Pediatric Constraint-Induced Movement Therapy in a Young Child With Minimal Active Arm Movement

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KEY WORDS

- constraint-induced movement therapy (CIMT)
- pediatric
- upper extremity

This study describes a single-subject design (ABA with follow-up evaluation) that demonstrated the possible effective use of constraint-induced movement therapy (CIMT) in producing gains in movement and function for a 24-month-old child with chronic hemiparesis. The noninvolved upper extremity was placed in a removable splint for 21 consecutive days. The child was involved in intensive occupational therapy in the home environment. Daily measurements were completed on the use and quality of motion of the involved upper extremity for eight specific fine and gross motor activities. Change in performance and quality of movement were measured and significant at the $p < .05$ level with the calculation of the C statistic for the motor activities with gains maintained after completion of the treatment and postsplinting phases. The results of the study contribute to the body of evidence finding CIMT to be effective for increasing movement and function in children with hemiparesis.

Dickerson, A. E., & Brown, L. E. (2007). Pediatric constraint-induced movement therapy in a young child with minimal active arm movement. *American Journal of Occupational Therapy, 61,* 563–573.

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Traditional treatment of upper-extremity hemiparesis consists of increasing awareness of the involved side; teaching the person to integrate or incorporate the weaker side into activities along with the stronger side; preparing the person for function by improving trunk control, weight shift, and proximal stability; and using neurodevelopmental treatment techniques. These traditional intervention methods, however, often produce gains that are short lived or little progress (Graham, 2002). Many patients compensate for the affected arm rather than trying to use it, leading to learned nonuse and halting further progress with the functioning of that arm.

Constraint-induced movement therapy (CIMT) is an innovative approach to treating hemiparesis that facilitates use of the hemiparetic arm through constraint of the unaffected arm. It has been shown to be an effective treatment for hemiparesis in adults (Calautti & Baron, 2003; Liepert, Bauder, Miltner, Taub, & Weiller, 2000; Taub, Uswatte, & Morris, 2003; Taub, Uswatte, & Pidikiti, 1999) and children (Charles, Lavinder, & Gordon, 2001; Glover, Mateer, Yoell, & Speed, 2002; Willis, Morello, Davie, Rice, & Bennett, 2002; Yasukawa, 1990).

Theoretically, CIMT can overcome learned nonuse of the affected side through forcing the brain's plasticity toward a more physiological and efficient activation pattern (Calautti & Baron, 2003). CIMT is hypothesized to work by inducing a use-dependent cortical reorganization that counteracts the adverse brain function changes that occur after nervous system damage and then enhances recovery-associated plastic changes in the brain after a stroke (Liepert et al., 2000). Studies of brain activity before, during, and after CIMT show evidence of plasticity and cerebrocortical reorganization (Kopp, Kunkel, & Muhlnickel, 1999; Liepert et al., 2000).

Intensive and repetitive training of the affected limb, or some combination of restraint and training, have been shown to lead to remarkable improvements in upper-extremity function (Calautti & Baron, 2003; Taub et al., 1999). Studies by Liepert et al. (2000) and Levy, Nichols, Schmalbrock, Keller, and Chakeres (2001) also found that the changes produced in the brain were enduring rather than short-lived, and greater than those achieved with traditional treatment methods. CIMT increases not only movement and motor skill but also functional use of the extremity in the real-world environment (Taub et al., 2003).

Although CIMT has been studied primarily with adult stroke patients, some studies in the pediatric population have had promising results. These studies include children as young as 15 months who have achieved notable improvements in strength, control, and use of a hemiparetic arm with maintenance of gains up to 1½ years later (Charles et al., 2001; Glover et al., 2002; Willis et al., 2002; Yasukawa, 1990). One of the most compelling studies with children was completed by Taub, Ramey, DeLuca, and Echols (2004), who cast the less-involved extremity for 21 consecutive days while intensively training the more-involved upper extremity for 6 hr daily during the 21 days. The children receiving CIMT acquired new motor skills and increased the use and quality of use of the more-involved upper extremity. Further, the improvements were maintained over 6 months, further establishing this intervention as an effective treatment for children with hemiparesis.

Although most studies of CIMT have been implemented in the clinic environment, the single-study design reported here assessed CIMT as a treatment approach in the home environment with a single pediatric participant with minimal active use of the impaired upper extremity. CIMT was expected to enable this child to increase function and movement in his right upper extremity and improve performance: spontaneous use in unilateral and bilateral tasks, grasp and release, and push and pull.

