The Functional Composite Movement Scale: A Comparison of the Pre- and Post-Functional Movements of Participants in a mCIMT Pediatric Day Camp

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This research, submitted by Amy Bingen, Tamara Burt, and Michelle Gangi, has been approved and accepted in partial fulfillment of the requirements for the degree of Master of Science in Occupational Therapy from the University of Puget Sound

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Abstract

Objective: The purpose of this study was to examine the pre- and post- functional movements of 13 children with cerebral palsy, 4 to 12 years of age, who participated in a three-week mCIMT outpatient summer camp. The means of achieving the purpose was to develop a reliable tool to analyze pre- and post- photos of participants in the camp.

Method: The Functional Composite Movement Scale (FCMS) was composed and its reliability investigated. Photos were taken in nine functional end range positions and scored by the researchers, resulting in a quantitative measure of the movement required to achieve the position. Photos were randomly divided and each scored by at least two of the three researchers to check and strengthen reliability.

Results: The mean change in average pre- to post- FCMS scores, across all participants was positive ($\bar{x} = 0.06$). Eight participants had an increase in average FCMS scores, three participants had a decrease in average FCMS scores, and two participants showed no change. There was a statistically significant difference in pre- to post- group average FCMS scores for the overhead position, $t(12) = 2.483, p = .029$. This finding for the overhead position suggests that participants made functional improvements in shoulder range of motion, a movement that is critical to activities of daily living.

Conclusion: The FCMS shows potential as a clinical tool to assess changes in upper extremity function as a result of mCIMT intervention. The FCMS may help close the current gap in assessments by addressing composite movements of the upper extremity. Finally, the FCMS may be useful for assessing gain in functional movement that is generalizable to the performance of activities of daily living.
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Children with upper extremity motor impairments experience limitations in a multitude of occupational areas including self-care, school or work, and play or leisure activities that negatively impact their participation and independence (Eliasson, Krumlinde-Sundholm, Shaw, & Wang, 2005). These limitations are classified by the Occupational Therapy Practice Framework as occupations, and are aspects of function that occupational therapists address during treatment (American Occupational Therapy Association, 2014). Diagnostic groups experiencing such unilateral dysfunction include, but are not limited to cerebral palsy, stroke, brachial plexus palsy, and traumatic brain injuries.

Conventional treatments for individuals with upper extremity motor impairments attempt to draw attention to the involved hemiparetic side during the completion of activities, but they often only produce short-term gains (Dickerson & Brown, 2007). Unlike traditional treatments, constraint-induced movement therapy (CIMT) is a therapeutic intervention, delivered individually or in a group setting, wherein the unaffected upper extremity is physically constrained with the goal of promoting increased spontaneous use of the affected extremity. The scientific basis of CIMT is that the brain has plasticity and that neurological reorganization enables an individual to have more efficient use of the affected upper extremity (Dickerson & Brown, 2007). This idea that reorganization may be long lasting is further supported by Martin, Burtner, Poole, and Phillips (2008), who demonstrated that gains from CIMT were maintained two weeks after CIMT therapy ended. Motor function continued to increase over a three-month period following the use of CIMT in adults who experienced a cerebrovascular accident (Page, Murray, & Hermann, 2011). In a study of 16 children with cerebral palsy (CP), CIMT was
shown to promote children’s functional self-care skills and decrease caregiver assistance (de Brito Brandão, Gordon, & Mancini, 2012). These studies suggest that CIMT may produce long-lasting results and increased functional self-care skills, thus supporting additional research on the use of CIMT in occupational therapy. It is important to consider that although CIMT results may be long lasting, CIMT is more intensive than most traditional therapies, oftentimes delivered for multiple hours daily for many consecutive weeks.

There has not been a consensus in the literature regarding methodology to use with CIMT intervention. Due to this variability in methodology, outcome measures used to assess client changes are not consistent nor do they examine the complex movements undergone by the upper extremity. In a literature review, Sheehan (2012) noted that this inconsistency in outcome measures created difficulties in assessing and comparing outcomes of CIMT intervention. Sheehan (2012) suggested that future attention should be given to increase the consistency of such outcome measures.

