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The effects of constraint-induced movement therapy for a child less than one year of age

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Abstract. The aim of this single case study was to determine the effectiveness of a modified version of constraint-induced movement therapy (mCIMT) on a child less than one year of age with a diagnosis of hemiplegic cerebral palsy. A single-subject ABAB design with a 6-month follow-up evaluation used repeated measures of gross and fine motor skills to determine changes at each phase of the study. Measures included the Peabody Developmental Motor Scale-2 (PDMS-2), the Gross Motor Fine Motor Measure-88 (GMFM-88) and videotape analysis of specific motor skills typically seen in children less than one year of age. The child in this study participated in a conventional occupational and physical therapy for 2 hours a week during the 2 baseline phases, A1 and A2, and mCIMT during the 2 intervention phases, B1 and B2. The mCIMT involved constraint of the non-affected limb for 1-hour a day for 30 consecutive days as the child was engaged in developmentally appropriate, task specific activities implemented by therapists and parents. Following participation in this mCIMT, the child demonstrated clinical improvements in both gross and fine motor skills as measured by standardized assessments and videotape analysis of motor behaviors. He was completing developmental motor tasks at his chronological age despite motor deficits resulting from a right-sided hemiparesis. The results of this study supports the use of mCIMT for children less than one year of age and could shift the focus of future research studies to determining the age in which to implement mCIMT before patterns of learned non-use begin to affect the normal development of skilled motor movements in children with hemiplegic CP.

Keywords: Cerebral palsy, hemiplegia, rehabilitation, constraint therapy, motor skills

1. Introduction

While there is a growing body of literature on the use of modified constraint-induced movement therapy (mCIMT) in children with hemiplegic cerebral palsy, there is only one published study on CIMT that involves children less than one year of age, and the data for the infants are combined with data from other children in the study [19]. In our case study, we report the results for one infant treated with mCIMT under conditions that allow interpretation of systematic assessments. Our study modified a CIMT program used by Eliasson et al. [10], with young children between 18 months and 4 years of age in the home/school environment. The intervention period in the Eliasson et al. [10], study involved mCIMT for two months and treatment for seven days a week. The children were expected to wear a restraint on their stronger, non-affected limb for at least two hours a day, which could be split into different sessions in the day. This varied from adult CIMT protocols where patients wear a restraint (sling) for 90% of waking hours and have six hours of task specific training at a clinic [19]. We modified the Eliasson et al. [10] mCIMT protocol for a child less than one year of age by providing mCIMT for 1-hour a day for 30 consecutive days. Our clinical hypothesis was that the infant could tolerate this level of modification and that benefits could be measured by attainment of expected gross and fine motor skill by the time the child was 12 months old.

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2. Background

Cerebral palsy is a neurodevelopmental disability that affects at least 2 in 1000 children in the United States with hemiplegic type cerebral palsy representing approximately 25% of these cases [12]. Children with this type of cerebral palsy display significant motor and sensory impairments in the upper and lower extremity on one side of his or her body which affects overall adaptive function in everyday activities. When children are unsuccessful in attempts to use the affected limb, they often resort to a unilateral approach to motor activities using the stronger, more skilled limb. Learned non-use develops as the children neglect to use the weaker, impaired limb. The children begin to find some success using a unilateral approach to activities which becomes a pattern in all daily activities [9,25]. However, this increased reliance on the stronger limb and decreased use of the weaker, impaired limb can have negative consequences such as loss of motor control and function [7–9,14,16,23]. The children demonstrate poor weightshifting and balance responses to the affected side of the body and can fall frequently without a mature protective response to prevent injury [16,23]. Delays in neuromotor function can have a profound effect on other developmental domains including sensory awareness, and engagement with the physical and social environment [19]. Infants have difficulty with early mobility such as crawling, cruising and walking as well as limited ability to explore their environment [16, 24]. Older children have difficulty with bimanual activities such as dressing, fastening buttons, tying shoes, or cutting with scissors later in life [23]. The affected arm and leg do not grow at the same rate as the non-affected extremities causing limb length discrepancies which become more noticeable during growth and height changes [16,23,24].

CIMT was developed by Edward Taub in the 1980's as a therapeutic treatment for adult stroke patients [18]. Traditional CIMT involves the placing of a restraint on the client's non-affected arm for 90% of their waking hours to encourage the use of the affected arm. The client is then engaged in mass practice and intensive shaping techniques to train their affected arm.

