CONSTRAINT INDUCED MOVEMENT THERAPY AS A PHYSICAL THERAPY INTERVENTION FOR PEDIATRIC HEMIPLEGIA

A Case Report
Presented to

The Faculty of the College of Health Professions and Social Work
Florida Gulf Coast University

In partial fulfillment
of the Requirement for the Degree of
Doctor of Physical Therapy

By
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2015
Constraint Induced Movement Therapy

APPROVAL SHEET

This case report is submitted in partial fulfillment of
the requirements for the degree of
Doctor of Physical Therapy

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The final copy of this case report has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.
Acknowledgments

I would like to thank several people for assisting me in the development and final completion of this scholarly paper. Firstly, to a wonderful and knowledgeable committee, specifically Professor Ellen Donald, Professor Jacqueline van Duijn, and Doctor Sharon Bevins, who provided me with great guidance and insight as I began to narrow the focus of my Independent Study, and with finalizing this paper, I thank you! A significant amount of gratitude goes to my two children, Kevin and Ryan, which served as motivating factors for me throughout the past two years while completing this paper. To All Children’s Hospital of St. Petersburg, Florida, for providing me with the opportunity to observe several patient treatment sessions and offering clinical insight, I thank you. Finally, the greatest amount of appreciation and thanks goes to my husband, William Murphy, Jr., for always being there for me, encouraging me, and believing in me as I underwent this great study, and developed this paper. I cannot thank you enough for providing me with the love and support I needed to achieve this great accomplishment.
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Abstract

Objective: This case report describes the intervention of constraint induced movement therapy (CI therapy) to improve upper extremity function and hand use in a twenty-five month old child with left hemiplegia. Method: The participant received the recommended CI therapy protocol. Treatment consisted of a uni-valve cast worn on the uninvolved upper extremity for twenty-three hours per day, three hours of intensive therapy in the clinical setting offered five days a week, and a consistent daily home exercise program (HEP) for task practice and carryover at home over a three week period. Assessment measures included the upper extremity Pediatric Motor Activity Log (PMAL) and the Pediatric Arm Function Test (PAFT) as pre and post-test measures and PMAL administration daily during the intervention. Results: The child made significant gains in upper extremity use and hand function. Discussion: The findings from this case report suggest that CI therapy can be effectively utilized in the out-patient clinical setting.
Introduction

Hemiplegia is a term which is commonly used to describe the total or partial paralysis of one side of the body which results from disease or injury to one side of the brain. In adults this is commonly the result of a cerebral vascular accident (CVA). In the pediatric population, hemiplegia can be the result of many neurological disorders, including cerebral palsy (CP), cerebral hemispherectomy, and congenital assaults to the neurological system including congenital CVA.

Current research suggests that the incidence of congenital CVA is approximately one in every 1600 live births (CHASA, 2011). Hemiparetic children present with decreased strength and motor control on the affected side, which hinders normal child development (Brady & Garcia, 2009). These children exhibit a form of learned disuse as a result of repeated unsuccessful attempts to utilize the affected extremity and limited incentive due to the proficiency of the unininvolved extremity (Aarts, Jongerius, Geerdink, van Limbeek, & Geurts, 2010). Over 50% of these stroke survivors experience long-term disability which requires skilled physical therapy (PT) and occupational therapy (OT) services (Gordon, Charles, & Wolf, 2006). Conventional therapy approaches have previously emphasized the development of compensatory strategies, the reduction of tone, and the prevention of contractures in order to promote function (Brady & Garcia, 2009). A relatively new approach in the treatment of hemiparesis, constraint induced movement therapy (CI therapy), has been developed based on concurrent discoveries in the areas of neuroplasticity and behavioral theory (Brady & Garcia, 2009). The purpose of this study is to review the theoretical framework of CI therapy, to describe the
successful administration of CI therapy in an out-patient pediatric setting for a child with hemiparesis, and to discuss the measured outcomes.

**Theoretical Framework**

To better understand rehabilitation implications of stroke recovery it is important to delineate the differences noted between the treatment of the adult and the child affected by hemiparesis. In adults post-stroke, the functional use of the involved upper extremity is further impacted by repeated failed attempts to use the affected upper extremity, which has been termed “learned non-use” (DeLuca, Echols, Ramey, & Taub, 2003). Though children do not encounter learned non-use, they present with similar idle neural pathways because they lack the opportunity to experience normal child development (DeLuca et al., 2003). This has been termed “developmental-disregard” (Deluca, Echols, Law, & Ramey, 2006; Gordon et al., 2006).

CI therapy was initially presented in the literature as a treatment approach for adults who exhibited chronic hemiparesis following stroke. It was developed by a behavioral neuroscientist, Dr. Edward Taub, PhD, and was based on basic behavioral neuroscience research observations made during studies with deafferented primates (UAB CI Therapy Research Group, 2011). This series of studies led Dr. Taub to the hypothesis of “use-dependent cortical reorganization” which is the neural foundation for a permanent increase in the use of the affected upper extremity via focused use (UAB CI Therapy Research Group, 2011, p. 5). This intervention approach involves three essential components: 1) the immobilization of the unaffected upper extremity by some method of constraint (primarily the use of a removable cast which is split on two sides and reattached by some means to create a bi-valve cast), 2) intensive focused use of the
involved upper extremity, 3) behavioral techniques in the form of shaping and transfer of acquired skills utilizing a home exercise program.