**Background**

**Incidence of CP.** There are a variety of diagnoses that impact upper extremity function in children, including CP. The Centers for Disease Control and Prevention (CDC) defines CP as “a group of non-progressive, but frequently changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising at any time during brain development. The impairment of motor function might result in paresis, involuntary movement, or incoordination” (CDC, 2006, para. 15). The prevalence of CP was 3.6 per 1,000 in 1996 and 3.1 per 1,000 in 2000 (CDC, 2006, para. 4). According to Boulet, Boyle, and Schieve (2009), 40.8% of children with CP are limited in their ability to crawl, walk, run, or play, while 29.3% require assistance with personal care. In addition, 15.5% reported a health status of fair or poor and 10.3% required
home health care in the prior year. The accumulated lifetime costs of children born in the United States in 2003 with CP will total approximately $11.5 billion with an average lifetime cost per person of $921,000 (CDC, 2004, para. 1). This amount justifies the use of “effective primary and secondary prevention measures” by targeting risk factors during high-risk pregnancies and providing early intervention to children with CP (CDC, 2004, para. 1). These prevention and intervention programs targeting CP, if successful, improve the occupational well-being of the child, mitigate the caregiver burden, and reduce the financial impact on families and third party payers.

**Diagnosis of CP.** Clinical symptoms of CP vary from person to person dependent upon the area of damage to the motor center or other areas of the brain, but may include abnormality in muscle tone; uncoordinated movement or control; impaired reflexes or balance; poor posture; as well as fine, gross, and oral motor impairments. The most notable of these symptoms is muscle tone which may be either hypertonic or hypotonic, or a combination. Abnormal muscle tone leads to limbs that are flaccid, hypotonic, perpetually extended, contracted, or moving constantly in jerking or rhythmic patterns of spasticity. Symptoms of CP impact function in multiple areas depending upon severity and topographical distribution and may affect feeding, mobility, self-care, and other basic activities of daily living.

**Effect of CP on participation.** Decreased upper extremity function has widespread effects on children at all levels of the World Health Organization’s International Classification of Functioning, Disability, and Health, including activity and participation levels (Martin et al., 2008). Specific areas of functional activity impacted in children with unilateral CP are object and social play, self-care, and educational activities (Case-Smith, DeLuca, Stevenson, & Ramey, 2012). Secondary effects of CP such as spasticity, contractures, stiffness, failure to grow, and
visual and motor limitations can delay development. The limitations in mobility can decrease a child’s opportunities to explore the environment. According to Case-Smith, Frolik Clark, and Schlabach (2013), this limitation in independent interaction with toys, objects, and environment can lead to passivity and social isolation. Dysfunction in occupations secondary to the effects of CP may further lead to activity limitation, decreased participation, and ultimately dissatisfaction for the children and their families (Van Zelst, Miller, Russo, Murchland, & Crotty, 2006).

Cerebral palsy remains a significant concern for occupational therapists, who focus not only on the motor functions of the child but also on the effect of dysfunction on occupational performance.

**Traditional treatments for CP.** Dickerson and Brown (2007) reviewed conventional physical and occupational therapy treatments for CP, which focus on increasing awareness of the hemiparetic side through incorporation of the limb into bimanual activities. While these treatments have been shown to produce gains, the authors asserted they are only short-lived because clients compensate for their affected side as opposed to incorporating it into daily activities. This suppression, or learned non-use of the affected extremity after insult to the brain, can lead to decreased motor function (Taub, 1980). Dickerson and Brown (2007) furthermore expressed concern that when traditional treatments enabled patients to compensate for their affected arm, learned non-use occurred and interfered with improving sensorimotor function in the affected extremity. Occupational therapy treatments such as bimanual or repeated unilateral tasks often require verbal and physical cues to prompt the child to use the affected extremity, a frustrating requirement for both the therapist and the child because it can result in incomplete or unsuccessful completion of the task (Aarts, Jongerius, Geerdink, van Limbeek, & Geurts, 2010).

