Home-based Constraint Induced Movement Therapy Poststroke

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Abstract

Background: This study examined the efficacy of a home-based Constraint Induced Movement Therapy (CI Therapy) protocol with eight poststroke survivors.

Method: Eight ABA, single case experiments were conducted in the homes of poststroke survivors. The intervention comprised restraint of the intact upper limb in a mitt for 21 days combined with a home-based and self-directed daily activity regime. Motor changes were measured using The Wolf Motor Function Test (WMFT) and the Motor Activity Log (MAL).

Results: Grouped results showed statistically and clinically significant differences on the WMFT (WMFT [timed items]): Mean 7.28 seconds, SEM 1.41, 95% CI 4.40 – 10.18, $p = 0.000$; WMFT (Functional Ability): $z = -4.63$, $p = 0.000$). Seven out of the eight participants exceeded the minimal detectable change on both subscales of the MAL.

Conclusion: This study offers positive preliminary data regarding the feasibility of a home-based CI Therapy protocol. This requires further study through an appropriately powered control trial.

Keywords
Stroke, Rehabilitation, Upper limb

Credentials Display
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Constraint-Induced Therapy (CI Therapy) is a treatment method that has shown promising results for people who have reduced upper limb function as a result of stroke (Wolf et al., 2006). While there is some debate about the mechanism and magnitude of change following CI Therapy (van der Lee, 2003), the consensus is that CI Therapy is one treatment method that can improve upper limb function in people with chronic stroke who also have some motor return. This opinion is reflected in the Australian National Stroke Foundation Clinical Guidelines for Stroke Management (2010).

Stevenson, Thalman, Christie, and Poluha (2012) conducted a systematic review of the CI Therapy literature that involved dose-matched control interventions. They reported results for 22 trials in relation to four categories of outcome measures: upper limb motor capacity, upper limb ability, comprehensive function, and self-report measures. Meta-analysis of the trials that included these outcome measures showed significant effects favoring CI Therapy: Trials that reported upper limb motor capacity assessments favored CI Therapy (SMD = 0.47, 95% CI, 0.27-0.66), trials that reported measures of upper limb ability favored CI Therapy (SMD = 0.80, 95% CI, 0.57-1.02), and trials that reported measures of comprehensive function favored CI Therapy (SMD = 5.05, 95% CI, 2.23-7.87). The trials included in this systematic review used CI Therapy in a range between 15-60 hr in total and over a range of 3-10 weeks.

Peurala et al. (2011) also conducted a systematic review of the literature addressing CI Therapy. The 27 randomized controlled trials included in this review were categorized by the hours per week that the subjects received CI Therapy. The results of this review reported improved mobility of the affected upper limb when CI Therapy was conducted for 60-72 hr over two weeks; 20-56 hr over two weeks; 30 hr over three weeks; and 15-30 hr over 10 weeks.

The reported limitations of CI Therapy include the intensity required of the patients and the resources required to administer the treatment (Daniel, Howard, Braun, & Page, 2012; Page, Levine, Sisto, Bond, & Johnson, 2002). These results have prompted clinicians to argue for refinements of the CI Therapy protocols to address issues of patient engagement and resource allocation when administering CI Therapy.

The 22 randomized controlled trials in the Stevenson et al. (2012) systematic review included hospital- and clinic-based CI Therapy protocols. However, there have been published papers investigating the effect of a home-based CI Therapy model in both stroke and cerebral palsy therapy (Al-Oraibi and Eliasson, 2011; Azab et al., 2009; Tariah, Almalty, Sbeith, & Al-Oraibi, 2010). Tariah et al. (2010) conducted a randomized controlled trial in Jordan (n = 18) using a home-based CI Therapy protocol consisting of treatment for 2 hr per day, 7 days per week, for 2 months. There were significant differences at 4 months between the CI Therapy group and a group receiving Neurodevelopmental Treatment (NDT) in the Wolf Motor Function Test in Functional Ability (WMFT) (t(9) = 6.52, p < 0.001) and timed items (t(9) = 5.82, p < 0.001).

