Affected Upper-Extremity Movement Ability Is Retained 3 Months After Modified Constraint-Induced Therapy

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The practicality and patient compliance of constraint-induced movement therapy limit its application in many clinical environments. For more than a decade, the principal investigator’s laboratory has shown efficacy of an outpatient, modified constraint-induced therapy (mCIT). The current study examined whether participants administered mCIT retained motor changes 3 mo after intervention. The upper-extremity section of the Fugl-Meyer Impairment Scale (FM) and the Action Research Arm Test (ARA) were administered directly after mCIT intervention. Thirteen patients poststroke were tracked prospectively from directly after intervention concluded to 3 mo after intervention, at which time the FM and ARA were readministered. Three months after intervention, 25 of the 26 scores on the FM and ARA increased between the time after intervention and 3 months after intervention, reflecting continued increases in affected extremity movement ability. It is believed that the continued motor changes were caused by the comparatively larger number of extremity-use opportunities during the 10-wk mCIT intervention period. These opportunities encourage habitual extremity use even after the intervention period has concluded, leading to the changes observed.


Constraint-induced therapy (CIT) is an intensive intervention shown to increase affected upper-extremity use and function (Miltner, Bauder, Sommer, Dettmers, & Taub, 1999; Taub et al., 1993; van der Lee et al., 1999), including data from Phase 2 (Taub et al., 2006) and Phase 3 studies (Wolf et al., 2006). Recent data also suggest that CIT effects on affected-extremity use and movement are retained in the months after participation (e.g., Kunkel et al., 1999).

CIT consists of two components: (1) participation in 6-hr affected upper-extremity therapy sessions and (2) forced use of the affected upper extremity by restricting patients’ unaffected upper extremities during 90% of waking hours during a 2-wk period. Shaping, in which the participant is verbally encouraged to perform progressively more difficult movement components until the targeted movement is ultimately attained (see Taub, 1976, for a description), is also applied during the 6-hr therapy sessions. Yet, despite its promise, the CIT practice schedule is difficult for participants to tolerate for a full 6 hr (Kaplon, Prettyman, Kushi, & Weinstein, 2007); a significant proportion of participants may not fully comply (Ploughman & Corbett, 2004; Roberts, Vegher, Gilewski, Bender, & Riggs, 2005), and some people experience burns, muscle soreness, or discomfort in the affected upper extremity (Taub et al., 1993; van der Lee et al., 1999).

Given these limitations, our laboratory was the first to examine efficacy of an outpatient, modified CIT (mCIT) protocol that, over a 10-wk period, combines structured, 30-min, functional practice sessions with restriction of the less affected upper extremity 5 days/wk for 5 hr. Although increased use and function in the affected upper extremity are reported directly after mCIT participation (e.g., Page, Levine, & Leonard, 2005; Page, Levine, Leonard, Szaflarski, & Kissela, 2008; Page, Sisto, Levine, & McGrath, 2004), it is unknown whether the motor
changes are retained in the months after mCIT use. Other studies have similarly suggested that more distributed CIT practice schedules are efficacious (e.g., Pierce et al., 2003; Sterr et al., 2002), but the long-term retention of their benefits also remains undetermined. Because rehabilitative contact time is declining, identifying the rehabilitative approaches that confer sustained motor changes—even after the rehabilitative sessions have ended—is desirable.

Given that mCIT has conferred comparable motor benefits to CIT directly after intervention in several studies, we examined whether motor changes observed directly after mCIT participation were retained 3 mo after the intervention period had concluded. To our knowledge, this study was the first to examine retention of motor changes after participation in any distributed CIT protocol. Given the increased clinical applicability of such protocols, determining the long-term impact of their use is important.

Method

Participants

The participants in this study had been administered mCIT in two previous pilot trials and were being longitudinally tracked as part of those studies. They had been identified using advertisements placed in local therapy clinics in the northeastern and Midwestern United States and had met the following inclusion criteria:

- Able to actively extend the affected wrist a minimum of 10° and actively extend the metacarpophalangeal (MP) joints of the thumb and at least 2 additional MP joints in two additional fingers at least 10°, repeating the movements at least 3 times in 1 min
- Stroke experienced >3 mo before study enrollment
- A score ≥70 on the Modified Mini-Mental State Examination (Teng & Chui, 1987)
- No hemorrhagic lesions
- Age >18 and <85 yr
- No excessive spasticity in the affected biceps, triceps, wrist, or fingers, as defined by a score ≤2 on the Modified Ashworth Spasticity Scale (Bohannon & Smith, 1987)
- No excessive pain in the affected upper extremity, as measured by a score ≤5 on a 10-point visual analog scale
- Discharged from all forms of physical rehabilitation.