There are currently no cures or successful prevention methods for CP. Spasticity in
clients is addressed by medications or, in some cases, costly surgical intervention to permanently reduce spasticity. Splinting and casting may be utilized to alleviate unwanted movement and posturing or aid in mobility and function. Orthopedic correction for joint deformities or muscle length is utilized for improved function as well as pain reduction.

**Role of occupational therapy with individuals with CP.** Occupational therapists contribute to the multidisciplinary treatment team by partnering with the client to treat decreased function. The focus of intervention includes areas of fine motor abilities, particularly in the use of the upper extremity for activities of daily living (ADL). According to Patel (2005) occupational therapy is effective in improvement and maintenance of adaptive fine motor activities for children with CP. Occupational therapy also targets play, self-care, and learning through the use of adaptive equipment, orthotics, mobility devices, modification of the environment, as well as facilitation of attention and information processing. When used in conjunction with other interventions, occupational therapy increases client function and participation leading to increased independence and ultimately improved occupational engagement. A systematic review by Majnemer et al. (2008) indicated there were very few studies investigating the impact of CP on participation in leisure activities among children and adolescents. They conducted an analysis of 67 school-aged children with CP to assess their participation level and enjoyment of leisure activities. Their findings supported the use of leisure activities in rehabilitation as a means to increase independence in mobility and hand function. Majnemer et al. (2008) recommended that the improvement of communication skills, social development, and adaptive strategies should be given high priority in therapy to promote functional success, suggesting that using the intrinsically motivating nature of leisure activities with children to guide treatment would help promote favorable outcomes in occupational
participation. The authors further asserted that active engagement in meaningful activities is necessary for personal autonomy and life satisfaction and essential for rehabilitation programs and services and will ultimately lead to an improved life for children with CP and their families (Majnemer et al., 2008).

**Constraint-Induced Movement Therapy.** Alternative treatments, such as CIMT, aquatherapy, myofascial release, Doman-Delacato, biofeedback, electrical stimulation, BOTOX injections, Baclofen-oral, and hippotherapy have been studied as intervention approaches to be used for individuals with CP. CIMT, a deviation from traditional therapies used to treat hemiplegia, is an alternative treatment for CP aimed at promoting active functional use of the involved upper extremity and reversing the effects of developmental disregard by forcing use of the affected extremity through constraint of the unaffected or lesser affected upper extremity. Developmental disregard, is similar to the term learned non-use, but results from damage to the central nervous system, which occurred early in development. Developmental disregard often occurs in children with hemiparesis or unilateral motor involvement resulting from CP, and is due to the asymmetrical development and therefore decreased use of the affected extremity (Houwink, Aarts, Geurts, & Steenbergen, 2011). Children with hemiplegia can acquire developmental disregard as a result of minimal use of their affected upper extremity (Wu, Hung, Tseng, & Huang, 2013). According to a neuropsychological model presented by Houwink et al. (2011), it is possible that using the affected extremity in daily routines demands high attention, which may hamper its use and potentially result in developmental delay. Due to the CP focus of this paper, we will henceforth use the term developmental disregard.

Traditional CIMT intervention consists of (1) restriction of movement of the unaffected or lesser affected upper extremity by constraining the limb in a resting hand splint, sling, or cast
for approximately 90% of waking hours for 2 weeks, and (2) intensive training of the affected arm by a procedure termed *shaping* for approximately 6 hours per day for 10 weekdays (Taub et al., 1993). Shaping is defined as use of the impaired upper extremity during tasks of increasing difficulty, with an outcome goal of improved motor function and voluntary use of the affected extremity. Improvements made during the shaping process are encouraged with immediate positive feedback (Uswatte, Taub, Morris, Barman, & Crago 2006).