Pediatric CIMT literature to date typically involves mostly a small convenience sample of children or single case studies [5,6,10,12,19]. CIMT protocols have been modified for the pediatric population (mCIMT) by using shorter constraint periods over longer intervals of time while maintaining the CIMT principles of shaping and repetition [4–6,10,12,19]. However, there are no standard protocols regarding the intensity or duration of mCIMT that facilitates the greatest motor gains. Only a few studies have compared CIMT treatment to conventional rehabilitation approaches [6,10,19].

The only published CIMT study to date with infants less than one year of age involved eighteen children with hemiplegic cerebral palsy (7 to 96 months) who were assigned randomly to receive either pediatric CIMT or conventional occupational and physical therapy [19]. This study included one infant seven months of age and one infant ten months of age. The children participating in CIMT had the non-affected limb casted with a lightweight fiberglass cast for 21 days. Taub and his team of researchers developed two assessment scales for use with pediatric CIMT that were published with this study, the Pediatric Motor Activity Log (PMAL) and the Toddler Arm Use Test (TAUT). Although some items on these scales are developmentally appropriate activities for a child less than one year old, many activities were not, including throwing a ball, using a marker for scribbling, taking off socks/shoes, and unclipping a clothespin. There was no specific information in the study on how participants tolerated intensive CIMT therapy or any specific descriptions of motor and functional gains seen after participation in the CIMT program. Also, the assessment data collected for the infants was combined with data from older children in the study.

Most research related to the movement behaviors of children with hemiplegic CP has focused on deficits in the *execution* of movement [2,10,16]. Movement planning is essential for the execution of skilled movement, and this develops during the first year of life [21]. As an infant performs motor patterns, skill development occurs from the integration of many body systems under specific conditions in the environment [1, 20,21]. Development of motor movements occurs by expanding the repertoire of patterns so that movement can become skilled and functional [1,11]. Research has shown that the ability to respond to the environment affects many other areas of development and each new motor accomplishment can have implications in social-emotional and cognitive development [9,13,20,21,24]. According to the neuronal group selection theory, primary cortical networks can be enlarged in children up to two years through new motor experiences alone [20, 21]. Therefore, we believe that infants and young toddlers could greatly benefit from the early introduction of a mCIMT while rapid changes in motor patterns are normally occurring in the developmental process. The purpose of this single case study was to evaluate the effectiveness of a mCIMT program for a child less than one year of age diagnosed with congenital hemiplegic cerebral palsy. Our clinical hypothesis is that an infant less than one year of age could tolerate participation in a mCIMT program and that benefits could be measured by attainment of expected gross and fine motor skill by the time the child was 12 months old.

3. Methods

3.1. Study design

An ABAB design was used to determine the effectiveness of a modified CIMT approach introduced into therapy sessions. The child was assessed for both occupational and physical therapy services at the initial evaluation, at the end of first baseline phase A (A1), the end of the first intervention phase B (B1), the end of the second baseline phase A (A2), the end of the second intervention phase B(B2), and at a 6 month follow-up evaluation. The evaluations were administered by the child's treating occupational and physical therapist. The Peabody Developmental Motor Scales-2 (PDMS-2) and the Gross Motor Fine Motor-88 (GMFM-88) were used during occupational and physical therapy evaluations. The PDMS-2 and the GMFM-88 are the two most well-known motor instruments for children with cerebral palsy [25]. The PDMS-2 is a standardized, norm-referenced test which includes 98 items from 2 fine motor subtests: grasping and visual-motor integration. The PDMS-2 has been shown to have good test-re-test reliability and acceptable responsiveness to evaluate motor skills for children with CP [25]. The GMFM-88 is a standardized observational instrument that measures gross motor function in children with CP, based on their performance of 88 gross motor tasks upon instruction in a specific test situation [15].

Videotaping of unstructured play was also used to examine motor changes that occurred during the mCIMT trials and baseline phases. The videotaped sessions included 10 minutes of unstructured play using the same developmental toys while the child was not wearing the constraint and free to use both hands for play. The videotapes were then analyzed by a licensed occupational therapist blind to the purpose of the study who was trained to observe specific motor behaviors of the affected limb that we were examining in this study. The examiner recorded the number of times the child used his affected right arm and hand during developmentally appropriate tasks such as reaching, approaching midline, sensory exploration, bimanual assistance, and weightbearing during the 10 minutes play session.

