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Pilot Study of the Efficacy of Constraint-Induced Movement Therapy for Infants and Toddlers with Cerebral Palsy

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Abstract

The evidence for Constraint-Induced Movement Therapy (CIMT) effectiveness for infants and toddlers with unilateral cerebral palsy is minimal. We performed a pilot study of CIMT using one-month usual care, one-month intervention, and one-month maintenance (return to usual care) phases on five infants (7- to 18-month old). For the CIMT phase, the infants received 2 hr of occupational therapy and 1 hr of parent-implemented home program for five days/week. The infants were casted for the first 23 days, and bimanual therapy was provided for the last three days. Fine motor skills for the more affected arm and gross motor skills improved significantly during the CIMT; these gains were maintained at one-month follow-up. Individual infant data show mixed effects. This pilot study provides initial evidence that CIMT is feasible for infants with unilateral cerebral palsy, and presents preliminary data for CIMT on fine and gross motor performance.

Keywords

Cerebral palsy; cohort studies; compliance; health systems; infant development; intervention studies; motor development; outcomes; service delivery

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BACKGROUND AND SIGNIFICANCE

Cerebral palsy (CP) is the most common cause of physical disability in childhood (Pellegrino, 2007). Approximately 3.6 in 1,000 children are diagnosed with CP (10,000 new cases in the United States each year) and about 30% of these are diagnosed with spastic unilateral (hemiparetic) CP (Roper & Samuels, 2009). The cause of hemiparesis is often prenatal, perinatal, or antenatal stroke, and through improved imaging procedures, neonatologists and pediatric neurologists can better identify the infants who have these brain lesions. Therefore, more children at risk for hemiparetic CP are identified early and have the potential to begin treatments that can prevent or limit physical disability.

Motor skills develop rapidly in the first two years of life, and through motor experience, infants develop a map of their body. Infants with hemiparetic CP may develop an incomplete or faulty map during this early period, and begin to demonstrate a disregard of the affected upper extremity. Early intervention has the potential to prevent unilateral disregard, improve movement in the affected upper extremity, improve the infant's development across domains, and long-term increase his or her potential for independence in life skills (DeLuca, Echols, Ramey, & Taub, 2003; Pellegrino, 2007).

Constraint-Induced Movement Therapy (CIMT) has extensive evidence of efficacy with older children and adults, but has rarely been applied to infants (Bollea et al., 2007; DeLuca, Echols, Law, & Ramey, 2006; Wolf, Barton, & Jann, 1989). Trials of CIMT in 3- to 18-year-old children have demonstrated positive effects and functional benefits (Charles, Wolf, Schneider, & Gordon, 2006; DeLuca, Case-Smith, Stevenson, & Ramey, 2012; Sakzewski et al., 2011; Taub, Ramey, DeLuca, & Echols, 2004); however, the CIMT trials in children younger than two years are few. Four case studies have reported the effects of CIMT in infants (Coker, Lebkicher, Harris, & Snape, 2009; Cope, Forst, Bibis, & Liu, 2008; DeLuca et al., 2003; Fergus et al., 2008) and one controlled trial (Eliasson, Krumlinde-Sundholm, Shaw, & Wang, 2005) included children aged 18 months to 4 years (mean age = 28.8 months for the CIMT group). These studies varied in the type of constraint (two used casting, one a splint, and another a soft mitt), the setting (in three the intervention was home-based), the parents' participation (in two studies the therapists gave parents a home program), and outcome measures (e.g., Peabody Developmental Motor Scales, Pediatric Motor Activity Log, Assisting Hand Assessment). In addition, the intensity and duration of intervention varied from 1 hr per week for 18 months to 6 hr per day for three weeks. These studies were further limited by a variety of constraint methods without clear rationale for selecting a method; wide variations in duration and intensity of interventions (two weeks, 1 hr/week); and unspecified intervention protocols. These four case studies resulted in positive changes for the infants; but do not allow for generalizing the findings. The controlled trial (Eliasson et al., 2005) found positive effects ($ES = 0.72-1.16$), but older children improved more than younger children, making it difficult to determine the effect of CIMT for infant participants. Clearly, additional research and further development of infant-specific protocols are needed. Our research aim was to perform a pilot study examining the feasibility and efficacy of CIMT in infants and toddlers with CP. Our CIMT intervention incorporated the theory-based elements of the published case studies that appeared to be most related to positive outcomes and most appropriate for infants. These research-based