The traditional form of CIMT was first found to be beneficial for the treatment of adult patients with hemiplegia resulting from stroke (Taub et al., 1993). Benefits included satisfaction with performance and increased participation in real-life activities relevant to participants’ daily lives (McCall, McEwen, Colantonio, Streiner, & Dawson, 2011), improved motor function (Treger, Aidinof, Lehrer, & Kalichman, 2012), increased spontaneous use of the affected extremity (Schaechter et al., 2002), decreased level of disability, and increased use of the affected limb in daily activities (Shi, Tian, Yang, & Zhao, 2011). The reason behind these improvements in motor function post-cerebrovascular accident (CVA) is that the neuroplasticity of the human brain allows for recruitment and activation of different neural pathways, outside the lesioned area, to carry out previously impaired but desired movements (Schaechter et al., 2002). According to Schaechter et al. (2002), increased motor function post-CVA as a result of CIMT was associated with increased activation of motor cortices as evidenced on functional MRI screens. It is hypothesized that through repetitive use of the impaired upper-extremity, activation of neural connections within the brain increases, and connections for motor function are strengthened. Supporting research shows that CIMT post-CVA resulted in increased cortical activation of the peri-infarct region (Levy, Nichols, Schmalbrock, Keller, & Chakeres, 2001), as well as increased ipsilesional cortical activation within the primary motor cortex (Laible et al.,
These studies suggest the brain can reorganize sensory and motor functions, perhaps through growth of new neural pathways around the lesioned area. Although the exact location of cortical reorganization is unknown, many researchers have concluded that this reorganization is the mechanism for improved motor function in adults.

According to Berger (2007), the opportunity for cortical reorganization may be even greater in children due to the overproduction of neural connections within the brain. As children learn and grow, neural connections that are used often are reinforced, while those connections not being used are eliminated through a process called pruning. These malleable characteristics of the brain allow children to learn and develop at a rapid pace, whether it is motor learning or language development (Berger, 2007). For this reason, CIMT continues to attract research interest as a treatment option for children with hemiparesis.

Constraint-induced movement therapy has been shown not only to be effective based on immediate post-treatment measures, but also on long-term follow-up measures (Dickerson & Brown, 2007; Nordstrand & Eliasson, 2013; Taub, Ramey, DeLuca, & Echols, 2004). According to Dickerson and Brown's (2007) single-subject study, activity and participation levels had continued to increase when the participant, a 24-month-old with chronic hemiparesis secondary to a prenatal stroke, was measured three months post-CIMT intervention. Taub et al. (2004) found that outcome measures such as acquisition of new motor skills and increased spontaneous use of the affected upper-extremity were maintained six months after the CIMT intervention in children with hemiparesis resulting from CP. A follow-up study conducted six years post-CIMT (Nordstrand & Eliasson, 2013), reported an increase in grip strength and maintenance of speed and performance scores of young adults with unilateral CP, however, a slight decline in quality of movement was observed.
**Modified CIMT & camp models.** A modified version of the original CIMT protocol (mCIMT) is often used with children, but particular methods vary among studies. Hoare, Imms, Carey, and Wasiak’s (2007) Cochrane review reported differences in the frequency or duration of the daily intensive therapy, and the overall length of the intervention in studies using mCIMT. Additional variations included type of constraint for the unaffected upper extremity, and the nature of adjunct therapy (Wallen et al., 2011).

Modified constraint-induced movement therapy, provided in a camp model, has been used by several researchers as a way of administering this treatment in a child-friendly way by using activities that will engage the children for a long period of time (Bonnier, Eliasson, & Krumlinde-Sundholm, 2006; Eliasson et al. 2005; Eliasson, Shaw, Pontén, Boyd, & Krumlinde-Sundholm, 2009).