3.2. Initial evaluation

The child was a 5 month old infant boy referred to occupational therapy and physical therapy for weakness in his right upper and lower extremity due to hemiplegic cerebral palsy. The diagnosis of hemiplegic cerebral palsy was confirmed by significant medical history of prenatal stroke, revealed by marked clinical symptoms and confirmed by magnetic resonance imaging findings. This study was approved by the Institutional Review Board of (*university identifying information withheld from this document*) and informed consent was obtained from the family of the child involved in this study. The Peabody Developmental Scale – 2 (PDMS-2) was administered at the child's initial occupational therapy evaluation and follow-up assessments. The child demonstrated fine motor skills for grasping and visual motor skills in the 50th percentile and an age equivalent of 5 months as measure by the PDMS-2. He was unable to use both hands for activities such as holding a bottle with two hands, holding toys with two hands or transferring objects from one hand to the other. A referral was made for physical therapy services when the child was 6 months old. The child was able to sit with support of a caregiver, but was unable to roll, crawl, sit unsupported, stand using hands as support, or use his affected right arm for protective responses.

4. Results

4.1. First baseline phase (*A1*)

During the baseline phase A1, the child received occupational therapy and physical therapy services for 1 hour a week. At the end of the first baseline phase (B1), when the child was 9 months old, he demonstrated an age equivalent of 6 months on the PDMS-2. During this baseline phase when the child was receiving a traditional frequency of occupational therapy services (1 hour a week), his scores in visual motor and grasping had declined from the 50th percentile to the 9th percentile and 16th percentile, respectively. The child had standard scores in the below average range for both the grasp and visual-motor sections of the test. The child was able to sit unsupported, but was not able to move or transition in his environment, roll to his affected right side, or pull to standing. The GMFM-88 was administered by the physical therapist at the end of this baseline phase. The child completed a percentage total of 35.6% of the gross motor skills represented in the GMFM-88 for rolling, sitting, crawling, kneeling, standing, walking, running, and jumping categories.

4.2. *First intervention phase* (*B1*)

The first mCIMT treatment phase was initiated when the infant was 9 months old. This phase involved the use of a modified CIMT protocol for one hour each day for 30 consecutive days. A resting hand splint covered by a soft cloth mitt was used to restrain the stronger, non-affected extremity. One-on-one therapy sessions were provided 4 days a week by an occupational therapist, a physical therapist, or occupational therapy graduate students supervised by a licensed occupational therapist. The parents were trained to provide a constraint program at home 3 days a week and given a written activity plan for these 1-hour home sessions. Upon completion of the first CIMT treatment phase (B1) when the child was 10 months old, the child demonstrated a significant increase in the use of his affected right upper extremity as measured on the PDMS-2. He improved in grasping skills from the 9th percentile to the 63rd percentile with an age equivalent of 11 months and visual motor skills from the 16th percentile to the 37th percentile with an age equivalent of 9 months (Fig. 1). His standard scores in both fine motor sections of the PDMS-2 improved to within the average range. He demonstrated improvements in the number of gross motor skills he could perform with an increase to a percentage total of 55.6% of the gross motor skills represented in the GMFM-88 from a percentage total of 35.6% during the first baseline phase. He was beginning to stand at a large bench with two hands, cruise, roll, and transition into and out of sitting. From analysis of the videotaped sessions without wearing the constraint mitt, the child demonstrated an increase in number of times he used the affected right upper extremity for reaching, approaching midline, and using the right arm for weightbearing as measured by the videotape analysis (Fig. 2). No significant changes were noted in the use of the right arm for sensory exploration or bimanual assistance.

4.3. *Second baseline phase 2* (*A2*)

The child went back to a traditional therapy schedule of 1 hour of occupational therapy and 1 hour of physical therapy a week during the second baseline phase. The parents worked on therapy goals at home, but without use of the restraint mitt or the mCIMT schedule of 30 consecutive days of 1 hour constraint therapy each day. Upon completion of the second baseline phase (B1) when the child was 11 months old, the child demonstrated a decrease in grasping skills and no change in visual motor skills as measured on the PDMS-2. He scores in grasping skills decreased from the 63rd percentile to the 50th percentile with an age equivalent of 11 months and visual motor skills remained the same at the 37th percentile with an age equivalent of 9 months (Fig. 1). His standard scores for both the grasp and visual motor sections remained within the average range for his age. From analysis of the videotaped sessions when the child was not wearing the constraint mitt, the child demonstrated a slight decline in motor behaviors for reaching for an object, stabilizing weight with the affected arm, and approaching midline with the affected arm during A2. No significant changes were noted in the use of the right arm for sensory exploration or bimanual assistance.

