 (78.3%)	10 (50%)	Chi-square = 4.77	0.029*
Compliance to shoulder sling (% of waking hours)	87.3 ± 12.9%			

*Statistically significant.

CIMT, constraint-induced movement therapy; MAL, Motor Activity Log; AU, 'amount of use' subscale; HW, 'how well' subscale; ARAT, Action Research Arm Test; MBI, modified Barthel Index; *U*, Mann–Whitney *U*-test for baseline ordinal variables; KW, Kruskal–Wallis test for independent ordinal variables, *F*, value in ANCOVA.

Discussion

This study demonstrates that constraint-induced movement therapy in the early subacute period improved real world and laboratory-based measures of upper extremity function in a group of Chinese patients. The improvements achieved at post intervention were sustained at 12 weeks.

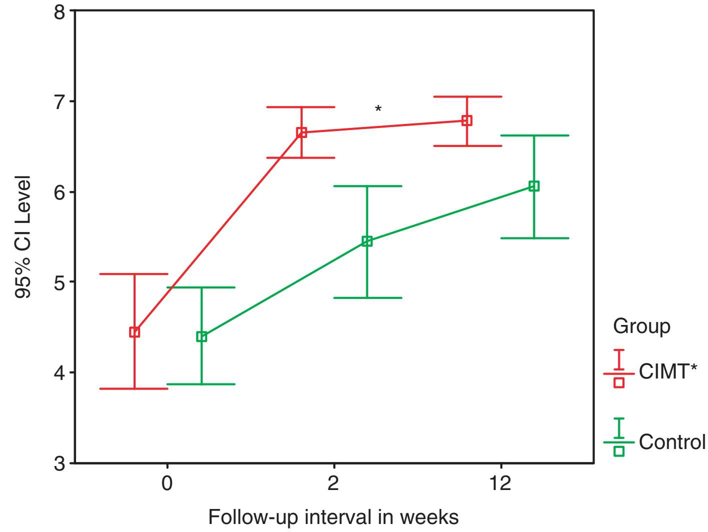

Figure 2 Functional test for hemiparetic upper extremity. $F = 14.08$; $P = 0.001$*. Bars indicate 95% confidence intervals of mean measurement score indicated. Time: 0, baseline; 2, post intervention, 12, 12-week follow-up.

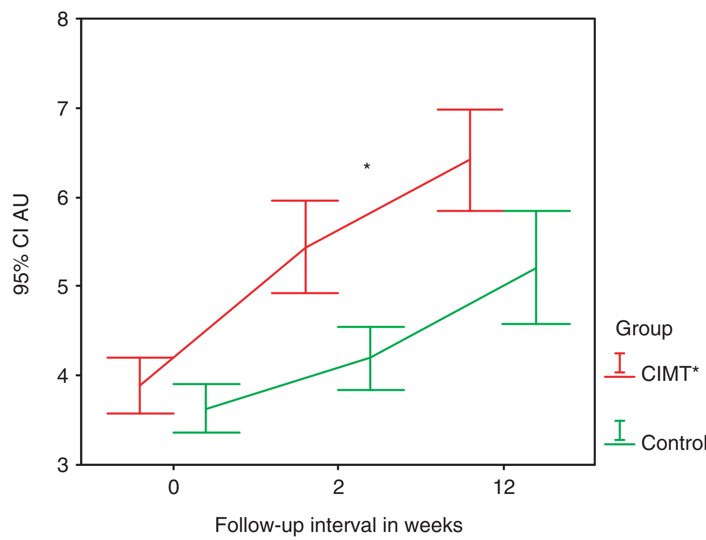

Figure 3 Motor Activity Log – 'amount of use'. $F = 12.67$; $P = 0.001$*. Bars indicate 95% confidence intervals of mean measurement score indicated. Time: 0, baseline; 2, post intervention; 12, 12-week follow-up.

For the subcomponents of Action Research Arm Test and the functional test for hemiparetic upper extremity, there was a plateau seen after the initial rapid improvement. Recovery was also evident in the control group especially in the modified Barthel Index but improvements in upper extremity function did not reach the level of the intervention group even at 12-week follow-up. This study is one of the few[13,32] to report such significant difference in two simultaneously