Methods

Participant

The participant was a 24-month-old White boy named Trevor who had hemiparesis in his right arm secondary to a prenatal stroke of unknown cause. He was born full term without other medical complications. Trevor was from a middle-class family consisting of a 6-month-old sister and both parents in a rural community in eastern North Carolina. At the time of the study, Trevor presented with increased tone in his right upper extremity. He had full passive range of motion with some resistance from spasticity. He had no observed active range of motion in his right shoulder, elbow, or wrist. A typical pattern of shoulder girdle retraction, elbow flexion, forearm pronation, wrist flexion, and thumb adduction with hand fisting existed in the right upper extremity. Trevor did not use his right arm or hand and seemed at times unaware of his right side. When an object was presented to him on the right side, rather than attend to the right, he turned his whole body around so that the object was on his left. He did not perform bilateral tasks and was limited in his ability to tolerate weight-bearing on the right side or on two hands in prone. Trevor did not walk independently and was just beginning to be taught how to use a rolling walker. Thus, the right upper-extremity hemiparesis had affected Trevor's development in gross and fine motor skills and limited his self-help abilities.

Design

This study used an ABA single-subject design with one follow-up evaluation. The participant was evaluated on measures before, during, and after treatment and during a 2-week follow-up period. CIMT was carried out in the home for 6 hr a day for 21 consecutive days. This ABA design was selected to demonstrate, first, that there was no function before the CIMT (A), and then to demonstrate that there was change both with intervention (B) and after the intervention was eliminated (A). An additional measure was added in the follow-up period to measure whether the effects of the intervention were maintained. In addition to the CIMT, the child received 2 hr a week of physical therapy (with goals of increased mobility and use of a rolling walker) and 1 hr a week of speech therapy (with goals to increase language skills). Before this study began, Trevor received 2 hr of occupational therapy a week. He had been seen by all three therapies since infancy, or just about 2 years before beginning CIMT.

Motor behaviors of the right upper extremity were documented during 15-min sessions of structured measurements at the same time each day. The measurements included reach, grasp, release, sustained grasp, push, pull, and finger feeding. The activities were presented consistently in the same order, and each 15-min session was videotaped. The videotape was reviewed later in the day along with the observations recorded on the data collection form to ensure accuracy of the data collected for that day. For the pre-CIMT, post-CIMT, and follow-up phases, an additional measurement of bilateral hand usage was recorded. This bilateral task involved use of the right upper extremity along with the left upper extremity in the bilateral activity of catching a rolling ball.

Procedure

IRB approval was obtained as well as full consent of Trevor's parents and physician. A custom-molded removable splint was fabricated for Trevor's left upper extremity using a low-temperature, lightweight thermoplastic material. A man's tube sock was applied over the splint later to ensure that Trevor could not use his fingers or knock the splint off his arm.

Pre-CIMT Phase (A), Days 1–5. Trevor was observed in a structured evaluative session of 8 measurements of performance for 15 min on each of the 5 days. Because there was essentially no active use of his right arm, this phase required only minimal time for observation and measurements.

CIMT Phase (B), Days 6–27. Trevor's left arm was splinted for most of his waking hours for 21 days. The splint was removed for bathing, sleeping, and short rest periods during the day. During the 21 days, Trevor received 6 hr a day of occupational therapy treatment with measurements recorded during the evaluation of structured activities that took place at the same time each day, exactly as in the pre-CIMT phase.

The occupational therapist worked with Trevor on various fine motor and gross motor activities and activities of daily living during the 6 hr of treatment. None of the evaluation activities were used for intervention. A typical day began with therapy right after breakfast. Activities progressed with donning the splint first; getting dressed; using normal play activities, as well as structured ones, to measure progress; eating lunch; and encouraging more play activities to motivate use of the affected arm. If Trevor showed frustration or refusal to work, a few different approaches were used: the activity would be changed or modified to be more fun, the therapist would back off and let Trevor initiate the next move, or he would be given a few minutes of "quiet time" with his mother.

Post-CIMT Phase (A), Days 28–32. The splint was no longer used. The measurements of use of the right hand were recorded during a 15-min session at the same time each day, just as during the intervention phase.

Two-Weeks After the Post-CIMT Phase, Days 32–37. Five 1-hr sessions took place on nonconsecutive days over 2 weeks. Trevor did not wear the splint at any time over that 2-week period. Measurements were recorded in each session for 15 min, as in previous phases.

Data Analysis

Use of the right upper extremity was recorded for eight specific behaviors using frequency, rate, and duration. *Frequency* is the number of times a certain behavior occurs, *rate* is the frequency of the behavior divided by the time frame in which it occurred, and *duration* pertains to the length of occurrence of each behavior (Ottenbacher, 1986). The behaviors recorded included (a) rate of spontaneously hitting an inflated balloon; (b) frequency of successful attempts to grasp a deflated balloon; (c) frequency of successful attempts to release the deflated balloon without dropping it; (d) rate of successful attempts to pull a toy car to activate it; (e) rate of successful attempts to push a button on a toy to activate noise; (f) duration of sustained grasp on a marker; (g) ability to grasp small, round pieces of cereal and bring them to his mouth for finger feeding; and (h) frequency of use of two hands together to catch a ball. Each behavior was recorded during the pre-CIMT (A), CIMT intervention (B), post-CIMT (A), and 2-week follow-up period, except for the last bilateral activity, which was recorded only during the pre-CIMT, post-CIMT, and follow-up. The behaviors were measured using only the affected hand. During the testing, the unaffected hand was constrained either by the splint or the therapist (for the pre-CIMT phase). After the intervention phase, the unaffected extremity was not restrained, but only the affected extremity was measured, with the exception of the bilateral activity. Each behavior was given a quality rating from 0 to 3 or 4 with specific criteria for each behavior (see the Appendix for description of behaviors and quality rating scales).