4.4. *Second intervention phase* (*B2*)

A second CIMT treatment phase was initiated using the same protocol from the first mCIMT treatment phase (B1). The child received mCIMT for one hour each day for 30 consecutive days. One-on-one therapy sessions were provided 4 days a week by an occupational therapist, a physical therapist, or occupational therapy graduate students supervised by a licensed occupational therapist. The parents provided the mCIMT at home 3 days a week. At the end of B2, the child demonstrated grasping skills in the 50th percentile (the same as in the A2 phase) with an age equivalent of 12 months. The child's visual motor skills increased from the 37th percentile to the 50th percentile with an age equivalent of 12 months (Fig. 1). His standard scores in both fine motor sections of the PDMS-2 remained within the average range for his age. The child demonstrated the ability to functionally use a gross grasp in his weaker hand and transfer toys from one hand to another. He demonstrated improvements in the number of gross motor skills he could perform with an increase from 55.6% of the gross motor skills represented in the GMFM-88 to percentage total of 63.2% of motor skills represented in this assessment. The child was able to two-hand cruise in both directions on furniture, crawl up stairs, stand unsupported, and sit on a bench independently. Out of the six motor skill areas targeted in the videotape analyses, he demonstrated gains in number of times he approached midline, reached for an object, and stabilized weight with his affected limb. He showed improved spontaneous use of his affected limb, improved body awareness, and improved ability to use his weaker limb for weight-bearing and transitions. By 13 months of age, the child was walking independently.