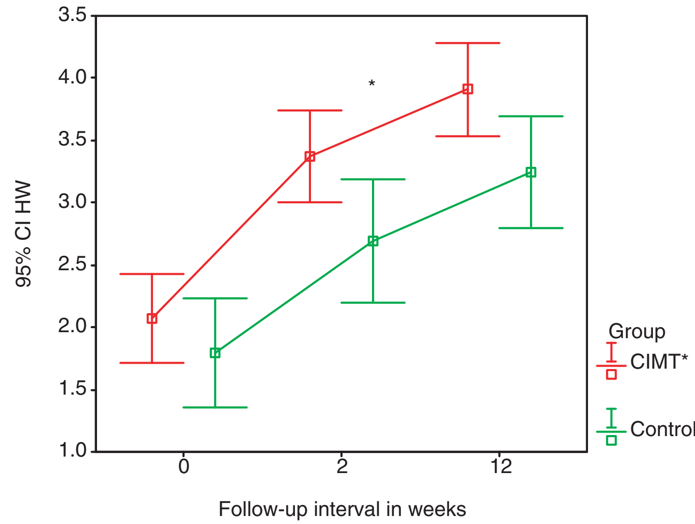

Figure 4 Motor Activity Log – 'how well'. $F = 5.82$; $P = 0.021$*. Bars indicate 95% confidence intervals of mean measurement score indicated. Time: 0, baseline; 2, post intervention; 12, 12-week follow-up.

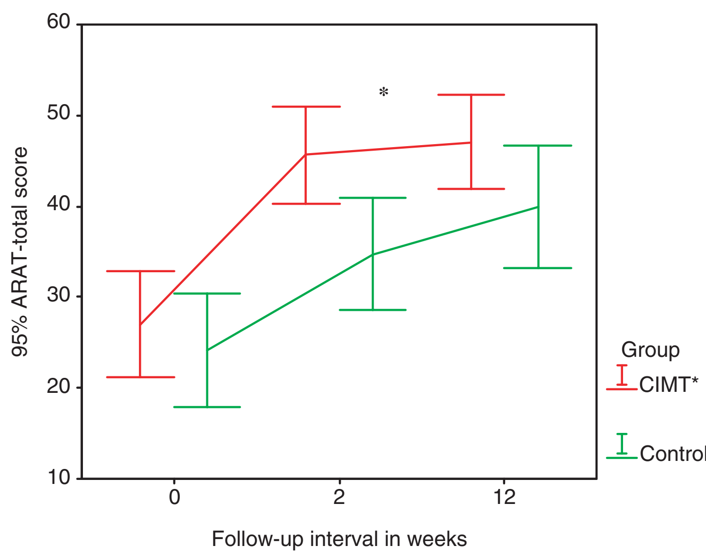

Figure 5 Action Research Arm Test (total score). $F = 7.601$; $P = 0.009$*. Bars indicate 95% confidence intervals of mean measurement score indicated. Time: 0, baseline; 2, post intervention; 12, 12-week follow-up.

recovering groups of patient soon after stroke whereas other studies[33,34] of constraint-induced movement therapy were in subacute stroke recruited patients who had stable upper extremity dysfunction. The magnitude of improvement for Action Research Arm Test and Motor Activity Log were comparable to previous reports in acute and chronic patients.[9,18,35]

Table 3 Changes in outcome measurement scores at baseline and post intervention and baseline and three-month follow-up

Outcome parameter	Change between baseline and post-intervention within each group (mean ± SD)		Change between baseline and 12th week follow-up within each group (mean ± SD)	
	CIMT	Control	CIMT	Control
Functional test for hemiparetic upper extremity	2.3 ± 1.3	1.1 ± 1.1	2.4 ± 1.3	1.8 ± 1.2
MAL – AU	1.53 ± 0.67	0.54 ± 0.42	2.41 ± 0.93	1.60 ± 1.21
MAL – HW	1.33 ± 0.56	0.89 ± 0.84	1.83 ± 0.72	1.51 ± 0.84
ARAT total score	20.1 ± 9.3	9.6 ± 12.4	22.6 ± 12.8	15.9 ± 15.5
MBI	5.9 ± 5.7	5.8 ± 7.3	10.9 ± 10.9	13.9 ± 11.4

CIMT, constraint-induced movement therapy; MAL, Motor Activity Log; AU, 'amount of use' subscale; HW, 'how well' subscale; ARAT, Action Research Arm Test; MBI, modified Barthel Index.

Most rehabilitation strategies for hemiplegic patients are aimed at compensatory means rather than restoration of upper limb function. Typically, patients are taught to use the unaffected limb and various assistive devices for activities of daily living to regain independence. In contrast, constraint-induced movement therapy attempts to maximize or restore motor function.