In response to these promising results, Wolf (2011) reported the potential to modify this

type of model for use in other cultures with different social and economic demands. This paper reports on the feasibility of a home-based CI Therapy protocol in Australia. Australia has specific challenges in delivering health care to 33.7% of Australians who live in regional and remote areas (Australian Bureau of Statistics, 2004), along with an increase in the aged-care population (who are more likely to have a stroke) and a decrease in the health workforce (Productivity Commission, 2005). There is a clear need to develop health interventions that are both effective and efficient. A home-based CI Therapy model is one that eliminates the requirement for hospital-based supervision, and therefore becomes a potentially useful treatment in a country like Australia.

The study was guided by the following research question:

- What is the effect of a home-based and self-directed CI Therapy protocol on upper limb activity following stroke?

Method

Participants

Approval to conduct the study was granted by the Human Ethics and Research Committees of ACT Health and the University of Sydney. Fifteen people volunteered for the study, and eight people met the inclusion criteria. The criteria for participating in the study included a clinical diagnosis of cerebrovascular accident (CVA), a minimum poststroke period of 6 months, and the ability to demonstrate the following physical signs: 20 degrees of active wrist extension and 10 degrees of active extension of all metacarpophalangeal (MCP) joints on the

hemiplegic side; good balance as evidenced by the ability to maintain balance during moderate physical distractions in standing while the intact hand was in the constraint mitt; and the ability to walk independently up and down two stairs. All of the participants had been discharged from formal rehabilitation programs.

Design and Intervention

This study tested the effect of the home-based and self-directed CI Therapy protocol on upper limb function. An ABA single subject research design (SSRD) was used where baseline measures were taken (A), the intervention was applied (B), and outcome measures were taken following the treatment (A).

The intervention was 21 days of constraint of the less affected upper limb for as many waking hours as possible, along with periods of intense upper limb activity. The participants were asked to undertake the CI Therapy-specific tasks as well as usual activities of daily living while wearing the constraint mitt. The key factors in the design of the mitt were that it was lightweight, washable, and restrictive to sensory input and hand use on the palmar surface. This type of restraint is similar to the restraints described in the literature (Wolf et al., 2006).

The participants were asked to practice 15 upper limb activities (see Table 1) for 2-3 hr a day and also asked to conduct the practice in at least 1 hr blocks. The massed practice component refers to the engagement in these 15 activities in blocks of time. The intensity of the treatment is a reported limitation of the applicability of CI Therapy (Page et al., 2002). Given that this CI Therapy protocol was self-directed and home-

based, it was thought that a less intense but longer duration treatment protocol would increase the chance of compliance with the treatment. With this in mind, the participants were asked to undertake 2-3 hr of massed practice per day for 21 days. This lower intensity protocol has been successful in improving upper limb function and self-reported upper limb use (Lin et al., 2009; Lin et al., 2007; Wu, Lin, Chen, Chen, & Hong, 2007).

The massed practice exercise component of the CI Therapy protocol was important, as it had to be intense enough to produce a treatment effect, but not so intense as to reduce compliance. The massed practice was to be completed at home in a self-directed way, so the participant had to find the practice interesting and relevant. In order to achieve this, the researchers convened a panel consisting of six occupational therapists with an average of 13 years of experience working in adult neurological rehabilitation. This panel was asked to name five upper limb activities that they believed to be the best for improving upper limb function while also being interesting and relevant. Many of the responses were similar and were grouped together to form 14 activities. These 14 activities were designed and presented to the same panel along with a group consisting of three people who had upper limb dysfunction following stroke. Both groups were asked to comment on the practicality and ease of use of the activities in a home setting. Following these consultations, one extra activity was added. These 15 activities were then task analyzed to biomechanically validate that they practiced all of the critical components of reach and grasp. These 15 activities became the massed practice exercise component of the CI Therapy protocol. See Table 1.