elements include that intervention (a) is provided in the home (Bailey et al., 1998; Hebbeler et al., 2007; (b) includes parent education and a parent-implemented home program (Colyvas, Sawyer, & Campbell, 2010); (c) uses continuous constraint through a cast (DeLuca et al., 2006; DeLuca et al., 2012); and (d) is provided on an intensive daily schedule (DeLuca et al., 2003). We hypothesized that infants' gross and fine motor skills would improve and parent report of upper extremity (UE) functional performance would increase during the intervention. The following research questions guided the study:

1. Does CIMT when compared to a usual care condition improve infants' fine motor and gross motor performance?
2. Does CIMT when compared to a usual care condition improve parents' report of infants' functional performance when using the affected UE?

METHODS

Pilot Study Design

We used a pretest–post-test cohort design, with the participants serving as their own controls to best control for the expected variability among individual infants. Traditional occupational therapy services in an outpatient clinic were used as the control condition, and CIMT as the experimental condition. The infants were tested four times one month apart. Each infant sequentially received an initial month of weekly occupational therapy treatment, one month of CIMT, and a final month of weekly occupational therapy treatment, with testing at baseline and after each phase.

Participants and Recruitment

Inclusion criteria for this convenience sample of seven infants were as follows: (a) A diagnosis of unilateral CP by a pediatric neurologist or pediatrician; (b) age of 6 to 18 months; and (c) family able to commit to the treatment protocol. Exclusion criteria included (a) co-morbid medical diagnoses (e.g., seizures and other neurological conditions other than CP); (b) visual impairment; (c) family unable to commit to treatment protocol; (d) history of botulinum toxin treatment; or (e) UE orthopedic deformity. All parents signed informed consent. Demographics are reported in Table 1.

Intervention

Occupational Therapy Treatment—The control intervention, “usual care” treatment, consisted of therapy for 1-hr a week in an outpatient clinic for four weeks. One occupational therapist with 12 years of pediatric experience provided the usual care treatment pre- and post-CIMT. The infants received traditional intervention that used functional tasks, play activities, sensory activities, strength building, and bilateral activities to promote the use of the involved UE. The infant's affected arm was not constrained during the “usual care” intervention portion of this study.

CIMT: We modified an existing CIMT protocol (DeLuca, Echols, & Ramey, 2007) so that it was appropriate for use with infants. The protocol has the following four core elements: (a) 24/7 casting of the less affected UE for 23 days, followed by four days without casting;

(b) intensive occupational therapy sessions for five days/week for four weeks; (c) parent education to promote use of the affected UE; and (d) services provided in the child's home. In the original protocol, children received 3 or 6 hr of therapy/day (DeLuca, Case-Smith, Stevenson, & Ramey, 2012), but to accommodate the infants' attention span and endurance, we provided 2 hr/day of therapy activities and asked parents to implement an additional hour/day of therapeutic activities over the remainder of the day.

The less affected arm was casted at the beginning of the CIMT program. We selected full arm casting because (a) the cast fully inhibit sensory and motor activation to the less affected arm (Sutcliffe, Gaetz, Logan, Cheyne, & Fehlings, 2007); (b) the custom fabrication reduces the changes of skin irritation; (c) the cast places the constrained arm in a functional position (elbow flexion) for weight bearing; and (d) the child cannot independently remove the constraint. The long-arm uni-valve cast was made using Focused Rigidity Delta-Cast (BSN Medical; www.bsnmedical.co.uk) material over stockinette and extended from the axilla to the fingertips of the non-affected arm with the elbow in 90° of flexion, the wrist in neutral, the fingers in partial extension, and the thumb in abduction. A uni-valve opening was created along the lateral aspect of the cast, which allowed for easy cast removal and re-application each week during the therapy. At the first session, the therapist placed the cast on the child's arm and covered it with latex-free Coban material to make the cast appear contiguous and non-removable.