CI therapy differs significantly in the aspects of duration, intensity and frequency from traditional physical therapy (PT) treatment. While traditional PT treatment may be offered up to one hour a day, three times a week or less, CI therapy is an intense training for prolonged periods of time (up to 6 hours), offered daily for several weeks. This treatment approach also consists of a one-time intensive therapy program in which rapid gains are made, typically in a camp-like setting, rather than a consistent long term treatment approach in which gains are achieved slowly over time. During this intense training of CI therapy activities are structured to include “shaping” and repetitive tasks (Taub, Ramey, DeLuca, & Echols, 2004). These shaping tasks provide positive reinforcement by allowing the subject to experience success using their affected limb before progressing to more challenging tasks (DeLuca et al., 2003). The success of CI therapy in adults prompted additional research exploring the use of CI therapy to treat children with hemiplegia. Dr. Taub hypothesized that the results of CI therapy in a pediatric population would be as good if not better than the recovery demonstrated in the adult population due to the presence of a more immature nervous system with greater neuroplasticity (UAB CI Therapy Research Group, 2011). In the resulting study conducted by Taub, Ramey, DeLuca and Echols in 2004, children who received CI therapy acquired over nine new motor tasks, demonstrated significant gains in use of the affected arm at home, and displayed increased spontaneous use of the affected arm (Taub et al., 2004). These results were maintained in follow-up measures taken six months following the conclusion of the study (Taub et al., 2004). A more recent study conducted
in 2013 confirmed structural grey matter changes in children following CI therapy (Sterling et al., 2013).

Based on the above stated positive findings many other studies investigated the implementation of modified CI therapy programs for use within the clinical setting. These studies often reduced the length of wear, modified the constraint and/or reduced the amount of intensive therapy.

The time period of immobilization varied greatly in subsequent studies. Some studies limited the use of immobilization to the periods in which the therapy intervention was being employed, such as Charles et al. (2006). In the research study of Martin, Burtner, Poole, & Phillips (2008) the immobilization was applied during the treatment and for an additional three to five hours per day following the treatment. In Wallen et al. (2011), immobilization was utilized for two hours per day. De Bode, et al. (2009) allowed for brief periods of removal of the immobilization device, but encouraged use during 90% of waking hours. Other studies employed the use of a removable cast in an attempt to immobilize the unaffected upper extremity during the entire length of the study (Reidy et al., 2011; Cope, Forst, Bibis, & Liu, 2008). The most effective outcomes were reported when the immobilization was applied continuously.

Other studies modified the form of constraint in an attempt to distinguish the extent of immobilization needed. Kuhnken et al (2008) coupled the use of a sling with a fabricated glove, which limited the child’s ability to grasp with the uninvolved hand but allowed the child to protect himself in the event of a fall. In de Bode et al. (2009), a standard resting splint was utilized on the unaffected upper extremity during the course of the study. The study conducted by Charles, Wolf, Scheider & Gordon (2006) utilized
immobilization via the use of a sling which was sewn shut to prevent the use of the hand, and then strapped to the trunk. Similarly, a study conducted by Aart, Jongerius, Geerdink van Limbeek & Geurts utilized a cotton sling sewn shut and then strapped to the trunk (2010). Wallen et al. (2011) employed the use of a cotton mitten which allowed the child the ability to utilize both upper extremities together, but prevented grasping of the unaffected hand. Wallen et al. concluded that this method of constraint was no more effective than intensive therapy without constraint (2011).

Many studies also varied in the lengths of the intervention. Some studies, such as Charles et al. (2006), utilized treatment intervention time similar to the CI therapy protocol consisting of four to six hours of focused treatment. Another study employed longer treatment sessions than conventional therapies, but allowed these sessions to be split into two shorter intervention sessions offered daily (Martin et al., 2008). An interesting study conducted by Reidy et al. (2011) focused on treatment time. Half of the participants received CI therapy three hours per day while the other half received CI therapy six hours per day. In this study, there was no significant difference in outcomes suggesting that three hours per day may be sufficient (Reidy et al., 2011). Additionally, a study conducted by Page, Levine, Leonard, Szaflarski, & Kissela in 2008 concluded that as little as 15 minutes of intensive task-specific training may promote cortical reorganization (Page, Levine, Leonard, Szaflarski, & Kissela, 2008).

In a study conducted by Reidy et al. in 2012, a single group, pre-test post-test design was utilized to determine the effectiveness of CI therapy in an out-patient setting. This study concluded that the CI therapy protocol could be effectively utilized in the clinical setting, and suggested that a potential paradigm shift could be implemented in the
use of therapeutic resources (Reidy et al., 2012). This study suggested the potential benefit with the utilization of short bursts of intensive therapy followed by occasional monitoring rather than the traditional weekly physical therapy treatment frequency administered long-term (Law & Darrah, 2014), which is generally utilized for this population. This proposed change in service delivery could potentially optimize the use of therapy resources. CI therapy presents a more comprehensive family-centered approach via behavioral and transfer components, which empowers the family by emphasizing functional activities and encourages family involvement for long-term carryover. Emerging changes in theoretical knowledge support the components of CI therapy as a more family-centered approach to rehabilitation services (Law & Darrah, 2014).

Based on extensive studies conducted by Dr. Taub in conjunction with UAB which have previously been mentioned, an out-patient clinic protocol has been advocated (UAB CI Therapy Research Group, 2011). The protocol consists of bi-valve casting of the unaffected upper extremity which is worn 23 hours per day and one-on-one intensive therapy treatment three hours per day for fifteen visits over a period of three weeks (UAB CI Therapy Research Group, 2011). The use of CI therapy in an out-patient setting is additionally supported by the findings in a case report conducted by Page, Levine, Leonard, Szaf Larski, and Kisselain (2008) and a separate study conducted by Ploughman, Shears, Hutchings, and Osmond (2008). The intensive and time consuming nature of this intervention can be prohibitive for many smaller out-patient clinic settings; therefore, there are few facilities which are able to implement this therapeutic approach successfully.
Case Description: TS

TS was a male child who was diagnosed with a congenital stroke at birth. His MRI revealed damage in the area of the middle cerebral artery on the right with resulting hemiplegia of the left side of his body with the upper extremity more affected than the lower extremity. He had no additional neurological or cardiovascular complications. TS received conventional physical therapy and occupational therapy services in an outpatient facility from the age of six months. These services were offered two to three times per week with his mother in attendance. With continued PT and OT intervention and the involvement of his parents, TS was able to meet all of his developmental milestones near the target ages.