A simple line graph was used to display each behavior measured during each phase of the study. Visual inspection involved looking at variations in level, variability, trend, and slope in each graph. The mean and standard deviation were used to summarize scores for frequency, rate, and duration. Means were calculated in each phase of the study by adding the scores and then dividing by the number of scores in each phase. In addition, the *C* statistic, a method of time-series analysis that can be used on small data sets to evaluate the effects of treatment interventions (Ottenbacher, 1986), was used to determine whether statistically significant changes occurred over time with both performance and quality rating scores. The *C* statistic is a step-by-step process that compares the baseline data and then the baseline and intervention data. If the baseline data show no significant differences, then the baseline and intervention data are combined and compared to determine whether there is a significant difference in the data. This method is explained elsewhere (Ottenbacher, 1986; Tryon, 1982).

Results

Performance Scores

Visual observations of scores were used to closely examine changes over time. All of the baseline measures of performance were at zero for the first 5 days. During the CIMT phase, all the scores for reach, grasp, release, push, and pull (sustained grasp is not included in the figures) showed a significant increase in performance (see Figures 1 and 2). However, finger feeding remained consistently at zero across all phases. Although bilateral performance was not measured during the CIMT phase because the child was unable to use two hands, it showed improvement during the post-CIMT phase.

Table 1 shows that mean scores increased across phases for the behaviors of reach, grasp, release, push, pull, sustained grasp, finger feeding, and bilateral use, indicating an overall increase in use of the involved arm in the treatment and post-treatment phases for all but one of the motor behaviors. The use of means in single-subject designs can be misleading; for example, a reversal in the direction of the response patterns across the phases could show means to be the same even though the actual performance was different. In addition, there could be a steady increase in performance (mean) unrelated to the treatment, and the means of two phases would falsely show a difference—an artifact of using mean values (Ottenbacher, 1986). However, in this study, the visual inspection of the scores in Figures 1 and 2 showed zero means in the first phase, and there is no steady increase or any reversal of performance that distorts the means.

Although there was variation in the amount of change among behaviors, in the post-CIMT phase all behaviors showed a decrease in performance. Nevertheless, all scores remained above baseline (pre-CIMT), which was nonperformance. The decrease in performance observed in reach, grasp, release, push, pull, and sustained grasp during the post-CIMT phase was followed by an increase that continued into the follow-up phase. For the behaviors of grasp, release, pull, and push, scores during the follow-up phase met or exceeded those in the intervention phase. Finger feeding continued to remain at zero. Bilateral use increased throughout the post-CIMT phase. In follow-up, bilateral use decreased initially but was followed by an increase. Overall, scores during the later phases indicated that some function and movement were obtained in the right upper extremity in reach, grasp, release, push, pull, sustained grasp, and bilateral use.

Sustained grasp on a spoon showed a similar pattern. During the CIMT phase, Trevor and his occupational therapist worked on use of the right hand during mealtime, including holding onto and bringing a filled spoon to his mouth and finger feeding. Trevor made significant gains: He would open his hand to allow the researcher to place the spoon into it. Although hand-over-hand was required to scoop the food onto the spoon, Trevor brought the spoon