Two occupational therapists with six to nine years of pediatric experience and training in CIMT provided the 2-hr intervention sessions in the home five days/week (20 total sessions). Home-based intervention was selected because it is a comfortable environment for the infant and family and the infant can easily generalize newly learned skills in naturally occurring opportunities (Valvano et al., 2004; Woods & Wetherby, 2003). Therapy sessions included functional, play-based, sensory, and strength-building activities that emphasized specific movements of the affected UE. The therapist encouraged repetition and elaboration of motor skill with consistent positive reinforcement. Specific sensorimotor goals were established for each infant. Chosen play activities considered the infant's skill level and motivation, the environment, and the family's goals. Because infants, 6 to 18 months, primarily engaged in sensorimotor exploration, session activities typically included sound toys, textures and tactile experiences, and visually engaging toys. The therapists frequently used gross motor activities that afforded UE weight bearing for strengthening in prone play, quadruped, and propped-sitting. Tasks were selected to elicit repeated movement and motor patterns targeted for therapy and were administered according to motor learning and shaping procedures (DeLuca et al., 2007). Table 2 shows examples of intervention activities used to improve targeted movements.

The family was instructed to perform activities with their infant that targeted specific UE skills for 1 hr each day. These activities were similar to the activities that the therapist had implemented, and were adapted so that they could easily be implemented in the family's daily routine (for example, promoting the infant's use of his or her affected UE in eating, bathing, or dressing). The parent was provided with a form that listed the child's targeted objectives and recommended activities. Each day the parent recorded the amount of time he or she spent involving the infant in targeted activities.

The cast was removed for the last three days of treatment to focus on bimanual activities. The focus of intervention for the days in which the cast was removed was bilateral integration for two-hand functional skills. A daily treatment log was used to document the sessions, and monitor progress and the child's tolerance.

Outcome Measures

An occupational therapist, who completed the hospital-specified reliability assessment for administering the Bayley Scales of Infant and Toddler Development-3 (BSID) (Bayley, 2005) and with more than 20 years of pediatric experience, administered the BSID Fine and Gross Motor Scales at enrollment and immediately following each of the monthly treatment phases for a total of four assessments. The cognitive scales were also administered at baseline. The evaluator did not provide the intervention but was not blinded to treatment phase. All testing was completed in hospital-based clinic.

Bayley Scales of Infant and Toddler Development—3rd Edition (Bayley, 2005)

—The BSID fine and gross motor subscales were administered at each time point. Although the intervention targeted fine motor performance, we anticipated that gross motor and cognitive performance might also improve due to an improved ability to use the arm for activities such as crawling and transitions from prone to sitting. The BSID fine motor items for infants aged 6 to 18 months (score range: 0–34) measure prehension, motor planning, grasping patterns, and eye–hand coordination. The BSID was recently re-standardized to include fine and gross motor sections (Bayley, 2005). On the fine motor subscale, the evaluator scored the unilateral items for right and left hands separately. Most (about 80%) of the BSID fine motor items for infants aged 6 to 18 months require unilateral reach and grasp. Scores for the unilateral items were added to the bilateral items to produce a raw score for each hand. The scores for each UE were entered in the analysis.

Infant Motor Activity Log (IMAL)—We developed the parent-reported IMAL by modifying the items of the Pediatric Motor Activities Log (PMAL; Taub et al., 2007) so that they were developmentally appropriate for infants (see Appendix). We eliminated items such as brushing teeth and using silverware, and replacing them with holds a cup or bottle, and reaches to be picked up. The IMAL is a 20-item parent-report measure of “How Well” and “How Often” the infant uses his or her affected arm. Parents rate their infant's unilateral and bilateral actions (e.g., holding a bottle or cup, eating finger foods, crawling on the floor, and taking off shoes and socks) using a 5-point scale for quality and frequency of movements. The IMAL gives separate scores (range 0–100) for “How Often” and “How Well” the child performs the actions. We have used the IMAL with more than 20 infants in our clinical program, finding the results to be clinically meaningful and consistent with standardized developmental testing. Parents completed the IMAL at enrollment and all subsequent monthly evaluations.