At the age of eighteen months TS had begun to grasp objects with limited strength. He lacked the ability to reach for a desired toy with the left hand and the ability to release it without assistance. TS had begun relying on his right upper extremity at play and during activities of daily living often neglecting the left upper extremity. Developmental disregard of the left upper extremity was evident. The occupational therapist recommended that TS would benefit from CI therapy after the age of two as suggested in the literature. TS’s mother hoped that her child would be able to use his left hand effectively in the future and she believed that the intensive approach would help TS be able to grasp and hold objects with his left hand. She researched CI therapy at UAB and located an out-patient clinic outside of her local area which offered the intensive therapy approach.

The CI therapy program offered at the out-patient clinic followed the approach performed at UAB. Two Occupational Therapists facilitated this intervention on alternate
days and were trained in CI therapy at a course offered at UAB. Inclusion criteria for the program included: 1) age of 2 or older, 2) limited functional use of one hand and arm, 3) a diagnosis of cerebral palsy, stroke, head injury, brachial plexus injury, etc., 4) the ability to follow directions and maintain attention for a minimum of fifteen minutes, 5) availability of the caregiver to participate in therapy sessions as well as extensive home programming.

TS’s mother was able to secure housing near the out-patient facility at a local Ronald McDonald house. Upon his second birthday TS met all of the inclusion criteria to participate in the CI therapy program. TS was two years and one month old at the onset of CI therapy.

Clinical Impression

TS was an appropriate candidate for CI therapy based on the presentation of developmental disuse of the left upper extremity and hand. His left sided hemiplegia, due to a congenital stroke, made him an appropriate candidate for CI therapy. Based on a recent study the literature supports the use of intensive therapy for children age two or younger (Arpino, Vescio, De Luca, & Curatolo, 2010), therefore he is at an appropriate age for the intervention. Another study conducted by Nordstrand and Eliasson also found a correlation between the higher effect of CI therapy if administered before the age of seven (2013). His mother was very involved as an active participant in his PT and OT services. Her interest, understanding, and pursuit of CI therapy indicated that she supported this intensive therapy approach. She had been proactive in securing living arrangements near the out-patient clinic and she was willing to alter her daily routine for the course of the three week CI therapy protocol. The active participation presented by
TS’s mother was essential for positive outcomes. An article published by Law and Darrah suggested that optimal child functioning occurs within a supportive family (Law & Darrah, 2014). Additionally, TS was a first and only child for the family at the time of the intervention, which reduced parental distraction.

**Examination Measures**

In the administration of pediatric CI Therapy as it was originally developed at UAB several assessment measures could be selected and utilized as deemed appropriate by the therapists. Based on the upper extremity Motor Activity Log (MAL) developed for adults, the UAB research team developed the upper extremity Pediatric Motor Activity Log (PMAL) for children between the ages of two and eight (UAB CI Therapy Research Group, 2011). The Pediatric Arm Function Test (PAFT) was also utilized as a measure of spontaneous upper extremity movement in play situations (UAB CI Therapy Research Group, 2011).

The primary assessment measure utilized in CI therapy is the upper extremity pediatric motor activity log (PMAL) which is considered a reliable and valid instrument that was developed specifically for this treatment approach at UAB (UAB CI Therapy Research Group, 2011). According to the study conducted in 2012 by Uswatte, Taub, Griffin, Vogtle, Rowe and Barman, the test-retest reliability was rated at 0.89 and the validity was supported by a correlation factor of $r (53) = .5$, $p<.001$. This assessment measure utilized a structured interview, consisting of twenty-two questions, with the child’s primary caregiver which is intended to examine the child using the involved upper extremity in the natural environment based on two scales: (1) how often (HO) and (2) how well (HW) (UAB CI Therapy Research Group, 2011). Each scale is 0-5 with half
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steps if needed to create a six point scale. The parent is encouraged to compare the involved extremity to the uninvolved extremity as he/she answers the questions. The HO scale is administered in completion on the first treatment day, and again on day fifteen upon completion of CI therapy. The HW scale is administered in completion on days one and fifteen and also half of the questions are administered on alternate days during the intervention (see Table 1). The purpose for the repeated daily assessment was to monitor the child’s progress, encourage daily follow through and participation of the parent, to facilitate problem solving, and to initiate the transfer process. On days one and fifteen the HO scale should be administered first and then the HW scale should be administered separately (UAB CI Therapy Research Group, 2011). The PMAL is scored by adding all of the items and dividing by the total number of questions asked. At the initial treatment TS scored below 1 on the PMAL. This indicated that TS used the involved upper extremity very rarely (5-10% of the time) or not at all.

The PAFT is a structured and video recorded test utilized in the 2-6 year old population (UAB CI Therapy Research Group, 2011). The purpose was to elicit and examine a variety of upper extremity movements during play. It was developed specifically by the UAB team to capture specific functional arm use of the involved upper extremity (Uswatte, et al. 2012). In the study conducted by Uswatte et al. in 2012 the test-retest reliability was found to be 0.74 while the validity was supported by the inverse correlation of $r = -0.6$, $p < .001$. The PAFT involves two sections: (1) unilateral and (2) bilateral (UAB CI Therapy Research Group, 2011). The test includes twenty-two items and the child is allowed three attempts at each task (UAB CI Therapy Research Group, 2011). The items are rated on a six point scale. Since the test includes bimanual activities
it can only be performed on days one and fifteen as a pre- and post-test measure when the cast is not in place.