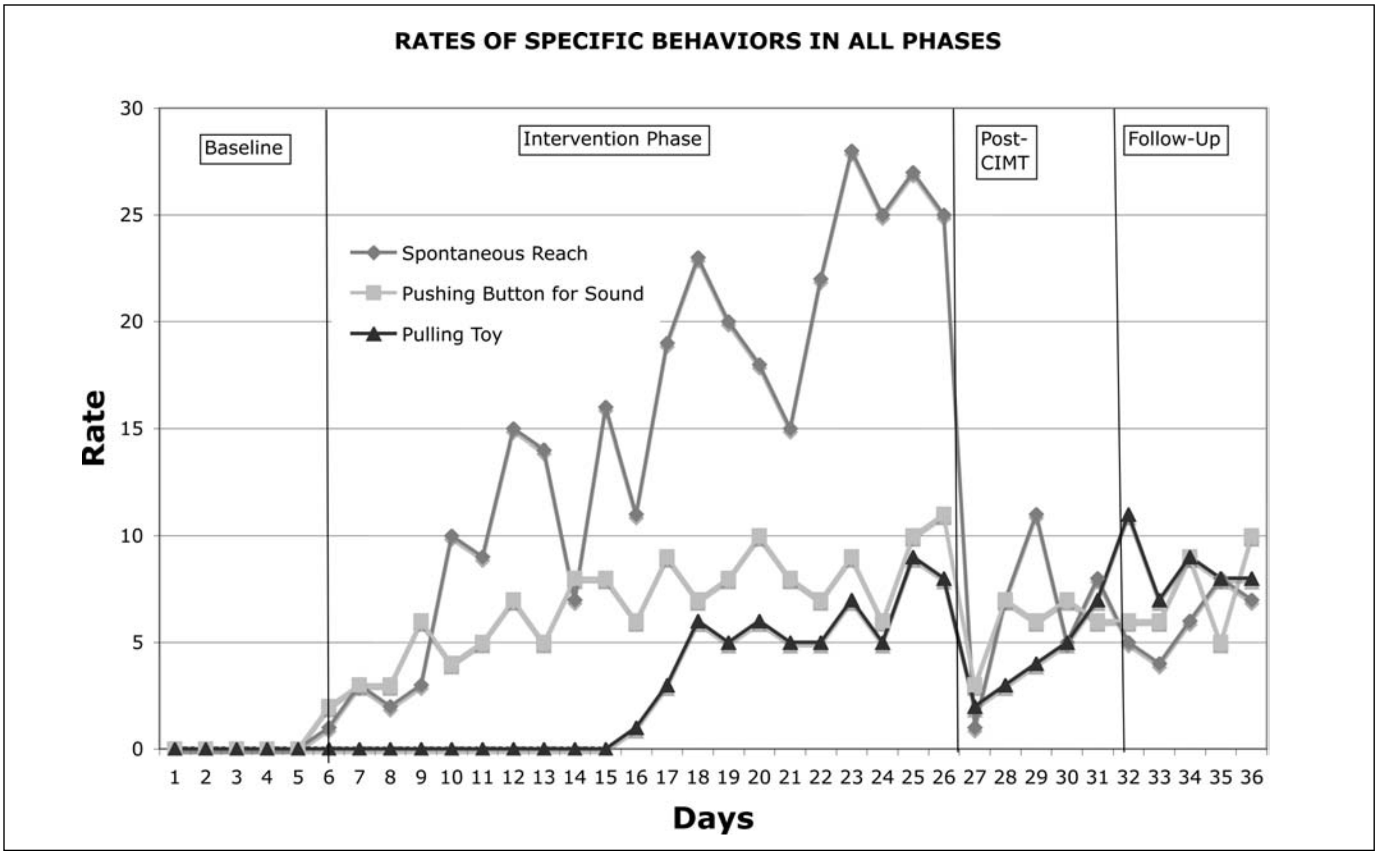

Figure 1. Rates of specific behaviors in all phases.

Note. CIMT = constraint-induced movement therapy.