Table 1

CI Therapy Activities, Materials, and Description

CI Tasks	Items	Description
Nuts/Bolts	Washers. 12mm Bolts ½ x 2 ½ # Hex Nuts ½ # Ply tubing 13mm	Alternatively place a nut, then washer, then spacer, then washer, then nut, onto the bolt.
Threading	5mm drip tubing Ply tubing 13mm	Thread the pieces of tubing onto the cord provided.
Cut/Paste	Glue Stick A4 Spiral Sketchbook	Choose two items out of the magazine to cut out as accurately as you can. Using the scrapbook provided, glue the pictures any way you like into the scrapbook.
Saw/File	Wood Clamps Mini Hacksaw Dressed pine 20cm Files	Clamp a marked bit of wood to a bench; use the small saw to cut two pieces along the line; use the file to smooth the rough edges.
Cards	Playing cards	Shuffle the cards. Place them in a grid. Pick a card. Try to find the matching pair. Place the card face down if not successful. Take the pair away if successful until completed.
Sanding	Dressed pine Sanding blocks Sandpaper	Clamp the block of wood. Use the sanding block and sand paper to sand the wood for 3-4 minutes.

Clips	Paper Laminate Containers Clips	Put the colored bits of paper in the box provided. Shake the box so the paper is mixed up. Gather all of the same colors and put them in numerical order. Put a bulldog clip on each pile once in order.
Coloring	Markers Templates	Pick a stencil and color 2-3 items into the exercise book using the markers provided.
Folding	Material	Unpeg the pieces of material and fold into the smallest possible squares.
Pegging	Pegs	Unfold the square bits of material and peg them onto the rope provided.
Tracing	Cardboard Markers	There are two laminated bits of cardboard. With the marker provided, trace over the line and then complete the writing tasks.
Dowel Game	Dowel pieces	Using the small dowel pieces placed in the wood block, jump adjacent dowel pieces until only one remains.
Rice	Rice Lunchbox Containers	Using the cup provided, pour the rice into the containers up to the mark shown. When you have finished, pour the rice back into the main container.
Notice board	Corkboard Velcro hook Signs	Pick one of the 10 notice board plans. Change the notices as the plan requests.
Ball	Ball	Bounce the ball against the wall so it comes back to you. Let the ball bounce once and then catch it. Do this 30 times.

The CI Therapy Manual and Kit

The CI Therapy manual contained three sections: detailed instructions, brief instructions, and documentation. The detailed instructions contained photographs and written, step-by-step instructions for each activity. The brief instruction sheet was a two paged, laminated, and condensed form of the detailed instructions. Documentation consisted of a daily log to record the amount of time spent wearing the constraint mitt each day as well as the amount of time spent doing the activities. Each of the participants was given all of the materials required to complete the CI Therapy protocol. This was the CI Therapy manual (including all instructions and recording sheets) and two CI Therapy mitts. Together, this was the CI Therapy kit, which was contained in a ten-litre storage container.

The multiple baseline design used to structure this study was similar to that described in the literature (Ottenbacher, 1986; Zhan & Ottenbacher, 2001). The participants were randomly selected to begin their baseline measurements. All of the participants were tested four times for all outcome measures for baseline measurements. The time between baseline measurements was one day. Once the participant was determined to have achieved a stable baseline (i.e., less than one second deviation on the timed WMFT scores on three consecutive measurements), the intervention commenced. The stable baseline measure was determined through the pilot testing of two normal participants.

All of the participants were given standard instructions and were visited during the 21-day intervention period as follows. On day one of the intervention, a visit was made to the participant's home to set up the CI Therapy kit, comprising a manual, two mitts, and 15 activities. During the visit, all of the activities were demonstrated, and then the participant attempted the activities while wearing the mitt. During this time, the participant

and any significant others had the opportunity to ask questions and to clarify any aspect of the protocol. On day three of the intervention phase, all of the participants were contacted by telephone and given the opportunity to address any concerns or questions, as well as to receive encouragement to complete the treatment as outlined.