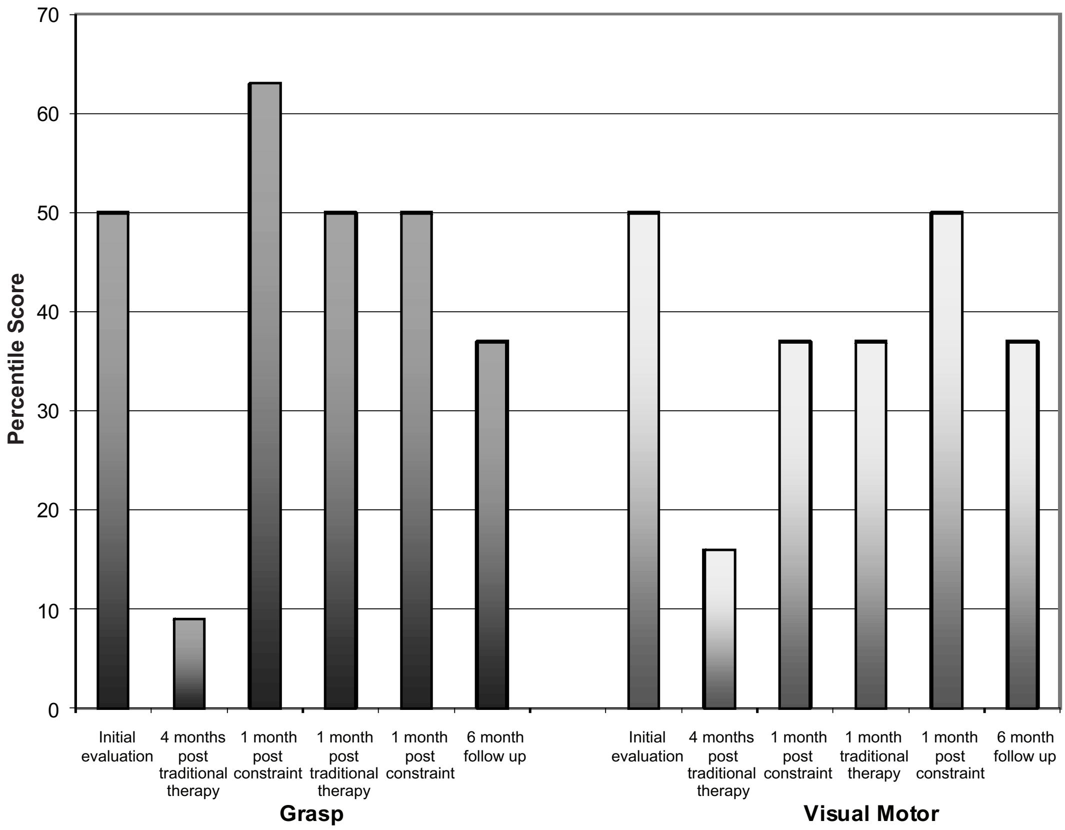

Fig. 1. Results of Peabody Developmental Motor Scales-2 (PDMS-2) for grasp and visual motor subtests with percentile scores at the initial evaluation, A1, B1, A2, B2 phases, and 6-month follow-up.

4.5. *Six-month follow-up evaluation*

A follow-up evaluation was completed when the child was 18 months old. At this time the PDMS-2 and the GMFM-88 were both administered. The child demonstrated grasping skills in the 37th percentile with an age equivalent of 14 months. The child's visual motor skills were in the 37th with an age equivalent of 14 months (Fig. 1). Although a slight decline from the end of the second intervention phase of mCIMT (B2), the child's standard scores in both fine motor sections of the PDMS-2 remained within the average range for his age. The child was able to use both hands to participate in undressing tasks as well as participate in developmentally appropriate play activities for his age. He continued to show steady progress in gross motor skills as measured on the GMFM-88 and was able was able to complete 83% of motor skills represented in the GMFM-88 (Fig. 3). The child was able to walk at home and in the community without assistance and climb stairs using a handrail without assistance.

5. Discussion

The results of this single case study show that a child less than one year of age can tolerate a mCIMT program and improvements can be measured by reliable developmental assessments that are commonly used for children with CP. The child in this study improved his gross and fine motor movement patterns after participation in mCIMT and demonstrated motor skills average for his chronological age despite motor deficits resulting from a right sided hemiparesis. These new motor movements were maintained during non-intervention phases of this study and after a 6 month follow-up evaluation when he was not receiving mCIMT. Studies on pediatric CIMT have shown that children who participate in constraint therapy gain significantly more new motor skills than children that participate in traditionally endorsed forms of occupational and physical therapy [3, 6,10,19]. This case study supports these findings as the child showed greater motor progress during mCIMT periods than when participating in traditional weekly therapy sessions. This was especially evident during