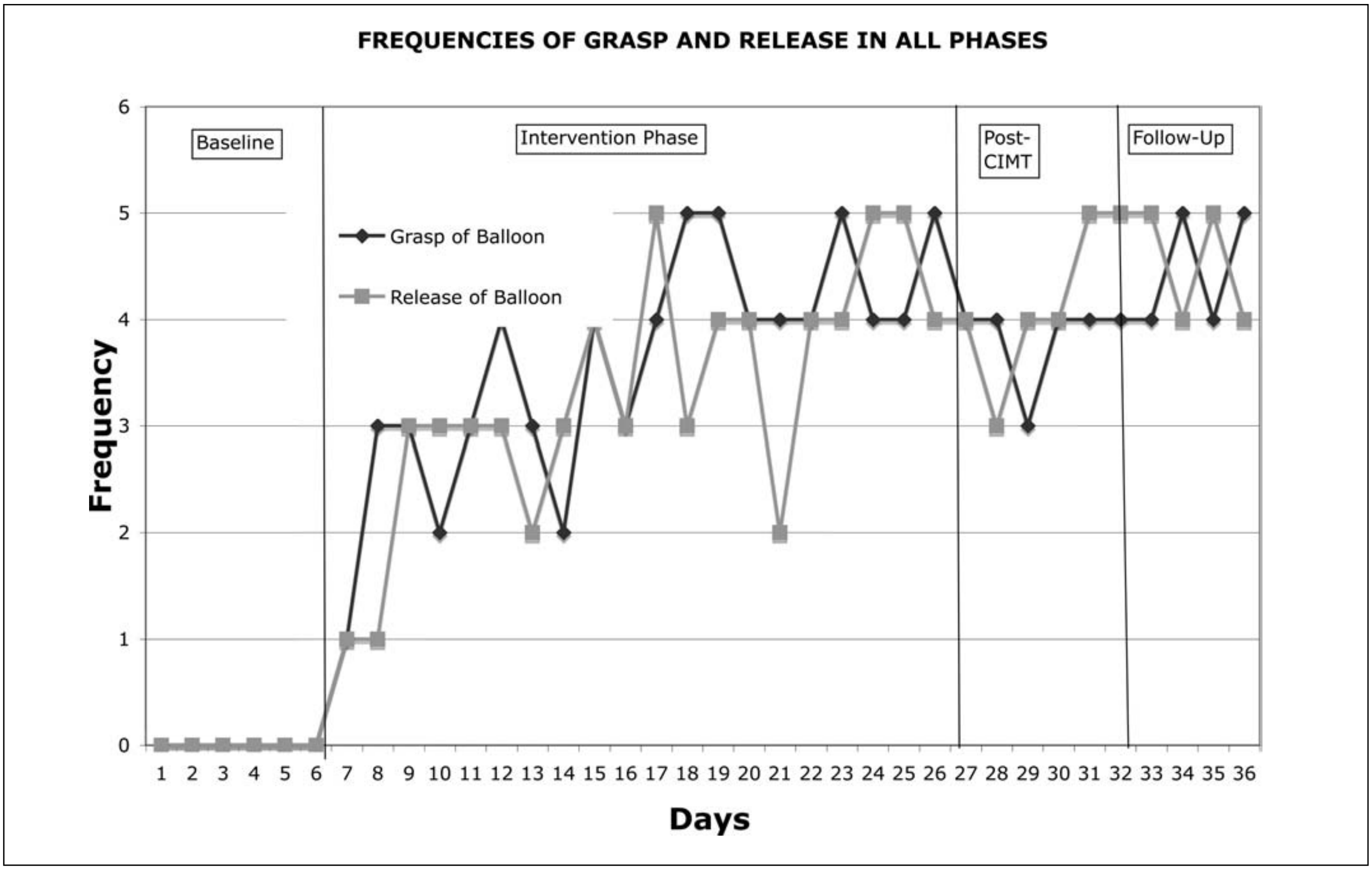

Figure 2. Frequencies of grasp and release in all phases.

Note. CIMT = constraint-induced movement therapy.

toward his mouth independently once the spoon was filled. He had difficulty flexing his shoulder to reach his mouth and would use his splinted arm to push the right arm up toward his mouth. Trevor was able to hold a cracker or chicken-nugget-size piece of food placed in his right hand. He would bring his hand toward his mouth with the assistance of his left splinted arm, bending his neck forward. At times, however, he would drop the food. Finger feeding remained unchanged through all phases.

Quality Ratings

Quality ratings increased from baseline to follow-up for reach, grasp, push, pull, finger feeding, and bilateral use (see Table 2). A decrease was observed in the quality of release and sustained grasp from intervention to postsplinting and follow-up evaluation. However, scores remained above baseline in all of the phases. The quality rating for bilateral use of hands to catch a rolling ball increased in the post-CIMT phase and remained steady through follow-up.

One behavior, spontaneous reach, showed particular increase in quality of performance. During the intervention phase, the quality of this movement increased steadily with an initial decline during the post-CIMT phase. However, higher quality of performance in spontaneous reach was attained in the follow-up phase. In reaching for the balloon, Trevor demonstrated shoulder movement greater than 30°, with elbow extension greater than 15°.

Table 1. Mean Scores for Behaviors During and After CIMT Intervention

	Splinting		Postsplinting		Follow-Up	
Motor Behaviors	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)
Rate of reach for inflated balloon	14.90	(8.59)	6.40	(3.71)	6.00	(1.58)
Frequency of grasp for deflated balloon	3.43	(1.33)	3.80	(0.45)	4.40	(0.55)
Frequency of release of deflated balloon	3.14	(1.35)	4.00	(0.71)	4.60	(0.55)
Rate of pushing button to activate sound	6.76	(2.47)	5.80	(1.64)	7.20	(2.17)
Rate of pulling toy car forward	2.86	(3.20)	4.20	(1.92)	8.6	(1.52)
Duration of sustained grasp	0.18	(0.09)	1.04	(0.04)	2.06	(0.01)
Amount of finger feeding	0	(0)	0	(0)	0	(0)
Frequency of bilateral use to catch ball	0	(0)	7.80	(3.83)	9.00	(2.12)

Note. CIMT = constraint-induced movement therapy. The behavior means for all measures were “0” in pre-CIMT phase.

Table 2. Mean Scores of the Quality Ratings of Behaviors During and After CIMT Intervention

	Splinting		Postsplinting		Follow-Up	
Motor Behaviors	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)
Reach for inflated balloon	2.57	(1.03)	2.8	(0.45)	4	(0)
Grasp for deflated balloon	1.38	(0.59)	3.0	(0)	3	(0)
Release of deflated balloon	2.38	(0.59)	3.2	(0.84)	3	(0)
Pushing button to activate sound	2.38	(0.74)	2.8	(0.45)	3	(0)
Pulling toy car forward	1.14	(1.15)	3.0	(0)	3	(0)
Sustained grasp	2.38	(0.74)	1.4	(0.89)	2	(0)
Finger feeding	0	(0)	0	(0)	0	(0)
Bilateral use to catch ball	0.86	(0.36)	1.0	(0)	1	(0)

Note. CIMT = constraint-induced movement therapy. The quality rating means for all measures were "0" in pre-CIMT phase.