Bonnier et al. (2006) had nine participants aged 13 to 18 years old participate in a day camp mCIMT study that used a glove-like restraint on the affected hand to be worn while they engaged in daily and recreational activities such as meal preparation and basketball. The constraint was worn for seven hours per day for five days during the two-week summer camp. Results demonstrated that restraint of the non-affected hand improved dexterity, coordination, and precision of movement in the hemiplegic hand of participants, although two participants did not maintain these gains at follow-up (Bonnier et al., 2006).

Eliasson et al. (2009) used a two-week day camp model to provide mCIMT with and without intramuscular botulinum toxin type A (BoNT-A) injections for children with congenital hemiplegia. Standardized assessments used included the Jebsen–Taylor Hand Function Test (excluding the writing test; Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969) to assess dexterity, the Melbourne Unilateral Upper Limb Assessment (Randall, Johnson, & Reddihough,
1999) to measure reach, grasp, release, and manipulation, and the Assisting Hand Assessment (Krumlinde-Sundholm & Eliasson, 2003) to measure the effectiveness of using the impaired hand during bimanual tasks. Results showed a significant improvement on the Jebsen-Taylor Hand Function Test (Jebsen et al., 1969) in the areas of speed and dexterity, but no improvement in quality of movement on the Melbourne Unilateral Upper Limb Assessment (Randall et al., 1999), and no difference in bimanual performance on the Assisting Hand Assessment (Eliasson et al., 2009). Participants did state they enjoyed the camp because they were able to make friends who had similar conditions, helping them understand they were not alone (Eliasson et al., 2009; Krumlinde-Sundholm & Eliasson, 2003).

Eliasson et al. (2005) conducted a mCIMT camp with 21 children aged 18 months to four years, and a control group of 20 children. Treated participants wore a constraint glove for two hours per day over two months (a shorter time per day than in many CIMT and mCIMT studies). The Assisting Hand Assessment was used to determine how effectively the participants used their affected hand during a bimanual task. Although the results of the study suggested that children in the mCIMT group had improved use of their affected hand compared to the control group, the Assisting Hand Assessment did not measure how well the children could use their whole affected upper extremity in functional tasks.

Gilmore, Ziviani, Sakzewski, Shields, and Boyd (2010) interviewed 32 children who participated in a circus-themed mCIMT day camp to gain their insights into the treatment. The participants attended camp for six hours per day for five days, over a two-week session. Children reported that the constraint was uncomfortable and interfered with activities such as eating, but they liked the camp format and thought it was beneficial to be around other children with similar functional impairments, motivating them to incorporate their affected side into daily tasks.
**Limitations in current literature.** These studies give promising support that mCIMT delivered in a camp model incorporating peer interaction and play into treatment with a deeper goal of improving functional use of the affected upper extremity in daily tasks may lead to beneficial therapeutic gains. Multiple standardized and non-standardized assessments, however, require extensive time for the therapist to administer and may be overwhelming for pediatric clients. Additionally, many of the assessments used focus on use of the hand rather than the function of the affected upper extremity as a whole. Understanding the child’s functional abilities with respect to his or her use of the affected upper extremity will allow the therapist to better direct mCIMT intervention.

Both CIMT and mCIMT show the potential to be effective in treating developmental disregard of the upper extremity, particularly in a summer camp model for children incorporating play and leisure activities with their peers. However, CIMT methods vary greatly, and no one single best practice method has yet been agreed upon. Variability in methods and outcome measures across studies resulted in decreased generalizability. In a systematic literature review conducted by Sheehan (2012), 21 CIMT studies were examined, in which 40 different outcome measures were used and 17 were used in more than one study and were chosen for review. Sheehan (2012) recommended that future outcome measures should address the Areas of Occupation, Performance Skills, and Body Function domains of the Occupational Therapy Practice Framework (American Occupational Therapy Association, 2008). The assessments that Sheehan (2012) recommended for future use with mCIMT were the ABILHAND-Kids (Arnould, Penta, Renders, & Thonnard, 2004), the Melbourne Assessment of Unilateral Upper Limb Function (Randall et al., 1999), and the Quality of Upper Extremity Skills Test (QUEST; DeMatteo et al., 1992) as well as utilizing a dynamometer (Sammons Preston Rolyan, 2003) to
measure grip strength. However, it is important to note that none of these assessments adequately fulfilled criteria for ease of use within the context of mCIMT summer camps due to necessary training or length of time needed for administration. In addition, some do not include the entire age range of children.