<table>
<thead>
<tr>
<th>Scale</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>HO</td>
<td>1-</td>
<td>22</td>
<td>1-</td>
<td>22</td>
<td>1-</td>
<td>22</td>
<td>1-</td>
<td>22</td>
<td>1-</td>
<td>22</td>
<td>1-</td>
<td>22</td>
<td>1-</td>
<td>22</td>
<td>1-</td>
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<tr>
<td>HW</td>
<td>1-</td>
<td>12-</td>
<td>1-</td>
<td>12-</td>
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<td>12-</td>
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<td>1-</td>
<td>12-</td>
<td>1-</td>
</tr>
</tbody>
</table>

Table 1

Scoring of the PAFT was similar to the PMAL. At the out-patient clinic the PAFT was administered by the same occupational therapist on days one and fifteen while it was video recorded by a therapy technician trained in the process. A second occupational therapist scored the exam based on the video. At the onset of CI therapy, TS scored a one which indicated that the involved upper extremity had very poor function (UAB CI Therapy Research Group, 2011).

**Clinical Impression**

Based on the initial PMAL and PAFT assessments, TS was an appropriate candidate for CI Therapy. The PMAL indicated that prior to CI therapy TS utilized the involved upper extremity ten percent of the time or less in daily function and play. The PAFT score indicated that during unilateral tasks the affected arm did not participate functionally and during bilateral hand use TS attempted to use the involved upper extremity however it served as more of a helper only through part of the task.
The initial scores of the PAFT and PMAL served as pre-test measures. These assessments were retested on the fifteenth day of the intervention as post-test measures upon completion of the CI therapy protocol. His low initial scores on the PAFT and PMAL indicated that he would likely have a better response to CI therapy. The literature indicated that children with poorer initial hand function benefited most from CI therapy (Sakzewski, Ziviani, & Boyd, 2011).

**Intervention**

The intensive focus of CI therapy utilized the components of motor learning (UAB CI Therapy Research Group, 2011). Initial treatments consisted of mass practice in a closed environment which was easily achieved in the clinical out-patient setting. As the treatment progressed, the family was constantly involved in the process of transference by assisting the child at home and facilitating continued “task practice” of the involved upper extremity in daily activities (UAB CI Therapy Research Group, 2011, p. 9).

<table>
<thead>
<tr>
<th>Table 2</th>
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</thead>
<tbody>
<tr>
<td><strong>Schedule for Day 1 of CI Therapy</strong></td>
</tr>
<tr>
<td><strong>Day</strong></td>
</tr>
<tr>
<td>Monday</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

The out-patient CI therapy protocol consisted of casting the uninvolved upper extremity, three hours of intensive therapy offered daily for three weeks, and a home
program performed daily and over the weekend with the cast in place. This protocol closely replicated the treatment described by Taub et al. (2004) and Deluca et al. (Deluca et al., 2006). The first day of CI therapy consisted mainly of evaluation measures, casting, and the development of the treatment plan with the parent (see Table 2) therefore limited time was available for initiation of the intensive therapy.

Casting

During pediatric CI therapy a uni-valve cast was utilized on the uninvolved upper extremity (UAB CI Therapy Research Group, 2011). Two separate casts are constructed of a light-weight fiber-glass material so that the child could wear the cast 24 hours a day (UAB CI Therapy Research Group, 2011). A thumb spica liner was applied to the arm and appropriately padded in the prominent elbow area to prevent skin breakdown. A trained therapy technician assisted in stabilizing the child’s upper extremity while the fiber-glass cast material was applied by the occupational therapist. The cast extended from the upper arm to the finger tips with the elbow held in ninety degrees of flexion, the wrist in neutral, the thumb abducted, and the fingers in slight flexion and abduction (UAB CI Therapy Research Group, 2011). Once the cast material had hardened, it was removed via a single cut along the lateral aspect of the cast. The technician then lined the cast with an adhesive fleece edger and secured the opening with three to four separate sections of adhesive hook velcro and stretch loop velcro. One cast was constructed on the first day of treatment and a second cast was constructed on the second day of treatment. The family was instructed to use one cast for wet activities such as bathing or water play and designate the other cast as a dry cast. This allowed the cast to be worn during all activities of daily living while reducing the risk of skin breakdown due to moisture. After
the cast was created and placed on the child’s arm the therapist encouraged the family to consider that the uninvolved extremity was now “on vacation” while the affected arm was now in “boot camp”.

TS tolerated the cast application well. He enjoyed picking the color of his casts. After the third day of treatment TS had completely adjusted to the cast and did not resist cast changes and application following his bathes. TS’s mother reported that she saw significant improvement almost immediately following the application of the cast.

Intensive Therapy

During CI therapy the parent was asked to provide ideas of preferred tasks, methods of positive reinforcement, and personal goals to help guide each session. A more family centered approach was facilitated by involving the parent in goal selection. TS’s mother reported that he had difficulty performing daily tasks such as opening doors and that he was very interested and motivated by cars and trains. The behavioral component of CI therapy involved the use of positive reinforcement such as verbal praise, smiles and encouragement (Reidy et al., 2012). The occupational therapist engaged the child in a variety of activities based on the principles of shaping and task practice.

A typical treatment session (see Table 3) often began with preparatory treatment activities such as stretching and joint compression while TS was engaged in an interactive book. Activities of daily living were incorporated into each session such as eating a snack, washing his face, and removing his shoes. Seated activities were alternated with floor and standing activities. The therapist took full advantage of every opportunity to engage the child in daily tasks such as opening doors and turning on/off light switches. TS’s mother was present and assisted throughout the session by offering
verbal praise and encouragement and by providing an assisting hand for bimanual activities as instructed by the OT.