Fidelity Measure

A fidelity measure to assess the therapists' consistency in following the intervention protocol was developed and piloted. Nine items emphasized the tenets of motor learning theory, rating the therapist's use of goal-specified activities, positive reinforcement, using a

just-right challenge, repetition, and generalization of skills. Five items rated the infant's participation in the intervention activities to quantify the infant's engagement in the treatment. The items were rated for frequency using 15-min video clips of the middle minutes of the intervention sessions. To assess inter-rater reliability, 10 video clips of 10 different sessions with five infants in the study were scored by two raters trained in the fidelity measure. Each scored the middle 15 min of a 30-min clip. Inter-rater reliability for two raters was moderate and acceptable ($r = 0.66$; $p = .037$; proportional agreement = 70%). A mean score for fidelity for the 10 video clips of treatment was computed from three independent reviewers (who were physical therapy or occupational therapy students).

Data Analysis

We first calculated the infants' summary and group's mean raw scores for the BSID. The fine motor items for the affected and less affected hand were analyzed separately to account for skill differences. Paired *t*-tests were used to compare raw scores for our primary outcomes: gross motor performance and fine motor (more affected UE) performance across the four testing times. We also examined the difference in fine motor scores for the less affected UE using paired *t*-tests. Scores for IMAL "How Well" and "How Often" scores at week 1 and 12 were also compared using paired *t*-tests. Individual graphs of each child were provided.

RESULTS

Participants

Of the seven children initially enrolled in the study, five completed the treatment protocol. One family (child 3) dropped out of the study due to an unrelated family crisis. The second family (child 7) withdrew from the study because the infant demonstrated irritability that escalated during intervention sessions, and the mother reported that wearing the cast appeared to be disruptive to the infant's sleep. This family had multiple young siblings and was also undergoing transitions that made participation and the time demands of program difficult. When interviewed upon exiting from the trial, the mother reported that she would be very interested in trying the program again when the child was older.

Fidelity Measure and Parent Participation

Overall fidelity for the five infants who completed the study was 89% consistent with the treatment protocol. The infants demonstrated engaged and on-task behavior 74% of the time and were not engaged in the treatment activities 26% of the time. The fidelity scores suggest that therapists can implement the protocol with high consistency, and that infant participation in the treatment, although less consistent, appears to be acceptable.

All parents recorded that they performed the home program for an hour or more each day. They reported that the individualized activities were easy to incorporate into their daily routine and naturally occurring opportunities. Parents' comments and feedback regarding the program were positive.

Developmental Skill and Functional Performance Effects

The BSID Fine Motor Scale raw scores are reported for involved and less involved arms. Scaled scores are not presented due to the modified scoring of each hand separately. Mean scores for the four tests are presented in Table 3. Mean fine motor scores for the more involved arm improved 2.2 ± 1.8 points during usual care occupational therapy and 4.2 ± 1.8 points during CIMT. Pre- to post-CIMT, four infants improved in three to seven fine motor items (skills). One infant did not improve; this infant demonstrated severe neuromotor impairment of the affected arm and was delayed in all BSID domains. The constraint phase produced a statistically significant increase on the BSID Fine Motor Scale for the affected arm raw score ($n = 5$; $t = -5.25$; $p = .006$), indicating that the infants improved significantly more in the CIMT intervention than usual care occupational therapy (see Table 3). The Gross Motor Scale raw scores increased 1.0 ± 1.7 points during “usual care” occupational therapy and 3.2 ± 1.9 during the CIMT phase. This increased rate of acquisition was maintained during the follow-up month (3.0 ± 1.9). The improvement for the Gross Motor Scale was significant for the CIMT phase ($t = -3.0$; $p = .04$) and the retention phase ($t = -3.59$; $p = .023$). Several of the children began to crawl and pull to stand (Figure 1).

Concurrent validity as examined by correlating initial IMAL scores with BDIS scores for the affected hand was high (“How Often”: $r = 0.97$; $p = .002$; “How Well”: $r = 0.96$; $p = .003$), indicating that parent perceptions agreed with therapists’ observations using a standardized test for infant performance. Parents’ rating of IMAL “How Often” improved significantly when baseline and 12 week scores were compared ($t = -4.4$; $p = .012$). IMAL “How Well” scores also improved significantly ($t = -3.9$; $p = .018$) (see Figure 2).