According to Phipps and Roberts (2012), the diagnosis of CP alone did not predict impact on self-care, mobility, and social function but the level of severity and gross motor and fine motor dysfunction did. Phipps and Roberts’ (2012) study supports the need for assessment of the extent that CP impacts motor ability and related function. This places an even higher importance on the need for definitive outcome measures for motor function and its relationship to functional activities. Sheehan (2012) concluded that of the outcome measures studied, those for body function were the least reliable and valid. Sheehan (2012) went on to say that the highest scoring tool for this category was the dynamometer. However, all outcome measures for this category were not concurrently valid with those related to areas of occupation and performance skill measures. The author suggested that this was due to difficulties with measuring the more complex joints of the upper extremities. Sheehan (2012) suggested that future research should consider the usability of outcome measures based upon still photos.

**Functional Composite Movement Scale.** The current authors created the Functional Composite Movement Scale (FCMS) as an assessment that measures the outcome of integrated movement of the affected upper extremity. It reflects nine positions required for adequate engagement in occupational tasks. The FCMS uses a simple and objective zero to five scale that quantifies how well the child achieved the desired position. Part of the uniqueness of this scale is that it allows the therapist to note if visible compensation was used in other parts of the body in the process of attempting the desired position. The FCMS provides a quantitative measure to
assess physical changes and compensation. A search of the current literature did not result in locating any other tools or assessments that utilize photography as an outcome measure or incorporate compensation as part of the measurement.

The purpose of this study was to examine the pre- and post- functional composite movement measurements of 13 children with cerebral palsy, 4 to 12 years of age, who participated in a three-week mCIMT outpatient summer camp. The means of achieving the purpose of this study was to develop a reliable tool to analyze pre- and post- photos of participants in the camp.

**Method**

**Research Design**

This study used a quasi-experimental research design, analyzing retrospective pre-test and post-test data of one group using a measurement tool created by the authors. The use of a quasi-experimental design allowed researchers to use available retrospective data and compare individual outcomes pre- and post- intervention. The analysis specifically examined functional composite movement data collected before and after a mCIMT summer camp held in 2012. The children were divided into two camp groups based on age, but received identical mCIMT interventions, so their data were pooled for analysis.

**2012 mCIMT Summer Camp**

The 2012 mCIMT summer camp examined in the current study had unique features compared to other camp models in the literature. First, the camp was three weeks in duration, from Monday through Friday, during which the clients participated in three hours of intense, continuous group activity. Children were instructed to continue wearing the constraint for three hours each day after the camp, for a total of six hours per day. Second, the constraint spanned
from mid-humerus to the fingertips and was a removable, flexible fiberglass cast. Finally, the camp provided a one to one ratio of “therapy buddies” to participants. Therapy buddies were occupational therapy students from the University of Puget Sound in Tacoma, Washington who had completed one year of graduate education in occupational therapy. This one-to-one ratio ensured participants received constant support to keep them engaged in all activities during the camp. Upper extremity length, girth, strength, and passive range of motion outcomes for each child were measured and recorded by an occupational therapist one to three weeks before the camp and again on the last day of the mCIMT intervention. Additionally, each participant was photographed during the assessment phase pre- and post-camp in nine positions that represent functional movements of the upper extremity. These composite movement positions are of particular interest to this study because they account for estimations of functional ability to engage both upper extremities in daily tasks, as well as demonstrating compensatory movements of the trunk, neck, and/or head in achieving these positions.