Table 3

*Typical Daily Routine*

<table>
<thead>
<tr>
<th>Times</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00-8:30</td>
<td>Stretching: Shoulder Internal Rotation, external rotation, abduction, supination, thumb abduction</td>
</tr>
<tr>
<td>8:30-8:45</td>
<td>Activity 1: side sit with bubble play</td>
</tr>
<tr>
<td>8:45-9:00</td>
<td>Snack in sitting at table</td>
</tr>
<tr>
<td>9:00-9:15</td>
<td>Clean up and ADLs after snack</td>
</tr>
<tr>
<td>9:15-9:30</td>
<td>Activity 2: puzzle with focus on supination x3</td>
</tr>
<tr>
<td>9:30-9:45</td>
<td>Activity 3: foam puzzle- pushing pieces out with pointer finger and co-ban to isolate pointer finger</td>
</tr>
<tr>
<td>9:45-10:00</td>
<td>Activity 4: upright activity on easel for wrist extension</td>
</tr>
<tr>
<td>10:00-10:15</td>
<td>Activity 5: ambulation activity pushing weighted lawn mower in the hall with the left hand</td>
</tr>
<tr>
<td>10:15-10:30</td>
<td>Activity 6: water play with squeeze toys for supination, wrist extension grasp and release</td>
</tr>
<tr>
<td>10:30-11:00</td>
<td>Review of PMAL HW scale and issuing HEP</td>
</tr>
</tbody>
</table>

Shaping activities were selected by the treating occupational therapist to keep the child engaged and motivated. The activities which were selected were easily achievable initially such as turning a page in a board book or placing large knob puzzle pieces in a puzzle. These activities became progressively more challenging as the child became more
successful. Whenever possible, the child was offered a choice of activities to encourage child participation.

Supination was facilitated by placing vehicle stickers under the puzzle pieces. When the child picked up the puzzle piece he was then asked to look under the puzzle piece to see “what was hiding” or to “show mom what was hiding”. Knobs on the puzzle pieces were built up with Co-ban to make them less difficult to grasp initially. As the child became more successful with the activity the Co-ban was removed and the activity was progressively made more challenging.

At the conclusion of each session, the last fifteen to twenty minutes were spent on completing the PMAL HW scale. The occupational therapist offered suggestions to help the parent problem solve any difficulties by offering probing questions such as “Why do you think he had difficulty with that?” or “Do you think it would help if you tried …?” This specific verbal communication was utilized to facilitate self-efficacy on the part of the parent, and to promote independent problem solving for daily activities (UAB CI Therapy Research Group, 2011).

Throughout each session the occupational therapist identified three to five tasks for the home exercise program (HEP) which would be performed by the child at home with the parent’s assistance. At the conclusion of the session, TS’s mother was provided with a handout with written instruction for the selected HEP activities. The parent was also given the opportunity to have any questions answered.

**Weekend Follow Through**

The fifth and tenth treatment dates included time allotted at the end of the session to discuss additional activities for home practice. The parent was instructed to perform
three to five shaping activities with the child and to facilitate frequent task practice of common activities of daily living such as opening drawers, etc. These tasks were selected to involve the family, help incorporate new skills into the daily routine and to promote ongoing motor development (Reidy et al., 2012). According to a study conducted by Rostami and Malamiri, carryover and implementation of activities in the familiar home setting by caregivers is an important component of the learning process (Rostami & Malamiri, 2012).

**Clinical Impressions**

TS responded well to the intensive CI therapy approach. His favorite activity involved walking through the hallways while pushing a toy lawn mower with his left hand. The most challenging aspect of CI Therapy for TS was remaining seated while performing upper extremity tasks for extended periods of time. TS’s mother encouraged him to stay on task by offering him a reward such as a toy car or a special activity for doing “a good job”.

**Outcomes**

TS exhibited improved left upper extremity arm and hand function upon completion of CI Therapy. TS scored a three on the PMAL when retested after the cast was removed. This score indicated that he used the affected upper extremity approximately fifty percent of the time, but it was only half as strong as the uninvolved upper extremity (UAB CI Therapy Research Group, 2011). On the PAFT TS scored a three which indicated he presented with a moderate amount of synergy or performed tasks somewhat slowly or with increased effort (UAB CI Therapy Research Group, 2011). This score reflected a rating of fair function.
Clinical Impression

The outcomes of the PAFT and PMAL reflected a significant improvement in the overall hand and arm function of TS. He was able to open the door with his left hand upon leaving the facility on the final day of CI therapy which was an important goal which was set by the family. TS’s mother reported that in her opinion CI therapy was “very difficult but worth the effort”.

Discussion

The findings of this case report suggest that the CI therapy approach can be successfully implemented in an out-patient setting with good outcomes. This child had been receiving traditional occupational and physical therapy services for the majority of his young life yet still had difficulty with grasp and displayed signs of developmental disregard of the left upper extremity. After the implementation of the intensive therapy approach presented in CI therapy, the child was able to improve his overall hand function and spontaneous hand use of the affected hemiplegic side was promoted. The implementation of a cast on the uninvolved side served to isolate the involved upper extremity. The child was constantly engaged in repetitive enjoyable activities both in the clinic and at home with appropriate parental facilitation and carryover of assigned home activities. Positive reinforcement served as behavioral reinforcement and facilitated participation of the child. The family support provided and constant involvement by the child’s mother was an essential component of the success of this intervention.

