Modified Constraint-Induced Therapy Combined With Mental Practice
Thinking Through Better Motor Outcomes

Stephen J. Page, PhD; Peter Levine, BA, PTA; Jane C. Khoury, MD, PhD

Background and Purpose—Modified constraint-induced therapy (mCIT) is an outpatient therapy encouraging repetitive, task-specific practice with the affected arm. mCIT has shown efficacy in all stages poststroke. Given its efficacy when combined with other therapy regimens, the current study examined the efficacy of mental practice when combined with mCIT versus mCIT only using randomized, controlled methods.

Method—Ten patients with chronic stroke (7 males; mean age, 61.4±3.02 years; age range, 48 to 79 years; mean time since stroke, 28.5 months; range, 13 to 42 months) exhibiting stable, affected arm motor deficits were administered mCIT, consisting of: (1) structured therapy emphasizing affected arm use in functional activities 3 days/week for 10 weeks; and (2) less affected arm restraint 5 days/week for 5 hours. Both of these components were administered during a 10-week period. Subjects randomly assigned to the mCIT+mental practice experimental condition also received 30-minute mental practice sessions provided directly after therapy sessions. These mental practice sessions required daily cognitive rehearsal of the activities of daily living practiced during mCIT clinical sessions.

Results—No pre-existing differences were found between groups on any demographic variable or movement scale. All subjects exhibited marked reductions in affected arm impairment and functional limitation. However, subjects in the mCIT+mental practice group exhibited significantly larger changes on both movement measures after intervention: Action Research Arm Test, +15.4-point change versus +8.4-point change for mCIT only subjects (P<0.001); Fugl-Meyer, +7.8-point change versus +4.1-point change for the mCIT only subjects (P=0.01). These changes were sustained 3 months after intervention.

Conclusions—mCIT remains a promising motor intervention. However, its efficacy appears to be enhanced by use of mental practice provided directly after mCIT clinical sessions. (Stroke. 2009;40:551-554.)

Key Words: hemiplegia ■ mental practice ■ motor imagery ■ physical therapy ■ stroke

During mental practice (MP), physical tasks are mentally rehearsed, usually in the absence of voluntary physical movement. The same muscular1–3 and neural structures4,5 subserve both physical and mental practice, enabling MP to offer similar benefits to physical practice of a particular skill. For example, MP can be used as a method of acquiring additional practice attempts in rehabilitative settings,6–8 especially when physical practice may be unsafe (eg, balance activities).9,10 In stroke rehabilitative settings, the addition of MP to repetitive, task-specific practice (RTP) regimens significantly increases affected arm use,11 movement kinematics,12 and function in subacute13,14 and chronic patients,11,15–17 including in a recent, randomized, controlled trial.18

Modified constraint-induced movement therapy (mCIT) is an outpatient-based, RTP protocol that increases affected arm use and function at all stages after stroke.19–25 During mCIT, affected arm use is emphasized in 2 ways, each administered during a 10-week period: (1) patients engage in ½-hour RTP sessions occurring 3 days/week that emphasize affected arm use. Shaping is also applied during the therapy sessions, in which subjects are verbally encouraged to perform progressively more difficult components of the activity; and (2) patients practice activities of daily living (ADLs) with the affected arm for 5 hours/day every weekday.

Given MP’s success when combined with other RTP regimens, this study examined whether the addition of MP, provided directly after clinical mCIT sessions and at the same duration as mCIT clinical sessions, increases the mCIT treatment effect. We hypothesized that subjects receiving mCIT and MP would exhibit larger reductions in affected arm functional limitation and impairment than participation in mCIT only.

Methods

Subjects
Volunteers were recruited using advertisements placed in local therapy clinics. A research team member screened volunteers using the following study criteria derived from previous mCIT research: (1) history of no more than one stroke; (2) ability to actively extend
at least $10^7$ at the metacarpophalangeal joints of each digit and actively extend $20^\circ$ at the wrist; (3) stroke experienced $>12$ months before study enrollment; (4) a score $\geq 69$ on the Modified Mini Mental Status Examination; (5) age $>18$ and $<80$ years; and (6) affected arm nonuse, defined as a score $<2.5$ on the amount of use scale of the Motor Activity Log. We also applied the following exclusion criteria: (1) excessive spasticity at any affected arm joints, defined as a score $\geq 3$ on the Modified Ashworth Spasticity Scale; (2) excessive pain anywhere in the affected upper limb, as measured by a score of $\geq 4$ on a 10-point visual analog scale; (3) still enrolled in any form of physical rehabilitation; and (4) participating in any experimental rehabilitation or drug studies.