All of the participants were asked to spend 2-3 hr doing the 15 activities in 1-hr blocks. These activities were set up around the participants' homes to be used in a circuit style arrangement. The participants were requested to attempt all of the activities but not in a particular order. While the activities were not specifically graded, they were designed to practice all aspects of reach and grasp.

The participants were asked to identify the activities they completed and the amount of time that it took to complete them on a recording form. The participants also were asked to wear the mitt for as many waking hours as possible. They were asked to record how long they wore the restraint mitt each day. After the 21-day intervention phase, all of the participants were assessed a further four times using the same procedures as outlined for the baseline phase.

Outcome Measures

The two primary outcome measures used were the WMFT and the Motor Activity Log (MAL) (CIT Research Group, 2002). The WMFT is a 17 item test of motor ability that tests speed of movement during 15 functional tasks and tests strength for two items. It also contains a Functional Ability Scale (FA scale) that uses a 5-point observer rated scale to determine the quality of movement throughout the 15 timed items.

The MAL is a structured interview used to determine how much (amount of movement) and how well (quality of movement) the participants used their hemiplegic upper limb before and after the CI Therapy treatment. The participants were asked a series of up to 30 functionally based questions and asked to self-rate using separate 5-point scales on how much they performed the activity and how well they used their hemiplegic upper limb. The WMFT test and the MAL are commonly used outcome measures when determining the effects of CI Therapy on upper limb motor ability and self-reported improvements in upper limb movement (Stevenson et al., 2012). The MAL and WMFT have established validity and reliability in sub-acute stoke populations (Morris, Uswatte, Crago, Cook, & Taub, 2001; Uswatte, Taub, Morris, Light, & Thompson, 2006).

Data Analysis

Results for the timed items and functional ability (FA) on the WMFT were analyzed at an individual and group level. Grouped data was analyzed using the Statistical Package for Social Sciences (SPSS) version 19.0. Paired sample t-tests were used to compare the mean times at all data points at baseline and posttreatment. Wilcoxen signed ranked tests were used to compare the means of the FA scores at all data points at baseline and posttreatment. The MAL was analyzed by comparing the quantum of change at an individual level.

Data from the WMFT has been grouped and analyzed in relation to minimal detectable differences and clinical importance. In relation to a stroke group, Lin et al. (2009) reports that the

clinically important changes for a stroke group for the WMFT is 1.5-2 s for timed items and 0.2-0.4 points on the FA scale. For a stroke population, the minimal detectable change in the MAL is reported as 14.4% for quality of movement and 16.8% for amount of movement (Chen, Wolf, Zhang, Thompson, & Winstein, 2012).

The WMFT contains timed items that can be broadly clustered into fine motor activities and gross motor activities. For the purposes of this study, a gross motor activity was defined as an activity that is primarily completed using the shoulder, arm, or forearm. A fine motor activity was defined as an activity that required hand, wrist, and finger function as primary capacities to complete the task. In this way, the gross motor tasks were defined as: forearm to table, forearm to box, extend elbow, extend elbow with weight, hand to table, hand to box, reach and retrieve, lift basket, and lift can. Fine motor tasks were

defined as: lift pencil, lift paper clip, stack checkers, flip cards, turn key in lock, and fold towel. Grouped gross motor and fine motor data were analyzed in the same way as the entire WMFT.

Results

Participants

The average age of the participants was 55 years (SD 9.86). The average age of onset of stroke was 59 months (SD 68.64). Table 2 describes the participants' characteristics, including the type of stroke (ischemic or hemorrhagic), the onset (time since stroke), the hemisphere of the stroke (CVA), the side of hemiplegia (hemi), and the participant's hand dominance. Five out of the eight participants had a caregiver present at their home during the intervention. Three out of eight lived alone during the intervention.