Using these criteria, 13 participants (9 men, 4 women), ages 44–77, were included in our analysis. Mean age was 63.4 yr (standard deviation = 9.4) and mean time since stroke at the time of mCIT intervention start was 29.5 mo (range = 5–162 mo). The participants received mCIT in the aforementioned pilot trials and returned for posttesting 3 mo after the mCIT intervention had concluded.

Outcome Measures

Consistent with previous mCIT work, we administered two outcome measures to measure affected upper-extremity movement before and after intervention: the Action Research Arm Test (ARA; Lyle, 1981) and the Fugl-Meyer Assessment of Motor Recovery After Stroke (FM; Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975).

The ARA is a 19-item test divided into four categories (grasp, grip, pinch, and gross movement). Each item is graded on a 4-point ordinal scale (0 = can perform no part of the test; 1 = performs test partially; 2 = completes test but takes abnormally long time or has great difficulty; 3 = performs test normally) for a total possible score of 57. For this test, participants were seated in a comfortable chair with a straight back. The ARA items that they had to grasp were placed on an adjustable table in front of them. Table height was adjusted according to the needs of each participant. The test is hierarchical in that, if the participant is able to perform the most difficult skill in each category, he or she will be able to perform the other items within the category and, thus, need not be tested. The ARA has high intrarater (r = .99) and retest (r = .98) reliability and validity (van der Lee et al., 2001).

The 66-point, upper-extremity section of the FM assesses several impairment dimensions using a 3-point ordinal scale (0 = cannot perform; 1 = can perform partially; 2 = can perform fully). The test is organized in a proximal-to-distal fashion: Movements that would be more difficult for most patients are presented later in the testing. For the test, participants were seated in the same chair as for the ARA. They were tested on each item by being given verbal instructions for each movement, immediately followed by performance with the unaffected extremity. Participants then attempted to perform the movement with the affected extremity.

Testing and Intervention Procedures

After participants were screened and signed consent forms that had been approved by the University of Cincinnati Institutional Review Board, we administered the ARA and FM on two occasions 1 wk apart. One week after the second testing session, participants were administered mCIT.

As in previous studies, the mCIT intervention, which began 1 wk after the pretesting session, consisted of two components. First, we held 30-min, one-on-one sessions of affected upper-extremity therapy 3 days/wk during a 10-wk period. This intervention included shaping techniques, in which operant conditioning is applied in such a way that participants are verbally encouraged to more fully perform selected motor skills using the more affected upper extremity. We applied shaping using two to three activities chosen by the participants with help from their therapist (e.g., writing; reaching for, grasping, and drinking out of a cup). Second, during the same 10-wk period, participants’ less affected upper extremities were restrained every weekday for 5 hr at a time of frequent use, as identified by the participant with assistance from the therapist. Their less affected upper extremity was restrained using a cotton hemisling, and their hand on that extremity was placed in a mesh, polystyrene-filled mitt with Velcro straps around the wrist. In addition, although mitt adherence has been high in our pilot work, techniques to enhance mitt use outside of the laboratory, described in detail elsewhere (Morris & Taub, 2001; Winston et al., 2003), included a behavioral contract, mitt-compliance device embedded in the mitt, and diary of daily extremity use.
Posttesting

One week after therapy completion, each participant returned to the laboratory where pretesting occurred, and the same examiner who administered the pretests administered the ARA and FM again. The rater was blinded to study purpose.

Results

The purpose of this study was to determine whether mCIT benefits were retained 3 mo after intervention had concluded. To allow comparison between changes after intervention and 3 mo after intervention, Table 1 displays participants’ outcomes directly after intervention (POST) as well as their 3-mo postintervention scores.

As shown in Table 1, participants retained their postintervention impairment levels of the affected upper extremity at 3 mo after intervention, as denoted by FM scores. Moreover, all participants exhibited nominal score increases on the FM at 3 mo after intervention. A similar trend was observed on the ARA, which indicated that all participants retained their previous functional limitation levels; 12 of the 13 participants showed ARA score increases at 3 mo after intervention. A similar trend was observed for change scores on the FM and ARA, respectively. These tests showed that neither FM nor ARA scores had significantly changed from the period directly after intervention to the 3-mo posttesting period ($t = 0.39$ for the FM and $t = 0.37$ for the ARA).