The progression of the quality of pushing a button also was particularly impressive. When Trevor first used his right hand to activate sound on the toy, he placed his whole fisted hand on the button. After only 3 days of intervention, Trevor began using his palm, and by the middle of the second week he demonstrated ability to open his hand and place it on the button of the toy, showing an increase in ability to open his hand and control the movements of the hand. The abilities to "pull" a toy car forward and to grasp a marker showed similar progression.

Finger feeding, with the small pieces of cereal, remained at zero across all phases and remained a difficult and frustrating task. If the cereal pieces were placed in Trevor's hand, he was able to bring them to his mouth; however, opening his hand to pick them up remained difficult, and often he refused to try. If a single piece of cereal was placed between the side of his index finger and pad of his thumb, he would bring the piece to his mouth using a lateral pinch grasp. Other grasping tasks involving larger items proved more successful.

Bilateral upper-extremity use to catch a rolling ball was measured only during the post-CIMT and follow-up phases when Trevor was able to use both hands. He used both hands to catch a ball that was rolled to him, with increasing quality of performance during the post-CIMT phase. Trevor's best performance included a shoulder flexion of at least 20°, his elbow extended at least 30°, and his hand open.

Finally, to test for this significance of changes in performance and quality of Trevor's behaviors, two calculations of the *C* statistic were made, for both performance and quality of the behavior (see Tables 3 and 4). Changes in scores on all behaviors except finger feeding were significant at the $p < .05$ level from baseline to the post-CIMT phase, for both performance and quality ratings. When follow-up scores were factored into the calculation, significance declined to below the $z = 1.64$ level for all behaviors except spontaneous reach for the balloon and bilateral hand use, which remained significant.

Discussion

Overall, Trevor improved considerably in movement of the right upper extremity during this study. He progressed in the ability to reach with his right arm and demonstrated the ability to extend his shoulder, elbow, and wrist while opening his hand to hit a balloon. Spontaneous use of the right arm also was established. His greatest gains were in active range of motion, spontaneous use of the right arm, increased opening of the right hand, increased strength for pushing and pulling activities, bilateral hand use, and attempts at grasping.

Although some fluctuations occurred during the post-CIMT phase, progress appeared to be both noteworthy and lasting. Trevor's gains were maintained throughout the post-CIMT and follow-up phases, especially considering that the baseline function was negligible. Nevertheless, it remained obvious that movement of the right upper extremity was not normal for Trevor. He had limitations in active range of motion, wrist extension, ulnar deviation, fine motor use, and grasping. Control and coordination of movement also remained challenging, and finger feeding was never accomplished.

One major factor contributing to the continued limitations Trevor exhibited in use of the right upper extremity was the severity of his initial impairment. Trevor often required verbal prompting to use the right upper extremity, and use of the left upper extremity continued to dominate. Taub et al. (2003) found that positive outcomes achieved with CIMT depended on the severity of the initial impairment: Persons with less impairment generally improved more than persons with greater initial involvement. Trevor began with no functional movement in his right upper extremity. Motor learning had not previously occurred. Because he had had no prior experience of using this extremity, he lacked the ability to plan and execute coordinated movement to effectively use the arm to interact with the environment. For the motor learning to take place that is required to plan and execute movement, active rather

Table 3. *C* Statistic Scores for Performance of Behaviors Across Phases

Motor Behaviors	Baseline/Treatment			Baseline/Treatment/Postsplinting			Baseline/Treatment/Postsplinting/Follow-Up		
	C Statistic	Standard Error	*Z* Score	*C* Statistic	Standard Error	*Z* Score	*C* Statistic	Standard Error	*Z* Score
Reach for inflated balloon	0.91	0.19	4.82*	0.79	0.17	4.52*	3.84	0.69	5.57*
Grasp for deflated balloon	0.54	0.19	2.86*	0.47	0.17	2.68*	0.34	0.69	0.49
Release of deflated balloon	0.82	0.19	4.34*	0.82	0.17	4.71*	0.83	0.69	1.20
Pushing button to activate sound	0.85	0.19	4.47*	0.72	0.17	4.14*	0.69	0.69	0.99
Pulling toy car forward	0.91	0.19	4.83*	0.84	0.17	4.83*	0.85	0.69	1.24
Sustained grasp on marker	0.87	0.19	4.62*	0.80	0.17	4.61*	0.81	0.69	1.17
Finger feeding	0.00	0.19	0.00	0.00	0.17	0.00	0.00	0.69	0.00
Bilateral use to catch ball	—	—	—	0.84	0.28	2.95*	0.87	0.24	3.62*

*A *Z* score of 1.64 is statistically significant at a level of $p < .05$.
— = not applicable.

than passive movement is required. We believe that CIMT played a critical role in allowing Trevor to overcome nonuse of his right upper extremity. Further, the use of the right upper extremity that resulted from CIMT was essential for enabling motor learning and ensuring continued use of the right upper extremity.