Table 2

Summary of Participant Characteristics

Participant	Sex	Age (years)	Etiology	Onset (months)	CVA	Hemi	Dominance
1	M	59	Ischemic	8	L	R	R
2	M	71	Ischemic	20	L	R	R
3	M	43	Ischemic	61	L	R	R
4	F	47	SAH	13	L	R	L
5	M	63	Ischemic	63	L	R	R
6	M	50	Ischemic	72	R	L	R
7	M	49	Ischemic	228	R	L	L
8	F	64	Ischemic	7	R	L	R

The Wolf Motor Function Test

Grouped data showed clinically important improvements that reached statistical significance (alpha = 0.05) in the timed items of the WMFT and FA (timed items: t = 5.15, p = 0.000; FA: z = -4.63, p = 0.000) (see Tables 3 and 4). The timed

items of the WMFT were divided into gross motor and fine motor activities. Clinically important improvements that reached statistical significance (alpha = 0.05) were seen in the timed fine motor activities and the associated FA scores (the fine motor items: t = 5.51, p = 0.000; FA: z = -4.33, p = 0.000). While the gross motor improvement exceeded the clinically important threshold for timed items, it did not reach statistical significance (p = 0.12). The gross motor FA exceeded the minimal detectable change and was statistically significant (the gross motor items: t = 2.68, p = 0.12: FA: z = -3.97, p = 0.000).

Table 3

Grouped Wolf Motor Function Test Results: Timed Items

Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig (2 tailed)
				Lower	Upper			
Total WMFT	7.29*	8	1.42	44	10.18	5.15	31	.000
Fine Motor	11.07*	11.37	2.01	6.97	15.17	5.51	31	.000
Gross Motor	4.76*	10.07	1.13	1.13	8.39	2.68	31	.12

Note. *Exceeds clinically important change of 1.5 seconds.

Table 4

Grouped Wolf Motor Function Test Results: Functional Ability

	Wilcoxon Signed Ranks Test		
	z value	p - value	Mean Change A1-A2
Total WMFT	-4.63	.000	0.34*
Fine Motor	-4.33	.000	0.45*
Gross Motor	-3.97	.000	0.38*

Note. *Exceeds minimal clinically detectable change of > 0.2.

The Motor Activity Log

All of the participants except for participant 5 improved on both subscales of the MAL. All of the participants except for participant 5 exceed the minimum detectable change for both subscales of the MAL (see Table 5).

Table 5

Individual Motor Activity Log Results

Phase	A1	A2	A1	A2
Participant	Amount	Amount	Quality	Quality
1	0.55	2.9*	0.8	3.06*
2	0.7	2.3*	0.8	2.67*
3	0.36	2.9*	0.4	2.9*
4	1.6	3.6*	0.35	3.8*
5	0.1	0.1	0.1	0.1
6	2.3	3.7*	0.1	4*
7	2.2	4.3*	2.2	4*
8	2.7	4.5*	2.9	4.5*

Note. *Exceeds minimal detectable change of 14.4% (quality) and 16.8% (amount).

Compliance

Compliance with CI Therapy has been reported as an issue (Page et al., 2002). A home-based CI Therapy protocol potentially increases the chances of non-compliance, as there is not daily supervision and encouragement by a therapist to complete the protocol. In this study, the participants were asked to use their restraint mitt for as many waking hours as possible and to engage in the CI activities for 2-3 hr per day.

Six out of the eight participants achieved the recommended 2-3 hr of engaging in the CI Therapy activities. The participants who did not achieve this level attended work or volunteer activities during the day, and so they reported that doing the activities was sometimes difficult after a busy day. The average time spent wearing the restraint mitt was 3.5 hr, and this was considerably less than the "all waking hours" as requested. The main reason for this was that some participants were reluctant to wear the restraint mitt out of the house. They reported that the mitt looked strange to be wearing in public and so most did not wear the mitt out of their homes.