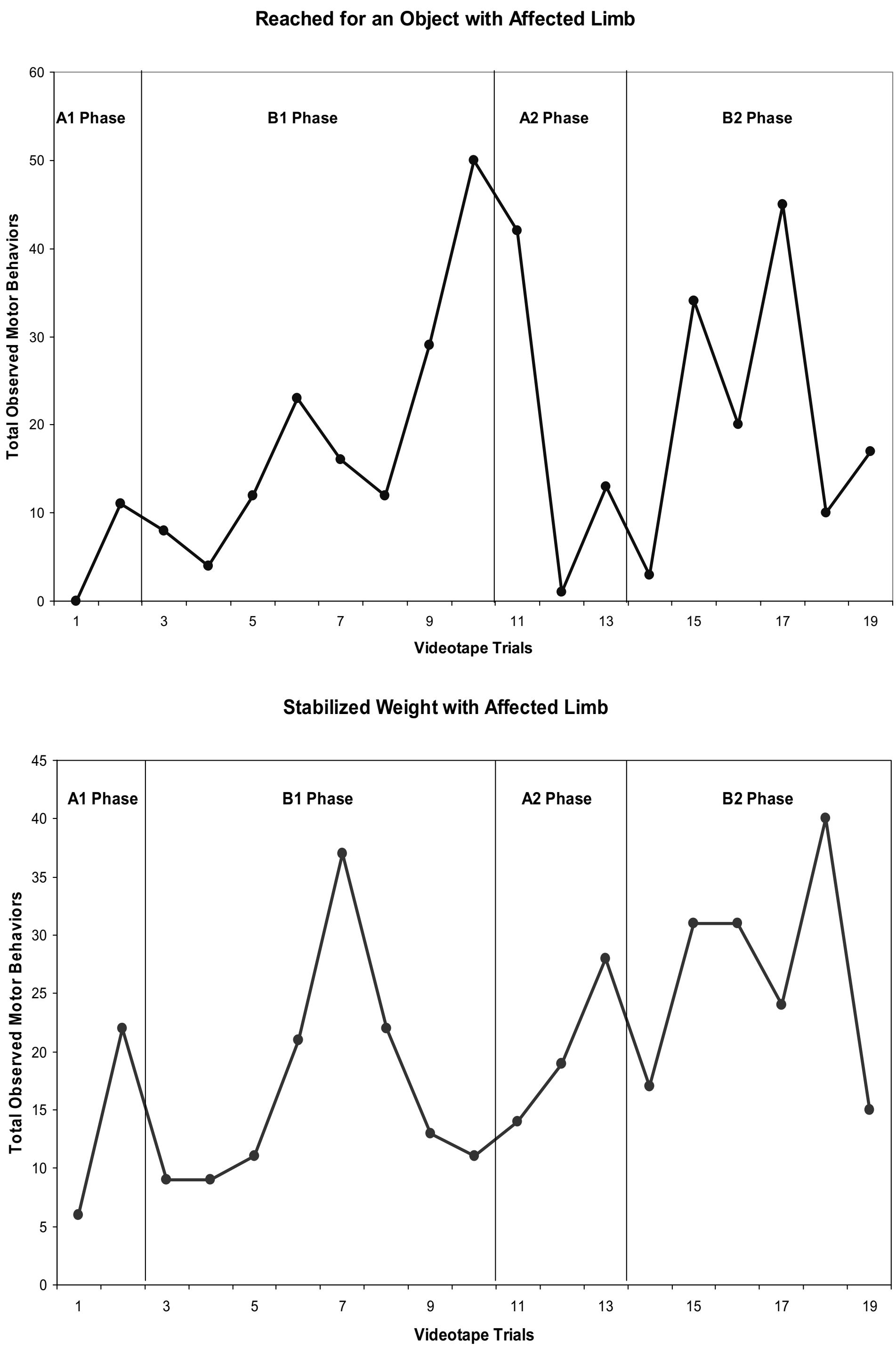

Fig. 2. Videotape analysis of reaching for an object, stabilizing weight and approaching midline with the affected limb for A1, B1, A2, and B2 phases.

the first mCIMT intervention phase (B1). As addressed in previous studies on mCIMT programs for children, it is important to consider the child's capacity and developmental level of function before implementing a constraint program [3,10,12]. Studies on young children that participate in mCIMT programs have deduced