**Outcome Measures**

Based on their extensive, successful use in previous MP and mCIT work, and their responsiveness to motor change after forced use protocols, we administered the following 2 outcome measures: (1) The Action Research Arm Test (ARAT) (our primary outcome measure), a 19-item, 57-point test divided into 4 categories (grasp, grip, pinch, and gross movement), has each item graded on a 4-point ordinal scale (anchored by 0=can perform no part of the test; 3=performs test normally). The ARAT has high intrarater ($r^2=0.99$) and test–retest ($r^2=0.98$) reliability and validity; and (2) The 66-point, upper-extremity section of the Fugl-Meyer Assessment of Motor Recovery After Stroke (FM), which assesses impairment using a 3-point ordinal scale (anchored by 0=Cannot perform; 2=Can perform fully). The FM offers impressive test–retest reliability ($r^2=0.99$; $p<0.01$) and interrater reliability ($r^2=0.87$ to $1.00$), and construct validity.

The main study goal was to compare differences in motor outcomes associated with participation in the 2 interventions. Moreover, previous studies have already demonstrated Motor Activity Log changes after MP and mCIT, and their responsiveness to motor change after forced use. Based on their extensive, successful use in previous MP and mCIT studies, the ARAT and FM were administered (primary study end point). The ARAT was administered by an occupational therapist, as mCIT only patients, because the MP intervention was self-administered by an audiotape.

**Posttesting**

Five weekdays after the end of his or her final treatment day, each subject returned to the same laboratory at which pretests were administered (primary study end point). The FM and ARAT were administered by the therapists comprised of functionally relevant activities using the affected arm.

### Mental Practice Intervention

In addition to mCIT participation, subjects randomly assigned to the mCIT + MP condition also engaged in MP sessions. These 30-minute sessions occurred directly after clinical mCIT sessions in a quiet treatment room adjacent to the gym where therapies were rendered. MP subjects received the appropriate MP intervention corresponding to the week of therapy in which they were currently engaged (Table 1). All MP interventions were audiotapes and were consistent in content and duration to MP tapes described elsewhere by Page and colleagues.

The tapes contained ADLs that subjects were also practicing during mCIT clinical sessions and consisted of: (1) approximately 5 minutes of guided relaxation exercises; (2) 15 to 20 minutes of guided motor imagery, in which the subject was instructed to imagine him/herself performing each component of each ADL using polysensory cues; and (3) 5 minutes of refocusing into the room. The scripts contained on the tapes were read by a male psychologist with over 10 years of experience administering mental practice interventions. Subjects were instructed to not mentally practice in environments other than those that were part of this study. We would also emphasize that both groups received the same amount of time with the occupational therapy staff, as mCIT only patients, because the MP intervention was self-administered by an audiotape.

### Results

#### Subject Characteristics

Applying the aforementioned study criteria, 30 subjects were screened for this study, with 20 excluded for the following reasons: (1) insufficient motor function ($n=15$); (2) excessive spasticity ($n=3$); (3) cognitive impairment ($n=1$); and (4) inability to make all sessions/transportation issues ($n=1$). Ten subjects were included (7 males; mean age, 61.4 ± 3.02 years; age range, 48 to 79 years; mean time since stroke, 28.5 months; range, 13 to 42 months; Table 2).