Adverse Events—None of the infants experienced adverse events that required medical care or withdrawal from the study. One child developed a small blister on the thumb while wearing the cast but this was corrected through a cast adjustment. One family had a very difficult time getting the cast back on after skin checks, so pedi-wrap was used instead for the last two weeks. Two infants who dropped out of the study did not experience adverse events; however, family circumstances limited and then ended their participation.

DISCUSSION

Our pilot study provides new and important findings regarding the feasibility of CIMT in infants and toddlers, the fidelity with which therapy can be delivered to very young children, and an estimate of the effect of CIMT in this age group.

Feasibility and Fidelity

The intensity of CIMT in previous infant case studies varied, e.g., from 1 hr/week (Fergus et al., 2008) to 30 hr/week (DeLuca et al., 2003). Our clinical experience and our experience in a recent trial (e.g., Case-Smith, DeLuca, Stevenson, & Ramey, 2012) suggest that 3 hr/day is sufficient to improve function, while remaining feasible and acceptable to families and therapists. Therefore, we designed a 3-hr/day model in which the occupational therapist provided intervention for 2 hr/day and the parent provided home activities for 1 hr/day using an individualized and daily updated program. In this model, the therapist provided the parent

a home program of activities that encouraged the infant to use the affected arm and generalize new or emerging skills. The parents reported that they performed an hour or more of their home programs each day, and appreciated that the recommended activities were designed to fit into their natural routines (e.g., feeding, bath, dressing, play).

Importantly, we found that five infants were engaged and participated in the intervention activity 74% of the time. This may be a realistic estimate of how long infants can effectively engage and participate in intervention activities. Our findings suggest that motivating and engaging the infant are important to the success of CIMT intervention and that a 2-hr intervention is appropriate for this age group. Our findings provide a baseline for future clinical trials of CIMT interventions for infants.

Of equal importance, the therapists achieved 89% fidelity in using motor control principles, indicating high consistency in following the intervention protocol, including (a) providing activities that met specific sensory-motor goals; (b) using repetition and practice; (c) applying positive reinforcement; (d) varying the activity to obtain generalization; and (e) providing a just-right challenge. The therapists were highly consistent in selecting developmentally appropriate activities, motivating the infant to participate, using positive affect, and providing positive reinforcement. They also adapted to the infant's needs at the moment, allowing the parent to comfort and/or care for the infant as circumstances required. Other studies (e.g., Bollea et al., 2007; Gordon, Schneider, Chinnan, & Charles, 2007) have explicitly defined examples of age-appropriate play activities that successfully engage children and motivate them to attempt and practice challenging skills. Our results suggest that therapists can easily and rigorously implement the CIMT protocol in a home environment. Parents also assisted in maintaining the infants' motivation and engagement in the activities.

Intervention Methods and Effects

The field continues to debate the optimal method of constraint. In previous case studies, infants' less involved arm was constrained during waking hours using a mitt or splint (Coker et al., 2009; Glover et al., 2002) or continuously constrained using a cast (Cope et al., 2008; DeLuca et al., 2003). The infants in our study wore a cast continuously for 23 days (18 days of intervention) similar to DeLuca et al. (2003). Whether the cast would limit or impair motor function in the less affected UE has been a concern in the field. Our findings demonstrated that infants could tolerate a cast for 23 days without losing UE skills. In fact, the casted arm continued to acquire new skills as demonstrated at the one-month follow-up.

Important elements of the study include intensive therapy using motor control principles and intervention sessions provided in the home. Each infant received 3 hr/day (2 hr with the therapist and 1 hr with the parent) of motor skill practice with his or her affected arm. Skill practice with both therapists and parents suggests that the infants experienced a wide variety of activities with varying degrees of challenge, support, and reinforcement. Intensive home-based services have a number of advantages: (a) The therapist can better understand the family's routines, interests, culture, and values, and can use these contexts in planning the intervention sessions; (b) the infant and parent are more comfortable and it is easier to support the infant's optimal arousal; (c) by using the infant's toys and environment, the

therapist can develop therapeutic activities that the parent can repeat beyond the intervention session; and (d) the infant can easily generalize and practice play activities that the therapist introduces. In previous infant CIMT studies (Glover et al., 2002; Cope et al., 2008; DeLuca et al., 2003), therapists provided intervention in the home, and our study contributes to the evidence for the feasibility and possible efficacy for using the infants' natural context.