Though there has been a recent increase in evidence which supports the implementation and effectiveness of CI therapy, there is limited application in the clinical setting (Ploughman, Shears, Hutchings, & Osmond, 2008). This may be in part due to
continued disagreement in the literature as to the optimal time frame for the intensive therapy approach. Some studies continue to support the need for six hours per day of intensive therapy such as the study conducted by Ploughman et al. in 2008. While other studies support the use of three hours of intensive therapy (DeLuca, Case-Smith, Stevenson, & Ramey, 2012). The results of this case report support the use of three hours of intensive therapy for this young child. Though the interventions in this case report were implemented by occupational therapists, positive outcomes have been reported when both physical therapists and occupational therapists alternated services (Ploughman et al., 2008). Perhaps additional studies could include the combination of physical therapy and occupational therapy interventions offered alternately over the three hour intensive therapy session.

In more recent years several studies have begun examining other factors related to the implementation of CI therapy. Two studies have reported and investigated the effects of CI therapy on gait and balance (Coker, Karakostas, Dodds, & Hsiang, 2010; Zipp & Winning, 2012) with positive outcomes noted in the areas of balance, speed, and velocity. Another study noted improvement in speech which was related to the intervention of CI therapy (Bibis, Cope, Forst, & Liu, 2008). Several studies have added a bimanual component to the CI therapy intervention with improved daily function reported (Aarts et al., 2012; Brandao, Mancini, Vaz, de Melo, & Fonseca, 2010; Cohen-Holzer, Katz-Leurer, Reinstein, Rotem, & Meyer, 2011). One study investigated the effects of a repeat course of CI therapy and reported that the benefits of CI therapy could be retained long-term with additional improvement resulting after a repeat course of CI therapy was performed (Charles & Gordon, 2007). In a more recent study conducted by Nordstrand
and Eliason the retention of functional skills following CI therapy was examined after a six year period (2013). The results of this study suggested that gains made in a CI therapy intervention could be retained over a six year period (Nordstrand & Eliasson, 2013). Each of these studies offered areas of interest for further future study on the topic of CI therapy.

Conclusion

The established CI therapy protocol was successfully implemented as an effective intervention in the clinical setting for this case patient. Reidy et al. suggested that outcomes such as these may indicate the potential of a paradigm shift in the use of rehabilitation resources away from the traditional long term care and toward short bursts of intensive therapy (2012). In this case, the intensive therapy approach helped this child with hemiplegia overcome a perceived plateau in upper extremity use. Further studies are needed to examine the impact of CI therapy on other areas of development such as gait, balance, and speech. Additional research is needed to further identify retention of the gained use and functional ability after the CI therapy intervention has been performed.
References


APPENDIX I: Pediatric Arm Function Test (PAFT)

PEDIATRIC ARM FUNCTION TEST (PAFT)
SCORE SHEET
CI Therapy Research Group
University of Alabama at Birmingham and
The Children’s Hospital of Alabama

Name __________________________ Examiner: __________________________

Date ______________  Diagnosis ______________ Pre Post F/U (Month) ______________
(Please circle one)

Group (circle):
Research: Experimental  Control  Crossover  ____weeks
Clinic: Initial  Brush-up  ____weeks

Affected UE: R  L

Parent Present: Yes  No
If the parent is present for pre-testing they must be present at post-testing.

Please indicate Administration number and Functional Ability score by circling the appropriate number.

Unilateral Tasks  Administration  Functional Ability  Setting

1. Reach above head  1 or 2  0 1 2 3 4 5

2. Reach at waist level  1 or 2  0 1 2 3 4 5

3. Reach across midline  1 or 2  0 1 2 3 4 5

4. Grasp ball  1 or 2  0 1 2 3 4 5

5. Carry ball  1 or 2  0 1 2 3 4 5

6. Release ball into cup  1 or 2  0 1 2 3 4 5

7. Pour ball out of cup  1 or 2  0 1 2 3 4 5

8. Throw ball onto target  1 or 2  0 1 2 3 4 5

9. This item has been dropped from test.

10. This item has been dropped from test.
## Pediatric Arm Function Test (PAFT) continued

<table>
<thead>
<tr>
<th>Unilateral Tasks</th>
<th>Administration</th>
<th>Time</th>
<th>Functional Ability</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Isolated finger use</td>
<td>1 or 2</td>
<td></td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>12. Remove big-knob puzzle piece</td>
<td>1 or 2</td>
<td></td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>13. Crayon grasp</td>
<td>1 or 2</td>
<td></td>
<td>0 1 2 3 4 5</td>
<td>Jumbo/Standard</td>
</tr>
<tr>
<td>14. Crayon use</td>
<td>1 or 2</td>
<td></td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>15. Grasp cracker-sized food</td>
<td>1 or 2</td>
<td></td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(e.g., animal or graham cracker, saltine)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Grasp small food item</td>
<td>1 or 2</td>
<td></td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(e.g., cheerio or raisin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Eat with a spoon</td>
<td>1 or 2</td>
<td></td>
<td>0 1 2 3 4 5</td>
<td>Thick handle/Standard</td>
</tr>
</tbody>
</table>

Circle type of chair used for Items 11-17: small rifton medium rifton regular chair

### UNILATERAL SECTION SCORES

1. **Amount of Use of Affected Arm**
   [Note. Only consider behavior on Items 1-4, 7, 12, 15, and 16 when completing this section. Items 5, 6, 8-11, 13, 14, and 17 are excluded because they have item-total correlations or test-retest reliability correlations < .3, which is the lower bound for a correlation of moderate size. Admin = Administration]
   a. Number of tasks on which affected UE used on Admin. 1
   b. Number of tasks on which affected UE used on Admin. 2
   c. Number of tasks on which affected UE not used
   d. Percent spontaneous use of affected UE on Admin. 1 (line a/total tasks tested; e.g., a/6)
      This quantity (i.e., Line d) is reported as the Limb Preference score.
   e. Percent tasks affected UE used on Admin. 2 (e.g., line b/2)
   f. Percent tasks affected UE not used (e.g., line c/2)