### Table 2. Subject Characteristics

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Age</th>
<th>Gender</th>
<th>Time Poststroke, Months</th>
<th>Arm Affected</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65</td>
<td>M</td>
<td>13</td>
<td>R</td>
<td>MP + mCIT</td>
</tr>
<tr>
<td>2</td>
<td>48</td>
<td>M</td>
<td>45</td>
<td>R</td>
<td>MP + mCIT</td>
</tr>
<tr>
<td>3</td>
<td>72</td>
<td>M</td>
<td>21</td>
<td>R</td>
<td>MP + mCIT</td>
</tr>
<tr>
<td>4</td>
<td>53</td>
<td>F</td>
<td>36</td>
<td>L</td>
<td>MP + mCIT</td>
</tr>
<tr>
<td>5</td>
<td>54</td>
<td>F</td>
<td>17</td>
<td>R</td>
<td>MP + mCIT</td>
</tr>
<tr>
<td>6</td>
<td>59</td>
<td>M</td>
<td>35</td>
<td>L</td>
<td>mCIT</td>
</tr>
<tr>
<td>7</td>
<td>62</td>
<td>M</td>
<td>17</td>
<td>L</td>
<td>mCIT</td>
</tr>
<tr>
<td>8</td>
<td>79</td>
<td>M</td>
<td>39</td>
<td>R</td>
<td>mCIT</td>
</tr>
<tr>
<td>9</td>
<td>56</td>
<td>F</td>
<td>42</td>
<td>R</td>
<td>mCIT</td>
</tr>
<tr>
<td>10</td>
<td>66</td>
<td>M</td>
<td>20</td>
<td>R</td>
<td>mCIT</td>
</tr>
</tbody>
</table>

M indicates male; F, female.
Outcomes

Due to our small number, the distributional assumptions that underlie the t test could not be satisfied. Thus, Wilcoxon tests were applied and revealed nonsignificant differences between the groups in mean age and in mean time since stroke. Preintervention FM and ARAT scores were also not significantly different across groups, and preintervention Test 1 scores were not significantly different from preintervention Test 2 scores on either the ARAT or FM.

After intervention, subjects in both groups exhibited marked score increases on both the ARAT and the FM. Qualitatively, all subjects reported using their more affected limbs for ADLs listed in Table 2 as well as new ADLs such as grooming and eating. Between pretesting and posttesting administered 1 week after end of intervention (our primary study end point), the mCIT+MP group exhibited a mean increase of +15.4 points on the ARAT (our primary outcome measure) and a mean increase of +7.8 points on the FM (Table 3). Subjects in the mCIT only group displayed a mean increase of +8.4 points on the ARAT and +4.1 points on the FM. To statistically analyze the above trends, 2 2-tailed Wilcoxon rank sum tests were performed (one for the ARAT; one for the FM) on the change scores of members of each group. Of the 10 individuals, the 5 with the highest change scores on both the ARAT and FM were the MP+mCIT patients. On both the ARAT and Fugl-Meyer, each of the 5 patients in the MP+mCIT group had a greater change score than did any patient in the mCIT only group (Wilcoxon rank sum for ARAT: \(P<0.001\); Wilcoxon rank sum exact for FM: \(P=0.01\)).

All subjects also exhibited slight, positive motor changes 3 months after intervention completion.

Discussion

Modified constraint-induced therapy is a RPT regimen encouraging affected arm use through participation in clinical and home-based practice sessions. It has emerged as a viable outpatient treatment option due to its efficacy and its clinical implementation using existing current procedural terminology codes. Given the efficacy of MP when combined with other promising RTP regimens, the current study examined efficacy of MP when combined with mCIT.

Consistent with previous mCIT studies,19-25 all subjects exhibited sizable changes on the outcome measures. These motor changes were clinically significant, conveying ability to perform skills not performed since before subjects’ strokes (eg, writing, buttoning a blouse). Moreover, like in previous mCIT studies, there was no attrition and full protocol adherence.

As noted earlier, MP elicits neural and muscular activations that are similar to those exhibited during physical performance of a task. Thus, we hypothesized that participation in mCIT and MP would provide more practice attempts for the affected musculature and cortical areas than mCIT participation only. This increased practice exposure would be behaviorally manifest in mCIT+MP subjects exhibiting larger functional limitation reductions (reflected by increased ARAT scores) and larger affected arm impairment decreases (reflected by FM score increases) than subjects in the mCIT only condition. Consistent with our hypothesis, mCIT+MP subjects exhibited significantly larger score changes on both the ARAT and the FM than mCIT only subjects (Table 3). Behaviorally, mCIT+MP subjects accomplished more ARAT tasks faster and more proficiently and exhibited more active movement on the FM wrist and hand items than mCIT only subjects. Although this is the first study combining mCIT with MP, our outcomes appear consistent with those of other studies in which MP was combined with RTP regimens for the affected arm.11-18 We were not surprised that the changes were relatively larger on the ARAT given that its items test mostly distally based motor abilities, and both interventions primarily targeted distally based abilities in the affected wrist and fingers.