Despite the small sample, this group of infants demonstrated clinically meaningful and statistically significant improvement in fine motor skills following one month of CIMT. The BSID raw scores for the affected UE improved significantly, and on average the infants gained four new skills during the intervention and two additional skills during the one month that followed CIMT. Three children maintained and two children did not maintain their gains one month after CIMT. The BSID gains were supported by the parents' rating of UE function using the IMAL. The IMAL indicated that four of the infants made substantial and clinically important gains in unilateral and bilateral functions; however, one infant exhibited minimal gain. The infant who improved the least had severe cognitive delay (BSID cognitive scale score of 5) that seemed to prevent his full participation in the intervention. In most studies of CIMT, children have had average cognitive ability (e.g., DeLuca et al., 2012; Eliasson et al., 2005; Sakzewski et al., 2011; Gordon, Charles, & Wolf, 2006), and the high demands of this intervention suggest that average cognitive ability may be necessary for the infant to receive full benefit.

Because infants use belly crawling or creeping for mobility and because they are learning gross motor skills that involve transitions from floor-to-quadruped and floor-to-stance, we investigated the effects of CIMT on gross motor skill. These gross motor skills were frequently implemented during the sessions to practice weight bearing and weight shifting on the affected arm. The BSID Gross Motor raw scores improved significantly during the CIMT phase and continued to improve in the month following CIMT. Gross motor performance appears to be a relevant outcome measure for CIMT with infants. Other studies have demonstrated the effect of CIMT on gross motor performance in infants (Coker et al., 2009) and on gait patterns in preschool children (Coker, Karakostas, Dodds, & Hsiang, 2010).

These findings suggest that use of CIMT in infants and young children should be further evaluated with a larger sample and longer follow-up duration. If CIMT interventions introduced early in development can prevent unilateral disregard and can promote functional use of bimanual skills, children with unilateral CP may benefit across developmental areas, potentially reducing the need for and cost of long-term interventions.

Limitations to this Study

A primary limitation of this pilot study was use of non-standardized measures and lack of blinding. Because standardized measures appropriate for infants (<2 years) with unilateral CP have not been developed, the study's measures had limited psychometric validation. In addition, the sample was small and we lacked a control group. One infant did not tolerate the cast and declined to continue participation; therefore, not every infant may tolerate CIMT with casting.

CONCLUSIONS

This study demonstrated feasibility of an intensive home-based occupational therapy, CIMT intervention UE casting, for 23 days with five of seven infants who completed the trial. During the CIMT intervention phase, the infants demonstrated significant improvement in fine and gross motor performance that was maintained at follow-up and in parent-reported functional performance. Our findings suggest that CIMT has positive effects for infants with unilateral CP, and recommend that researchers confirmed these findings in controlled, sufficiently powered clinical trials.

APPENDIX

Infant Motor Activity Log

	How Often	How Well
1. Hold a bottle/cup	----	----
2. Pick up and hold a small item while sitting in a chair	----	----
3. Pick up and hold a large item while sitting in a chair	----	----
4. Eat finger foods	----	----
5. Pick up an object out of arm's reach	----	----
6. Push a button	----	----
7. Open a door or cabinet	----	----
8. Use arm to move across floor	----	----
9. Take off shoes or socks	----	----
10. Pull a toy with a string	----	----
11. Turn a knob	----	----
12. Pick up a cylindrical object (eg, crayon, marker, Bottle, cup or rattle)	----	----
13. Throw a ball or similar object	----	----
14. Hold a handle on a riding, pulling, or push toy	----	----
15. Push up front of body with weaker arm while on stomach	----	----
16. Hold an item while in standing position	----	----
17. Carry an item from place to place	----	----
18. Push into sitting position	----	----
19. Reach to be picked up by parent	----	----
20. Push arm through sleeve of clothing	----	----

HOW OFTEN SCALE

- 0** Not Used – Your child did not use the weaker arm for the activity.
- 1** Very Rarely – 5% -10% of the time - Your child occasionally used the weaker arm for the activity, but only very rarely.
- 2** Rarely – About 25% of the time – Your child used the weaker arm at times, but did the activity with the stronger arm most of the time.
- 3** Sometimes – About 50% of the time – The weaker arm was used in performing the activity, but only about half as much as the stronger arm.