In addition, in their research with CIMT, Taub et al. (2003) found that adults with more severe impairments showed a decrease in treatment gains of around 20% a year after treatment and greater loss after 2 years. However, functioning patients with less severe impairments retained treatment gains when tested 2 years after treatment. To maintain treatment gains in more involved adult patients, Taub et al. (2003) suggested periodic "brush-up" training. We have decided, therefore, that brush-up training will be important for Trevor to maintain movement and function. This brush-up training will involve splinting Trevor's left arm as during the study and again focusing on intense training of the right upper extremity. The time period should be for no more than 6 to 8 hr every 4 to 6 months, as suggested for adults by Taub and associates.

The ability to open and close the hand, which is necessary for both grasp and release, was a major accomplishment for Trevor. Before the intervention, Trevor did not demonstrate this behavior with his right hand. When grasping a deflated balloon, Trevor used a raking grasp in which the object was raked into his palm through flexion of the fingers. The fingers on top of the surface of the object pressed it into the center of his palm. The thumb was adducted and wrist straight without wrist extension. This type of raking grasp is a primitive form of grasping observed in infants. Trevor's newly acquired ability to control the opening and closing of his hand in the manipulation of an object such as this was notable. However, the ability to further refine the grasp to a more mature grasping pattern was not observed in this study. He did not develop the dexterity and coordination of the fingers and hand movements required for fine motor control necessary for mature grasping patterns. The components of hand skill development, such as active wrist extension, thumb opposition, and forearm supination, will likely be difficult for Trevor to develop due to the degree of his impairment.

Qualitative Impressions

Trevor made major gains in function of his right upper-extremity use. Although not measured during the study, Trevor's awareness of his right side seemed to increase significantly, and he appeared to have greater self-confidence in the use of his right arm. He progressed from neglecting the right side to using his right arm for simple play activities,

Table 4. *C* Statistic Scores for Quality of Performance of Behaviors Across Phases

Motor Behaviors	Baseline/Treatment			Baseline/Treatment/Postsplinting			Baseline/Treatment/Postsplinting/Follow-Up		
	C Statistic	Standard Error	*Z* Score	*C* Statistic	Standard Error	*Z* Score	*C* Statistic	Standard Error	*Z* Score
Reach for inflated balloon	0.97	0.19	5.13*	0.95	0.17	5.46*	0.95	0.69	1.38
Grasp for deflated balloon	0.86	0.19	4.56*	0.69	0.17	3.98*	0.90	0.69	1.31
Release of deflated balloon	0.92	0.19	4.85*	0.90	0.17	5.15*	0.89	0.69	1.29
Pushing button to activate sound	0.97	0.19	5.14*	0.99	0.17	5.67*	0.94	0.69	1.36
Pulling toy car forward	0.84	0.19	4.46*	0.89	0.17	5.10*	0.85	0.69	1.23
Sustained grasp on marker	0.93	0.19	4.90*	0.80	0.17	4.61*	0.80	0.69	1.16
Finger feeding	0.09	0.19	0.48	0.09	0.17	0.49	0.92	0.69	1.33
Bilateral use to catch ball	—	—	—	0.84	0.28	2.94*	0.88	0.24	3.65*

*A *Z* score of 1.64 is statistically significant at a level of $p < .05$.
— = not applicable.

and he learned to weight shift onto his right side when standing to begin to take steps. In addition, it seemed that gains in lower-extremity movement and speech were observed. Trevor began to rely less on his walker during the study and, by the end, he was walking independently. Trevor's vocabulary also had increased.

Trevor held on to a marker placed in his right hand for coloring, although his ability to maintain the grasp varied from day to day. During post-CIMT, this score dropped because Trevor insisted on using his dominant left hand to hold the marker. Ability was maintained, but volition was a factor, as would be with such a young child.

Although the home environment was not a direct factor in the study, we believe that it had an important effect in facilitating increased function. In his natural environment, treatment activities included Trevor's own toys and encompassed his normal daily routine and functional activities. Trevor was comfortable with familiar and safe surroundings and people. In addition, family and extended family were involved in supporting Trevor's intervention. By participating in this experience in their home, the family learned how to encourage Trevor and follow through after the therapist left.

Limitations

This study found positive effects of pediatric CIMT for a 24-month-old child with hemiparesis. However, the generalizability of the results is limited because this is only a single-subject design. Additional studies using a series of direct and systematic replications of well-controlled single-subject designs are needed.

A limitation in this study was that videotaping was used during the activities measured, and videotapes were reviewed daily by the researcher to ensure accuracy of the data. Peer review of the videotape would have reduced the risk of bias in the study.

Brain imaging would have enhanced the study by possibly identifying whether the functional gains were associated with changes in the brain; unfortunately, brain imaging was not available for this study. In addition, standardized assessments were not used to measure progress. The measurements used in the study lacked reliability and validity studies, which brings the results into question.

Further studies of CIMT with children will increase our understanding of this innovative treatment approach and may lead to improved efficacy of CIMT to help children with hemiparesis increase movement, function, and overall independence. Future studies should assess CIMT's long-term effectiveness. Children like Trevor, who have gained movement and function from participation in CIMT, would be great candidates for longitudinal studies of maintenance of gains through childhood and adulthood. Research would be enhanced through magnetic resonance imaging, transcranial magnetic stimulation, or neuroelectric source imaging to identify brain changes occurring as a result of CIMT. Further, measurements could be taken by both the physical therapist and speech therapist before and after CIMT to provide further evidence of the effects of this treatment.