2. **Quality of Use of Affected Arm**
   [The note under the heading for section 1 does not apply here, i.e., scores on all tasks in the Unilateral section of the test are included here.]
   a. Sum of scores on tasks on which affected UE used on Admin. 1
   b. Sum of score on tasks on which affected UE used on Admin. 2
   c. Sum of lines a and b divided by total tasks tested (e.g., [a+b]/15)
      This quantity is reported as the Unilateral Functional Ability score.
Pediatric Arm Function Test (PAFT) continued

<table>
<thead>
<tr>
<th>Bilateral Tasks</th>
<th>Administration</th>
<th>Functional Ability</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Separate pull-apart toy</td>
<td>1 or 2</td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>19. Carry large ball (e.g., basketball)</td>
<td>1 or 2</td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>20. Throw ball into hoop</td>
<td>1 or 2</td>
<td>0 1 2 3 4 5</td>
<td>Hoop:</td>
</tr>
<tr>
<td>21. Place hat on head</td>
<td>1 or 2</td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>22. Put on boots (using hands)</td>
<td>1 or 2</td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>23. This item has been dropped from test.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Quadruped weight-bearing</td>
<td>1 or 2</td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>25. Crawling</td>
<td>1 or 2</td>
<td>0 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>26. This item has been dropped from test.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BILATERAL SECTION SCORES (Admin = Administration)**

1. **Amount of Use of Affected Arm**
   a. Number of tasks on which affected UE used on Admin. 1
   b. Number of tasks on which affected UE used on Admin. 2
   c. Number of tasks on which affected UE not used
   d. Percent spontaneous use of affected UE on Admin. 1
      (a/total tasks tested; e.g., a/5)
   e. Percent tasks affected UE used on Admin. 2 (e.g., b/2)
   f. Percent tasks affected UE not used (e.g., c/2)

2. **Quality of Use of Affected Arm**
   a. Sum of scores on tasks on which affected UE used on Admin. 1
   b. Sum of scores on tasks on which affected UE used on Admin. 2
   c. Sum of lines a and b divided by total tasks tested ([a+b]/7)
   
   *This quantity is reported as the Bilateral Functional Ability score.*

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TOTAL SCORE (Unilateral Plus Bilateral Scores; Admin = Administration)

1. **Amount of Use of Affected Arm**
   
   d. Percent spontaneous use of affected UE on Admin. 1
   
   
   
   
   
   e. Percent tasks affected UE used on Administration 2
   
   
   
   
   
   f. Percent tasks involved UE not used
   
   
   
   
   

Please note that Steps a-c in the Unilateral and Bilateral sections are not relevant here. Only Steps d-f listed immediately above are relevant for the calculation of the Amount of Use total score.

2. **Quality of Use of Affected Arm**
   
   c. Add line 2c from the Unilateral section and Line 2c from Bilateral section.
   
   
   
   
   Divide this sum by 2.  
   
   
   
   
   

   **This quantity is reported as the Functional Ability total score.**

Please note that Steps a & b in the Unilateral and Bilateral sections are not relevant here. Only Step c listed immediately above is relevant for the calculation of the Quality of Use total score.
Pediatric Arm Function Test (PAFT) continued

Functional Ability Scale:

0 – Does not attempt with UE being tested.

1 – Affected UE does not participate functionally; however, an attempt is made, or the less affected UE is used to move the UE being tested. In bilateral tasks, the more affected UE serves as a helper but through only part of the task. (Very Poor function)

2 – Requires assistance of the less affected UE, another body part, or therapist for minor readjustments or change of position; or requires more than two attempts to complete; or accomplishes very slowly. Movement is governed by synergy. In bilateral tasks, the more affected UE serves only as a helper. (Poor function)

3 – A moderate amount of synergy is seen (i.e., synergistic pattern observed with some involuntary posture or movement); and/or lack of control of movement; compensatory strategies with trunk/shoulder/elbows observed; or task performed somewhat slowly or with effort. In unilateral tasks, does not require assistance from other UE. (Fair function)

4 – Movement is slightly slower than normal; may lack precision, fine coordination, or fluidity. Some synergy may be present, but isolation of movement is predominant. (Good function)

5 – Movement appears to be normal.
APPENDIX II: Pediatric Motor Activity Log (PMAL)

PEDIATRIC MOTOR ACTIVITY LOG (PMAL) - 2-8 Years
SCORE SHEET
Pediatric CI Therapy Group
University of Alabama at Birmingham and
The Children’s Hospital of Alabama

Patient Name: ___________________________ Date: ___________________________

Parent’s Name: ___________________________ (Circle one) Pre During Post F/U

Day Wk/Mo

Group (circle):
Research: Experimental Control Crossover ______ weeks

Clinic: Initial Brush-up ______ weeks

Examiner: ___________________________

Please record the subject’s initial response; then after probing, record the final response for both HW and HO for all tasks. The HO rating scale should only be used during the pre- and post-treatment test administrations, as well as the day after the cast is removed and during follow-up. The full HW scale should be administered pre- and post-treatment, and TD 1, 6, and 11 (e.g., Mondays), as well as follow-ups. Successive halves of the PMAL should be administered on each of the remaining treatment days (e.g. Tuesdays- Fridays).