Whereas mere arm use does not convey motor changes, RTP produces substantive opportunities for both neural and motor change.36 Moreover, both mCIT and MP have independently been shown to produce neural changes.37,38 We hypothesize that the combination of mCIT and MP participation provided substantially more practice opportunities (and, thus, more opportunities for “plastic” changes to occur) than participation in the mCIT only condition. Future researchers should consider examining such changes using neuroimaging. However, the absence of such mechanistic work in the current study is not a weakness, because the goal of this pilot study was to demonstrate whether a comparatively larger motor effect was rendered through mCIT+MP participation.

Although this pilot trial admittedly involved a relatively small number of subjects, the use of a control group receiving equal treatment time, stability of motor deficits (substantiated by nonsignificant changes between pretesting Sessions 1 and 2), and the rapid period during which subjects exhibited motor improvements each argue for a treatment effect that is not due to chance. The preponderance of other trials showing that MP increases RTP efficacy would also seem to argue for the validity of data reported here. Nonetheless, our small sample size and the lack of measurement of fidelity of the MP

Table 3. Patient Scores on the ARAT and FM Before and After Intervention

<table>
<thead>
<tr>
<th></th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>mCIT + MP</td>
<td>27.6 (1.14)</td>
<td>26.8 (1.48)</td>
<td>42.6 (1.20)</td>
<td>43.5 (1.50)</td>
<td>+15.4</td>
</tr>
<tr>
<td>(n = 5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mCIT (n = 5)</td>
<td>28.0 (1.41)</td>
<td>28.0 (1.00)</td>
<td>36.4 (1.10)</td>
<td>38.0 (1.00)</td>
<td>+8.4</td>
</tr>
<tr>
<td>ARAT</td>
<td>38.4 (1.14)</td>
<td>38.8 (0.83)</td>
<td>46.4 (0.89)</td>
<td>48.8 (1.31)</td>
<td>+7.8</td>
</tr>
<tr>
<td>Post-3</td>
<td>39.8 (1.30)</td>
<td>39.6 (1.10)</td>
<td>43.8 (1.09)</td>
<td>45.3 (1.00)</td>
<td>+4.1</td>
</tr>
<tr>
<td>FM</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td></td>
</tr>
</tbody>
</table>

Note: “Pre-1” denotes mean score obtained during pretesting Period 1 and “Pre-2” refers to mean score obtained during pretesting Period 2. “Post” denotes mean score obtained during posttesting. SDs are provided in parentheses. "Change" refers to mean change scores, which are computed using the following formula:

\[
\text{Post mean} - \frac{\text{(Pre-1)} + \text{(Pre-2)}}{2}\]
intervention (other than the subjects telling us that they adhered to the intervention) are possible study limitations. With regard to the first limitation, we suggest that this study be replicated with a larger and more diverse group of subjects. With regard to the second limitation, we suggest that future authors use videotaping of subjects during MP sessions, subject diaries, and/or other methods to verify that they are fully complying with their MP regimens as prescribed. However, given the rather large outcome differences between the 2 groups, we find it likely that the MP subjects were compliant with the MP regimen as prescribed.

Conclusion

Modified constraint-induced therapy again rendered clinically significant changes. However, data also suggest that the addition of MP to the mCIT protocol renders comparatively larger motor changes than mCIT participation alone.

Disclosures

None.

References

Modified Constraint-Induced Therapy Combined With Mental Practice: Thinking Through Better Motor Outcomes
Stephen J. Page, Peter Levine and Jane C. Khoury

Stroke. 2009;40:551-554; originally published online December 24, 2008;
doi: 10.1161/STROKEAHA.108.528760
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2008 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/40/2/551

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/