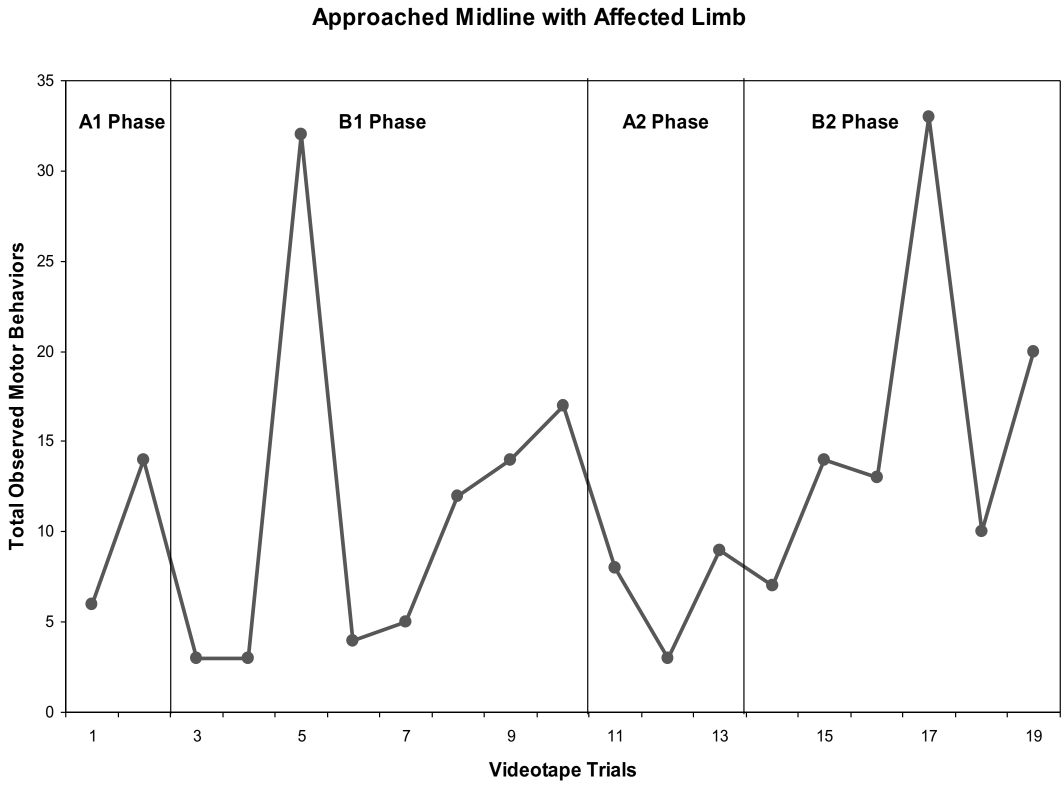

Fig. 2, continued.

that overcoming what Taub has defined has developmental learned non-use behaviors is key to improving motor function [10,12,20]. Following participation in mCIMT, younger children may gain an understanding that there are efficient ways to move and perform task by incorporating the weaker, more involved limb in daily tasks.

This case study highlights the benefit of using mCIMT with children less than one year of age before patterns of developmental learned non-use can form [10,12,19]. Although there are several studies that discuss the effectiveness of pediatric CIMT, the evidence on using mCIMT with children less than one year old is sparse [19]. Possible explanations for the lack of CIMT research with children under less than one year of age may be due to questions concerning the accuracy of the diagnosis of CP under one year old. The diagnosis could be substantiated for a child under one by a significant medical history of prenatal stoke and marked clinical symptoms confirmed by magnetic resonance imaging findings. Also, there may be concerns that younger children may not tolerate CIMT and fears that CIMT will negatively impact the function of the non-affected arm, but this has not been confirmed in the literature on pediatric CIMT. Children less than one year of age may actually demonstrate greater acceptance of the restraint treatment and begin to improve motor skills in the affected arm as part of the everyday, normal developmental process before learned non-use can develop. A child's first year of life is critical for the development of normal movement patterns [1,11,13, 20,21]. The introduction of a modified CIMT program for a child with hemiplegia who is less than one year old could greatly impact the development of normal postural and movement responses in the weaker, affected side of the body having a great impact on overall motor development.

6. Limitations

Since this study involves only one subject, it may be difficult to generalize the results to other children with similar diagnoses. We attempted to control for threats to internal validity through the use of an ABAB design rather than an AB design, but due to the clinical nature of this study, not all hallmark characteristics of a single-subject design could be accomplished. The