Conclusion

The improvement of this 2-year-old child with right hemparesis corresponded with the use of CIMT treatment. He gained both movement and function in the right upper extremity that had been relatively nonfunctional. Thus, the study supports the efficacy of CIMT as shown in other studies of children (Charles et al., 2001; Glover et al., 2002; Taub et al., 2003) and suggests that children with minimal active movement of the impaired upper extremity can benefit from CIMT and should be included in future controlled studies of CIMT. ▲

Acknowledgment

This study was completed as part of the thesis in a master's degree in occupational therapy by the second author.

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Appendix: Descriptions of Behaviors With Quality Rating Descriptions

REACH: Rate of Spontaneous Reach for Inflated Balloon

Present balloon for 1 min, 12 inches in front of Trevor's right hand, and count how many times Trevor reaches for balloon. To qualify for a reach, Trevor must open hand and move shoulder at least 10°. *Spontaneous* means that movement is independent, without verbal or physical prompting.

Quality rating:

4—Open hand and shoulder movement greater than 30° with elbow extension greater than 15°

3—Open hand and shoulder movement, 20° to 30°, with elbow extension less than 15°

2—Open hand and shoulder movement less than 20°, but greater than 10°

1—Shoulder movement only

0—No attempt to move shoulder or hand

GRASP: Frequency of Successful Grasp for Deflated Balloon

Balloon is placed flat in researcher's palm and presented to Trevor, 1 inch from his hand. Number of successful grasps out of 5 is counted. One verbal prompt, "pick up the balloon," is given each time. To qualify for a successful grasp, Trevor must secure balloon in his hand for 2 seconds.

Quality rating of movement:

3—Grasps and maintains hold 2 seconds or more

2—Grasps but maintains hold less than 2 seconds

1—Attempts to grasp but misses

0—No attempts to grasp made

RELEASE: Frequency of Successful Release of Deflated Balloon

Balloon has already been grasped or placed in Trevor's hand. Researcher places open palm below Trevor's hand and gives one verbal prompt, "give me the balloon." Count how many times Trevor releases balloon into researcher's hand, out of 5 attempts.

Quality rating of movement:

3—Opens hand and demonstrates controlled release of balloon into researcher's open palm

2—Drops balloon without voluntary release

1—Attempts to grasp without success

0—No opening of hand

PUSHING: Rate of Pushing Button to Activate Sound

Present toy on table in front of Trevor 2 inches in front of right hand for 1 min, with one verbal prompt, "push the button." Count number of times he activates sound on toy within 60 seconds by pressing the button with hand or fingers.

Quality rating of movement:

4—Places 1 or 2 fingers on button to activate

3—Places open hand on button to activate

2—Places palm with fisted fingers on button to activate

1—Places whole fisted hand on button to activate

0—No attempt to use right hand

(Continued)

Appendix: Descriptions of Behaviors With Quality Rating Descriptions (*cont.*)

PULLING: Rate of Pulling Car for Forward Movement

Present car on table in front of Trevor 6 inches in front of right hand for 1 min with one verbal prompt, "make the car go." Count number of times Trevor pulls the car forward in 60 seconds.

Quality rating of movement:

3—Car moves more than 2 inches
2—Car moves 1 to 2 inches
1—Car moves less than 1 inch
0—No car movement

SUSTAINED GRASP: Duration of Sustained Grasp on a Marker

Trevor is timed using a stopwatch from the time the marker is in his hand until he releases or drops it from his hand during feeding activity. Three attempts are made.

Quality rating:

3—Trevor independently grasps the marker
2—Trevor grasps marker with one verbal cue
1—Trevor opens hand and marker is placed into it
0—No attempt made

FINGER FEEDING: Ability to Pick up Small Pieces of Cereal for Finger Feeding

Four ounces of cereal pieces is placed on table in front of Trevor. One verbal cue is given, "use your right hand to eat" the cereal. Time of 30 seconds is given. Amount of cereal grasped is counted.

The following rating is used:

4—Grasps and brings cereal piece to mouth
3—Grasps and attempts to bring to mouth but drops
2—Grasps but does not attempt to bring to mouth
1—When placed in hand, brings to mouth
0—No attempt to grasp

BILATERAL USE: Frequency of Bilateral Use to Catch a Rolling Ball

Researcher sits 3 feet in front of Trevor. Ball is rolled back and forth for 2 min continuously. Number of times Trevor catches ball using both hands is counted and divided by number of times caught total.

Quality rating:

4—Shoulder flexion at least 20°, elbow extends at least 30°, hand is open
3—Shoulder movement less than 20°, elbow extends less than 30°, hand is open
2—Elbow extends some with shoulder movement but hand is closed
1—Shoulder movement only
0—No movement observed

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