Discussion

Currently, CI Therapy is mainly used in hospitals or outpatient clinics (Atteya, 2004; Boake et al., 2007; Dahl et al., 2008; Dromerick, Edwards, & Hahn, 2000; Page, Levine, Leonard, Szarflarski, & Kissela, 2008; Wolf et al., 2006). There has been some research that examines providing a home-based CI Therapy model (Tariah et al., 2010). Widespread application of this home-based model could improve access to the treatment for those who are unable to travel to hospitals or who do not have ready access to outpatient services. This study applied a home-based and self-directed CI Therapy protocol for 21 days for eight poststroke survivors with an average poststroke time of 59 months. This study was guided by the research question: What is the effect of a home-based and self-directed CI Therapy protocol on upper limb activity following stroke?

When the WMFT data was grouped, clinically and statistically significant changes were seen in speed of movement and functional ability. This is consistent with reported improvements in arm function from CI Therapy studies based in hospitals, outpatient clinics, and in a home-based study (Dromerick et al., 2000; Lin et al., 2007; Page et al., 2002; Page, Sisto, Levine, & McGrath, 2004; Page et al., 2008; Ploughman & Corbett, 2004; Tariah et al., 2010). The gross motor WMFT timed items reached clinical significance but did not reach statistical significance. The reasons for this require further investigation to determine the specific contribution of fine motor and gross motor capacity to overall motor improvement post-stroke.

A traditional CI Therapy protocol involves intense daily practice in a setting like a hospital or clinic, where support staff is on hand to encourage participants to complete the treatment. This CI Therapy protocol was implemented at home and used a lower intensity practice component while showing improvement in speed and self-perceived quality of movement. This is worthy of further investigation, as compliance with a CI Therapy program has been identified as a barrier by clinicians (Page et al., 2002). This paper reports a

less resource-intensive form of CI Therapy, as it can be done at home without 1:1 therapist to client interaction. It is also potentially more accessible, as the participants do not need to leave their homes to undertake the treatment, and this could be of particular benefit to people living in regional or remote areas.

Compliance with the intensity of the treatment was mixed in this study. While most of the participants attempted the CI activities for the recommended hours per day (2-3 hr), not all of the participants wore the restraint mitt for the recommended time (all waking hours). One reason for this was the perceived attention the restraint mitt attracted when outside of the home. All of the participants were instructed to take their mitt off during self-care activities, so this could be another reason for a low compliance to wearing the mitt. As all of the participants were active outside of their homes, the look of the restraint mitt requires further attention when a larger trial is conducted.

Limitations

This study has three main limitations. First, the sample size is too small to generalize to the stroke population. Second, the ABA design is the weakest single subject research design. And

third, not all of the participants had the benefit of the positive influence of a caregiver while engaging in the treatment. Replication of the study will contribute to the external validity of the preliminary results obtained, as will further controlled trials using larger numbers of participants. A cluster randomized controlled trial using a home-based CI Therapy protocol has been planned by another research group (Barzel et al., 2013). The methodology used in the proposed controlled trial will address the main limitations reported in this study.

Conclusion

The application of a home-based and self-directed CI Therapy protocol resulted in clinically and statistically significant improvement in upper limb activity. Upper limb activity is critical for many personal and instrumental activities of daily living; therefore, these results may be of interest to occupational therapists treating poststroke survivors at home. This study has offered positive preliminary data about the potential benefits of a home-based and self-directed CI Therapy protocol. If these results can be replicated, with attention to the compliance issues noted, in a larger controlled trial, stronger evidence may support its wider use in the community.

References

Al-Oraibi, S., & Eliasson, A-C. (2011). Implementation of constraint-induced movement therapy for young children with unilateral cerebral palsy in Jordan: A home-based model. *Disability and Rehabilitation*, *33*(21-22), 2006-2012. http://dx.doi.org/10.3109/09638288.2011.555594

Atteya, A-A. (2004). Effects of modified constraint induced therapy on upper limb function in subacute stroke patients. *Neurosciences*, *9*(1), 24-29.