Discussion

Stroke remains the leading cause of adult disability in the United States, and upper-extremity hemiparesis constitutes one of the most disabling stroke sequelae. mCIT appears to increase affected upper-extremity use and function directly after participation. However, the stability of the mCIT treatment effect over time remains unknown. The current study constitutes a first step in examining whether patients who participate in mCIT retain its motor benefits 3 mo after intervention.

From the pretesting to posttesting periods, participants exhibited marked gains on both the ARA (preintervention mean score $= 29.3$; postintervention mean score $= 40.5$; change score $= +10.8$) and the FM (preintervention mean score $= 40.8$; postintervention mean score $= 48.2$; change score $= +7.4$). Consequently, participants had already displayed clinically and statistically significant reductions in affected upper-extremity impairment and functional limitation. In the current study, participants retained their motor gains, as measured by the FM and ARA (indicative of sustained reductions in impairment and functional limitation, respectively) 3 mo after mCIT participation (Table 1). These findings were corroborated by nonsignificant changes in FM and ARA scores using $t$ tests, confirmed our study hypothesis, and were consistent with CIT studies reporting retention of motor changes 3 mo after intervention (Kunkel et al., 1999).

An unexpected finding was that participants exhibited increased FM and ARA scores 3 mo after the intervention had concluded. This finding is not only new to the mCIT literature but differs from aforementioned CIT studies (i.e., Kunkel et al., 1999). We speculate that this difference is caused by the more distributed nature of the mCIT intervention, which allows for more hours of home-based practice with the affected extremity than the CIT schedule (250 limb-restricted hours vs. the ExCITE trial; Wolf et al., 2006), which allowed for approximately 126 hr of limb-restricted hours). By definition, the larger number of practice opportunities during mCIT allows for more chances to operantly condition extremity use during mCIT and is thought to be responsible for the comparatively larger affected extremity use changes when participants participate in mCIT versus CIT (Page & Levine, 2008).

With regard to our study, the additional opportunities for operant conditioning of extremity use likely rendered participants more inclined to use their extremities, even when the intervention had concluded. Given the well-established relationships between extremity use, neuroplasticity, and function (e.g., Heddings, Fried, Plautz, Barbay, & Nudo, 2000), clients using their extremities more frequently would be likely to display some correlative motor increases as they continue to identify ways to use their extremities at home, even when not formally participating in mCIT. In this way, mCIT constitutes a promising pathway to independence in reacquiring valued occupations and roles, which is consistent with the goals of occupational therapy.

These motor changes were clinically relevant. Indeed, participants who had been administered mCIT retained the ability to perform valued new movements, such as

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**Note.** Numbers in parentheses denote significance levels using $t$ tests.

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### Table 1. Scores on the Fugl-Meyer Assessment of Motor Recovery After Stroke (FM) and Action Research Arm Test (ARA) After Intervention (POST) and 3 Mo After Intervention (POST–3)

<table>
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<th>POST</th>
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Mean 48.2 50.9 +2.7 (.39) 40.5 43.3 +2.8 (.37)
writing, using a computer or piano keyboard, and using eating utensils. By contrast, we have frequently encountered clients who underwent months of conventional therapies yet had not retained the motor changes associated with those therapies. We speculate that the retention difference between mCIT and conventional therapies is attributable to mCIT’s emphasis on movement and to the exceptional opportunities that mCIT provides to encourage extremity use, as described previously.

Given the motor changes observed in this brief report, longitudinal efforts are now under way to measure affected upper-extremity movement with qualitative and quantitative methodologies. Although motor changes are of primary interest to patients and payers, the lack of measurement of affected extremity use constitutes a minor limitation to this study that will be overcome with measurements of use in future work. Measurement of this construct is important because use appears to be an ingredient in eliciting cortical and functional changes (e.g., Heddings et al., 2000) and is of interest to occupational therapy practitioners.

Clients in our study did not participate in any rehabilitative intervention during the period between mCIT completion and 3-mo evaluation. Given this fact, the focal period during which participants showed changes, and the fact that 12 of the 13 participants displayed motor gains, it is likely that the changes herein described are attributable to a continued response to mCIT participation (as opposed to variation in test scores). Nonetheless, future longitudinal studies are needed, including larger samples and monitoring of a placebo group to compare long-term changes in mCIT participants with changes in those who are not administered mCIT.

Conclusion
mCIT is an outpatient-based intervention that has been shown to increase affected upper-extremity use and function directly after participation. The current results suggest that motor changes associated with mCIT participation are retained—and continue to increase—up to 3 mo after the intervention period has ceased. ▲

Acknowledgment
This work was supported by awards from the American Heart Association.

References