Some safety issues have been raised regarding constraint-induced movement therapy in the subacute rehabilitation setting. Painful overuse syndromes and the frustration of focusing on a weak and clumsy limb have been cited as potential problems.[18] The reason for withdrawal of three subjects from our constraint-induced movement therapy patients included new diagnosis of aortic aneurysm, transport problems, fear of fall and inability to comply with the arm sling due to frustration in two patients. Shoulder pain was not reported as a new-onset problem due to constraint-induced movement therapy but one patient had underlying shoulder pain before the intervention and reported exacerbation of shoulder pain one month after the end of the intervention period. After orthopaedic consultation, she was clinically diagnosed to have frozen shoulder without evidence of joint or rotator cuff pathology.

The other concern of starting constraint-induced movement therapy in the acute stage of stroke was the finding of lesion enlargement[20–22] in lesioned rats if started on constraint-induced movement therapy immediately. In human studies, acute constraint-induced movement therapy (within 1–2 weeks) has not shown any clinical adverse effects but neuro-imaging data are lacking. Our patients were recruited relatively late after the acute stroke at an average of 38–44 days so concerns about early lesion enlargement was not major. However, since the lower limb impairment may still be substantial at this stage, the risk of fall may be higher and this was the reason why many patients refused to participate in the study.

Several lines of reasoning support early implementation of constraint-induced movement therapy. From a motor learning perspective, early start in using the affected limb may minimize learned non-use. It may be easier to prevent learned non-use rather than attempting to correct it further on in time. One theory is that constraint-induced movement therapy is changing behaviour by the constraint component thereby individuals become more willing to use their affected limb. Another explanation may be neural reorganization.[19] Some biological evidence exists supporting the role of early training of the affected limb to maximize neuroplasticity. Long-term potentiation[36] or enhanced synaptic efficacy[37] may be mechanisms which help to promote task-specific limb usage by intensive training.

This study is limited by the small number of cases recruited. Despite there being over 100 cases referred to us, a substantial number were either too impaired or had recovered too fast for our intervention. The window of recruitment was limited to level 3–6 of the functional test for the hemiparetic upper extremity but the patient had to be able to ambulate well without great risk of fall. Finding such a combination in a cognitively intact patient was one of the challenges of the study.

Another limitation is the relatively short interval of follow-up after the intervention. If a longer follow-up assessment beyond 12 weeks was included, the relative improvement of upper extremity function in two groups could be better compared. This is especially interesting since both the control and the intervention group showed substantial improvements over the period of follow-up and the improvements seem to be converging at 12 weeks for the Action Research Arm Test and the functional level measurements.

An alternative to the above described protocol for early outpatient therapy is modified constraint-induced therapy (mCIT) developed by Page *et al.*[38] which may be more acceptable and less intensive for the patient as well as the therapist. This method consists of half-hour structured therapy three times a week for 10 weeks and less affected arm restraint five days a week for 5 hours for 10 weeks. It has recently been tested in subacute[34] and acute[39] stroke populations and encouraging results have been shown. However, for patients who find the restraint frustrating, the 10-week-long programme may result in a higher drop-out rate.

Although it may be the intensity of therapy to the affected upper limb that is the major contributing factor to the success of constraint-induced movement therapy in this study with patients in the early recovering phase of stroke, it is proposed that the restraint component was also significantly important. Evidence derives from the control group which received an equally intensive standard therapy. This group also showed impressive improvement over the time frame of 12 weeks, which may be contributed by spontaneous recovery, but the intervention group consistently showed superior performance in most outcome parameters relating to upper limb function.

Feasibility is demonstrated in a geriatric day hospital setting with generally moderate acceptance to the sling by the subjects, but intensive supervision and therapy by a trained therapist may not be cost-effective for routine use. Careful selection of well-motivated candidates may increase the successful outcome and may have an impact on quality of life.[2]

Further research is necessary in whether constraint-induced movement therapy is more effective in the subacute stage or in the chronic stage. Moreover, in the subacute stage, at the time when outpatient or day hospital-based rehabilitation is still on-going, the resource implication may not be as serious as in the chronic stage. This question may be answered by the cross-over arm of the EXCITE study (Extremity Constraint Induced Therapy Evaluation) which is an ongoing multicentre prospective controlled trial of constraint-induced movement therapy.[32,40]

In this study, constraint-induced movement therapy modified to 4 hours duration per day for 10 days was found to be a feasible technique for rehabilitation of subacute stroke patients with moderately impaired upper extremity function. It is superior to equivalent doses of conventional occupational and physical therapy over a 10-day period in the day hospital setting and the effects are maintained at 12-week follow-up.

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