Australian Bureau of Statistics. (2004). Year Book Australia 2004. Retrieved 16 June, 2014 from http://www.abs.gov.au/

Australian National Stoke Foundation. (2010). *Clinical Guidelines for Stroke Management.* Melbourne: Australia. Retrieved from http://strokefoundation.com.au/site/media/Clinical_Guidelines_Acute_Management_Recommendations_2010.pdf

Azab, M., Al-Jarrah, M., Nazzal, M., Maayah, M., Sammour, M., & Jamous, M. (2009). Effectiveness of constraint-induced movement therapy (CIMT) as home-based therapy on Barthel Index in patients with chronic stroke. *Topics in Stroke Rehabilitation*, *16*(3), 207-211. http://dx.doi.org/10.1310/tsr1603-207

Barzel, A., Ketels, G., Tetzlaff, B., Krüger, H., Haevernick, K., Daubmann, A., . . . Scherer, M. (2013). Enhancing activities of daily living of chronic stroke patients in primary health care by modified constraint-induced movement therapy (HOMECIMT): Study protocol for a cluster randomized controlled trial. *Trials*, *14*, 334. http://dx.doi.org/10.1186/1745-6215-14-334

Boake, C., Noser, E., Ro, T., Baraniuk, S., Gaber, N., Johnson, R., . . . Levin, H. (2007). Constraint-induced movement therapy during early stroke rehabilitation. *Neurorehabilitation and Neural Repair*, *21*(1), 14-24. http://dx.doi.org/10.1177/1545968306291858

Chen, S., Wolf, S., Zhang, Q., Thompson, P., & Winstein, C. (2012). Minimal detectable change of the actual amount of use test and the motor activity log: The EXCITE trial. *NeuroRehabilitation and Neural Repair*, *26*(5), 507-514. http://dx.doi.org/10.1177/1545968311425048

CIT Research Group. (2002). *The motor activity log*. Birmingham, AL: University of Alabama.

Daniel, L., Howard, W., Braun, D., & Page, S. (2012). Opinions of constraint-induced movement therapy among therapists in southwestern Ohio. *Topics in Stroke Rehabilitation*, *19*(3), 268-275. http://dx.doi.org/10.1310/tsr1903-268

Dahl, A. E., Askim, T., Stock, R., Langørgen, E., Lydersen, S., & Indredavik, B. (2008). Short- and long-term outcome of constraint-induced movement therapy after stroke: A randomized controlled feasibility trial. *Clinical Rehabilitation*, *22*(5), 436-447. http://dx.doi.org/10.1177/0269215507084581

Dromerick, A. W., Edwards, D. F., & Hahn, M. (2000). Does the application of constraint-induced movement therapy during acute rehabilitation reduce arm impairment after ischemic stroke? *Stroke*, *31*(12), 2984-2988. http://dx.doi.org/10.1161/01.STR.31.12.2984

Lin, K-C., Hsieh, Y-W., Wu, C-Y., Chen, C-L., Jang, Y., & Liu, J-S. (2009). Minimal detectable change and clinically important difference of the Wolf Motor Function Test in stroke patients. *NeuroRehabilitation and Neural Repair*, *23*(5), 429-434. http://dx.doi.org/10.1177/1545968308331144

Lin, K-C., Wu, C-Y., Wei, T-H., Chang, G., Lee, C-Y, & Liu, J-S. (2007). Effects of modified constraint-induced movement therapy on reach-to-grasp movements and functional performance after chronic stroke: A randomized controlled study. *Clinical Rehabilitation*, *21*(12), 1075-1086. http://dx.doi.org/10.1177/0269215507079843

Morris, D., Uswatte, G., Crago, J., Cook, E., & Taub, E. (2001). The reliability of the Wolf Motor Function Test for assessing upper extremity function after stroke. *Archives of Physical Medicine Rehabilitation*, *82*(6), 750-755. http://dx.doi.org/10.1053/apmr.2001.23183

Ottenbacher, K. (1986). Evaluating clinical change: Strategies for occupational and physical therapists. Baltimore, MD: Williams and Wilkins.