PART I

HO

Initial Final

HW

Initial Final

1. Eat finger foods ______ ______ ______ ______ If no, what do you think is the reason? (use code)

   (e.g., cookie, sandwich)

   Comments ___________________________

2. Pick up a small item ______ ______ ______ ______ If no, what do you think is the reason? (use code)

   (e.g., cheerio, raisin, small bead, or dice)

   Comments ___________________________

3. Self-feed with fork/spoon ______ ______ ______ ______ If no, what do you think is the reason? (use code)

   Comments ___________________________

Codes for recording “no” responses:
1. “Child used the stronger arm entirely.” (assign “0”).
2. “Someone else did it for the child.” (assign “0”).
3. “Child never has the opportunity to do that activity.” (assign “0” and ask caregiver to provide an opportunity).
4. “Child sometimes does that activity, but I did not see the child do it since the last time I answered these questions.” (carry-over last assigned score for that activity).
5. Child only did activity in therapy (carry-over last assigned score for that activity).
6. Impossible for child to do/developmentally inappropriate. (remove item from scoring; to get the mean score for the test, subtract this item from the number of total scores in denominator)

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### Pediatric Motor Activity Log (PMAL) continued

<table>
<thead>
<tr>
<th>PMAL Score Sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Brush teeth</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>5. Gesture (e.g., wave, blow kiss, peek-a-boo)</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>6. Push arm through sleeve of clothing</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>7. Turn a page in a book</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>8. Point to a picture</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>9. Reach for an object above head</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>10. Push a button or key (e.g., toy, doorbell, keyboard)</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>11. Steady self (e.g. use for postural support)</td>
</tr>
<tr>
<td>Comments</td>
</tr>
</tbody>
</table>

**Codes for recording “no” responses:**
1. "Child used the stronger arm entirely." (assign "0").
2. "Someone else did it for the child." (assign "0").
3. "Child never has the opportunity to do that activity." (assign "0" and ask caregiver to provide an opportunity).
4. "Child sometimes does that activity, but I did not see the child since the last time I answered these questions." (carry-over last assigned score for that activity).
5. Child only did activity in therapy (carry-over last assigned score for that activity).
6. Impossible for child to do/developmentally inappropriate.

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**Pediatric Motor Activity Log (PMAL) continued**

<table>
<thead>
<tr>
<th>PMAL Score Sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PART II</strong></td>
</tr>
<tr>
<td><strong>HQ</strong> Initial</td>
</tr>
<tr>
<td>12. Open a door or cabinet (push or pull)</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>13. Turn a knob (e.g., toy, door)</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>14. Use arm to move across floor (e.g., creep, crawl, scoot)</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>15. Take off shoes</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>16. Take off socks</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>17. Push large object across floor (e.g., box, chair, stool)</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>18. Hold a small ball</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>19. Throw a ball or other object</td>
</tr>
<tr>
<td>Comments</td>
</tr>
</tbody>
</table>

**Codes for recording “no” responses:**
1. “Child used the stronger arm entirely.” (assign “0”).
2. “Someone else did it for the child.” (assign “0”).
3. “Child never had the opportunity to do that activity.” (assign “0” and ask caregiver to provide an opportunity).
4. “Child sometimes did that activity, but I did not see the child since the last time I answered these questions.” (carry-over last assigned score for that activity).
5. Child only did activity in therapy (carry-over last assigned score for that activity).
6. Impossible for child to do/developmentally inappropriate.

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**Pediatric Motor Activity Log (PMAL) continued**

<table>
<thead>
<tr>
<th>PMAL Score Sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>20. Use a cylindrical object (e.g., crayon, marker) If no, what do you think is the reason? (use code) Comments</td>
</tr>
<tr>
<td>21. Hold a handle while riding, pulling, or pushing a toy (e.g., tricycle, shopping cart, baby buggy) If no, what do you think is the reason? (use code) Comments</td>
</tr>
<tr>
<td>22. Placement of object (e.g., puzzle piece, shape sorter) If no, what do you think is the reason? (use code) Comments</td>
</tr>
</tbody>
</table>

**Codes for recording “no” responses:**
1. “Child used the stronger arm entirely.” (assign “0”).
2. “Someone else did it for the child.” (assign “0”).
3. “Child never has the opportunity to do that activity.” (assign “0” and ask caregiver to provide an opportunity).
4. “Child sometimes does that activity, but I did not see the child since the last time I answered these questions.” (carry-over last assigned score for that activity).
5. Child only did activity in therapy (carry-over last assigned score for that activity).
6. Impossible for child to do/developmentally inappropriate.
PMAL Codes for recording “no” responses:

1. “Child used the stronger arm entirely.”
   (assign “0”)

2. “Someone else did it for the child.”
   (assign “0”)

3. “Child never has the opportunity to do that activity.”
   (assign “0” and ask caregiver to provide an opportunity)

4. “Child sometimes does that activity, but I did not see
   the child do it since the last time I answered these
   questions.”
   (carry-over last assigned score for that activity)

5. Child only did activity in therapy
   (carry-over last assigned score for that activity)

6. Impossible for child to do/developmentally
   inappropriate.
   (remove item from scoring; to get the mean score for the
   test, subtract this item from the number of total scores in
   the denominator)
Pediatric Motor Activity Log (PMAL) continued

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><strong>Not Used</strong> - Your child did not use the weaker arm at all for the activity.</td>
</tr>
<tr>
<td>1</td>
<td><strong>Very Poor</strong> - 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.</td>
</tr>
<tr>
<td>2</td>
<td><strong>Poor</strong> - 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.</td>
</tr>
<tr>
<td>3</td>
<td><strong>Fair or Moderate</strong> - The weaker arm was used to accomplish the activity, but the performance was very slow and/or involved great difficulty.</td>
</tr>
<tr>
<td>4</td>
<td><strong>Almost Normal</strong> - The weaker arm was able to accomplish the activity independently, but did so with some difficulty and/or inaccuracy.</td>
</tr>
<tr>
<td>5</td>
<td><strong>Normal</strong> - The weaker arm did the activity normally.</td>
</tr>
</tbody>
</table>