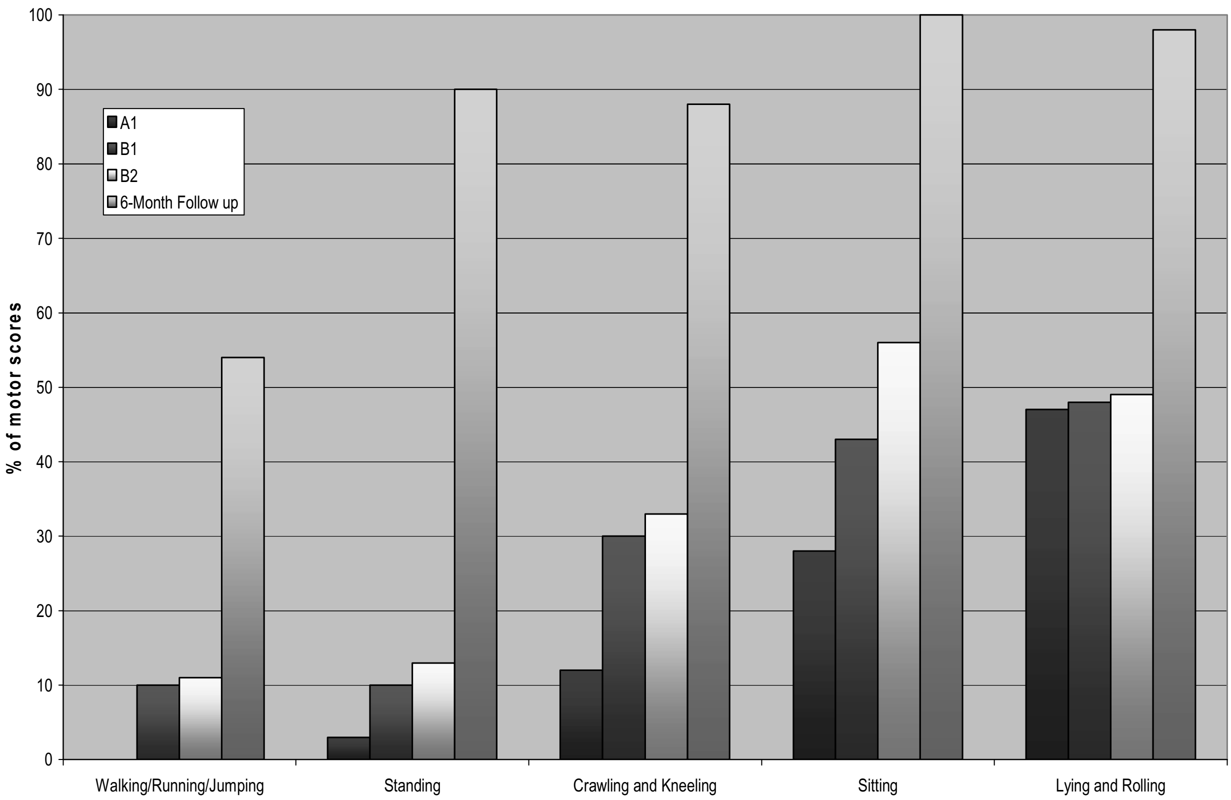

Fig. 3. Results of Gross Motor Fine Motor-88 (GMFM-88) measure including percentage of motor skills for walking/running/jumping, standing, crawling and kneeling, sitting, lying and rolling for A1, B1, B2 phases and 6 month follow-up.

baseline phase included only 2 assessments before the mCIMT intervention was started. The child was not making developmental progress in a traditional therapy regime of two hours of therapy a week while parents worked on therapy goals from a home program. Ethically, the clinicians felt it was imperative to try another clinical intervention and begin the mCIMT program due to the current literature on the benefits of constraint therapy for children with hemiplegic CP. Also, we recognize that the GMFM-88 measure was not administered at the initial PT evaluation or end of the A2 phase. However, the overall general trend of the child's motor skill improvements suggest parallel improvement in both fine and gross motor skill areas which were maintained at a 6 month follow up evaluation. The authors chose to include the valuable information obtained by the GMFM-88 assessments since it provided a measure of functional gross motor skills the child gained over the course of the mCIMT program and at a 6-month follow-up evaluation.

Although we attempted to control for the effects of the child's maturation on motor gains through the ABAB study design, it is possible that some of the motor skills attained could be attributed to normal growth and maturation since the first year of life is a time period of rapid neuromuscular growth and change. It is important to note, however, there were clinically significant increases in developmentally appropriate movement patterns in the child's affected extremity during mCIMT periods versus the baseline phases, based on the videotape analysis (Fig. 2). The child demonstrated increases in number of times he approached midline, reached for an object, and stabilized weight with his affected limb during both mCIMT trials which was not seen during the baseline phases when the child was receiving traditional therapy services.

7. Conclusion

This study demonstrates that a child less than one year of age can tolerate a mCIMT program and we feel the motor changes demonstrated after participation in a mCIMT program were meaningful and important to the child's overall development. It is imperative for clinicians who are using pediatric CIMT to be sensitive to the individual needs of children while encouraging participation from the family in this treatment approach. This modified protocol, while maintaining the basic principles of CIMT, was appropriate for a child less than one year of age who may have been less tolerant of having the non-affected extremity constrained for long time periods. The success of this program was supported by a motivated family, a child who was willing to accept and wear a constraint mitt, and the child's willingness to engage his weaker, affected limb in developmentally appropriate activities. For pediatric CIMT to become a more widely used therapy, clinicians will need to explore the best means of using mCIMT programs and determine the age in which to implement mCIMT before patterns of learned non-use begin to affect the normal development of skilled motor movements in children with hemiplegic CP. Future research on mCIMT should focus on establishing standard protocols regarding the intensity and duration of constraint that facilitates the greatest motor gains in children less than one year of age. Although these results are promising and suggest that CIMT protocols can be modified to suit the needs of children less than one year of age, further studies with a larger sample of children under one year of age would be needed to support the findings from this case study.

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