Page, S. J., Levine, P., Leonard, A., Szaflarski, J. P., & Kissela, B. M. (2008). Modified constraint-induced therapy in chronic stroke: Results of a single-blinded randomized controlled trial. *Physical Therapy*, *88*(3), 333-340. http://dx.doi.org/10.2522/ptj.20060029

Page, S. J., Levine, P., Sisto, S., Bond, Q., & Johnston, M. V. (2002). Stroke patients' and therapists' opinions of constraint-induced movement therapy. *Clinical Rehabilitation*, *16*(1), 55-60. http://dx.doi.org/10.1191/0269215502cr473oa

Page, S. J., Sisto, S., Levine, P., McGrath, R. E. (2004). Efficacy of modified constraint-induced movement therapy in chronic stroke: A single-blinded randomized controlled trial. *Archives of Physical Medicine Rehabilitation*, *85*(1), 14-18. http://dx.doi.org/10.1016/S0003-9993(03)00481-7

Peurala, S., Kantanen, M., Sjögren, T., Paltamaa, J., Karhula, M., & Heinonen, A. (2011). Effectiveness of constraint-induced movement therapy on activity and participation after stroke: A systematic review and meta-analysis of randomized controlled trials. *Clinical Rehabilitation*, *26*(3), 209-223. http://dx.doi.org/10.1177/0269215511420306

Ploughman, M., & Corbett, D. (2004). Can forced-use therapy be clinically applied after stroke? An exploratory randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, *85*(9), 1417-1423. http://dx.doi.org/10.1016/j.apmr.2004.01.018

Productivity Commission. (2005). Australia's Health Workforce, Research Report, Canberra. SPSS for Windows (2010). Chicago: SPSS Inc.

Stevenson, T., Thalman, L., Christie, H., & Poluha, W. (2012). Constraint-induced movement therapy compared to dose-matched interventions for upper-limb dysfunction in adult survivors of stroke: A systematic review with meta-analysis. *Physiotherapy Canada*, *64*(4), 397-413. http://dx.doi.org/10.3138/ptc.2011-24

Tariah, H. A., Almalty, A-M., Sbeih, Z., & Al-Oraibi, S. (2010). Constraint induced movement therapy for stroke survivors in Jordan: A home-based model. *International Journal of Therapy and Rehabilitation*, *17*(12), 638-645. http://dx.doi.org/10.12968/ijtr.2010.17.12.638

Uswatte, G., Taub, E., Morris, D., Light, K., & Thompson, P. (2006). The motor activity log-28: Assessing daily use of the hemiparetic hand after stroke. *Neurology*, *67*(7), 1189-1194. http://dx.doi.org/10.1212/01.wnl.0000238164.90657.c2

van der Lee, J. H. (2003). Constraint-induced movement therapy: Some thoughts about theories and evidence. *Journal of Rehabilitation Medicine*, *35*(41), 41-45. http://dx.doi.org/10.1080/16501960310010133

Wolf, S. (2011). Home based therapy can be of, at least, short term value. *International*

Journal of Therapy and Rehabilitation, *18*(2), 116-117. http://dx.doi.org/10.12968/ijtr.2011.18.2.116

Wolf, S. L., Winstein, C. J., Miller, J. P., Taub, E., Uswatte, G., Morris, D., Giuliani, C., . . . Nichols-Larson, D. (2006). Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke. *Journal of the American Medical Association*, *296*(17), 2095-2104. http://dx.doi.org/10.1001/jama.296.17.2095

Wu, C-Y., Lin, K-C., Chen, H-C., Chen I-H., & Hong, W-H. (2007). Effects of modified constraint-induced movement therapy on movement kinematics and daily function in patients with stroke: A kinematic study of motor control mechanisms. *NeuroRehabilitation and Neural Repair*, *21*(5), 460-466. http://dx.doi.org/10.1177/1545968307303411

Zhan, S., & Ottenbacher, K. J. (2001). Single subject research designs for disability research. *Disability and Rehabilitation*, *23*(1), 1-8. http://dx.doi.org/10.1080/09638280150211202