- 4 Often – About 75% of the time – The weaker arm was used in performing the activity regularly, but just three-quarters as often as the stronger arm.
- 5 Normal – 90%-100% of the time – The weaker arm was used as often as the stronger arm to perform the activity.

HOW WELL SCALE

- 0 Not Used – Your child did not use the weaker arm at all for the activity.
- 1 Very Poor – Your child had very little functional use of the weaker arm for the activity. The arm may have moved during the activity but was of no real functional help.
- 2 Poor – Your child had minor functional use of the weaker arm for the activity. The arm actively participated in the activity, but the stronger arm or caregiver did most of the work.
- 3 Fair or Moderate – The weaker arm was used to accomplish the activity, but the performance was very slow and/or involved great difficulty.
- 4 Almost Normal – The weaker arm was able to accomplish the activity independently, but did so with some difficulty and/or inaccuracy.
- 5 Normal – The weaker arm did the activity normally.

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FIGURE 1.

Bayley-3 raw score for the fine motor subtest for both affected and less affected upper extremities for each subject. The dotted line indicates performance of the less affected (or casted) upper extremity; the solid line indicates performance of the affected involved (non-casted) upper extremity.

FIGURE 2.

Individual Infant Movement Activity Log (IMAL) scores across intervention phases.

□ Indicates missing data point for subject 2 immediately post CIMT phase. Mean difference of post OT phases of treatment was estimated for graph.

TABLE 1
Demographic Information and BSID Raw (Scaled) Scores of Subjects at Enrolment with Group Means and SD^a

Subject	Age in months (CCA ^d)	Gender	Hemi side	Cognitive ^b	FM less involved	FM more involved	GM scaled score ^b	IMAL how often	IMAL how well
1	16.1 (15.1)	F	L	50 (12)	29	15	37 (4)	20	19
2	11.4	M	R	38 (10)	27	22	37 (8)	39	44
3 ^c	11.4	M	R	30 (5)	23	9	31 (4)	12	13
4	14.4 (11.2)	F	L	36 (9)	28	20	28 (3)	27	31
5	15.8 (12.3)	M	R	38 (9)	26	21	29 (2)	34	33
6	7.1	F	R	27 (8)	18	9	22 (5)	5	7
7 ^c	10.4 (8.7)	F	L	33 (9)	20	9	21 (1)	3	4

^aCCA = chronological corrected age;
^bCCA used to calculate scaled score if child was premature;
^cwithdrew from study.

TABLE 2
Example of Common Ways to Elicit Desired Movements from Infants During CIMT

Activity	Shoulder flexion	Shoulder abduction	Elbow flexion/ extension	Wrist flexion/ extension	Open hand	Close hand	Finger isolation	Thumb abduction
Turn pages in a book	x	x	x	x	x		X	
Holding a utensil	x	x	x	X		x	x	
Crawling	x	x	x		X			
Playing on a toy piano				x	x		X	
Throwing a ball	x	x	x	x	X			
Picking up a small toy	x	x	x	x	x	x	x	x

TABLE 3
Changes in BSID raw scores across treatment phases and *t* test analysis (*n* = 5)

Scores	Change in the 1 st month	Paired <i>t</i> test between months 1 and 2	Change in the 2 nd month	Paired <i>t</i> test between months 2 and 3	Change in the 3 rd month	Paired <i>t</i> test between months 1 and 3
Cognitive	4.8±2.8		1 ±1.4		1.4 ±1.7	
<i>p</i> value		0.0910		0.7780		0.0673
FM (more involved)	2.2 ±1.8		4.2 ±1.8		-0.8 ±2.2	
<i>p</i> value		0.0111 *		0.0089 **		0.0399
FM (less involved)	1.6 ±1.7		1.4 ± 1.9		1.6 ±1.5	
<i>p</i> value		0.8928		0.8276		1.0
GM	1.0 ±1.6		3.2 ±1.9		3.0 ±1.9	
<i>p</i> value		0.2238		0.7489		0.1419

* Significant at $p < .017$ (p adjusted for Bonferroni).