Participants

Retrospective data was examined from 13 children, ages 4 to 12 years, who participated in a mCIMT summer camp at the Children’s Therapy Unit of Good Samaritan Hospital (Puyallup, WA) in the summer of 2012. Participants were referred to the camp by local physiatrists and occupational therapists. All participants had been diagnosed with cerebral palsy and presented with predominantly unilateral impairment. Twelve participants were diagnosed with hemiplegia and one was diagnosed with spastic triplegia; all 13 had some volitional movement in the affected extremities, henceforth called hemiparesis. Participation in other forms of rehabilitation therapy before, during, or after the camp was neither controlled nor recorded. One participant had received prior constraint-induced movement intervention. Additionally, in
order to be enrolled in the camp, each participant was required to (1) have a “good” ability to
demonstrate behaviors conducive to group participation, (2) show no significant behavior issues,
(3) demonstrate the ability to understand two-step verbal directives, (4) demonstrate the ability to
fully participate in camp activities, and (5) be willing to participate in three additional hours of
activity at home wearing the constraint. Children with uncontrolled seizures were excluded from
the camp.

**Intervention**

Two, three-hour sessions were held during the camp, one in the morning (9:00 a.m. to
12:00 p.m.) for 4 to 7 year olds \( n = 7 \), and the second in the afternoon (1:00 p.m. to 4:00 p.m.)
for 8 to 12 year olds \( n = 6 \). The camp was three hours a day, five days a week, for three weeks.
A licensed occupational therapist directed the camp daily with additional assistance from a
second occupational therapist on Mondays, Wednesdays, and Fridays. Each participant was
paired throughout the camp with a “therapy buddy.” The camp began each day with gross motor
activities such as balloon volleyball, sword fighting, and throwing activities. Shoulder movement
with elbow flexion and extension was emphasized through activities including rope pull with
scooter boards, bean bag toss, and a bucket blast game (bucket blast also involved internal
rotation of the upper extremity, and bringing the hand to the buttock). Fine motor activities
included spoon and egg carry, craft activities with gluing pieces onto a target design, self-
feeding, including bringing food to mouth, drinking from a small cup, and ended with locating
items in the pirate treasure box filled with rice. Therapeutic intervention was active, play-based
functional movement focused on increasing use of the affected upper extremity.

A removable, flexible, fiberglass cast that spanned from fingertips to the mid-humeral
level was custom-made for each participant. The cast was worn for the entire three-hour session.
Participants were instructed to wear their constraint for an additional three consecutive hours each day immediately after camp, except during toileting, and were given a packet of suggested home activities. They were allowed to remove the constraint during the last three camp sessions, which consisted of bilateral upper extremity activities. All participants reported wearing the constraint for three additional hours each day following the three-hour camp session, however, not always consecutively.

**Outcome Measures**

Pre- and post-measurements were exclusively collected by the camp director, Lucretia Berg, MSOT, OTR/L, with the exception of the pre-evaluation measurements of two participants, which were collected by a second camp occupational therapist. Initial measurements took approximately 90 minutes and were collected between one and three weeks prior to the start of the intervention. Post-measurements took approximately 30 minutes and were collected for all participants on the last day of camp. Outcome measures were passive range of motion (PROM), gross grasp and lateral pinch strength, upper extremity length and girth, and photos of nine functional end range composite movements. Functional goals, if reported by parents or participants, were also documented (L. Berg, personal communication, March 27, 2013). For the purpose of the current study, only the photos illustrating functional end range composite movements were analyzed due to their resemblance to movements necessary for functional tasks and their potential ability to reflect the child’s overall ability to increase occupational participation.

The procedure for taking the photos of functional end range composite movements was established by Berg, and remained consistent for all participants. Participants were directed into nine specific positions, seven of which were based upon positions depicting function and motion.
of the brachial plexus and full active range of motion of the upper extremity (Nath, Somasundaram, Melcer, Bala, & Wentz, 2009) and two additional positions added by Berg that demonstrated common functional movement impairments in children with CP (L. Berg, personal communication, March 27, 2013; see Appendix A). The nine photographed positions reflect functional movement that can be generalized into occupational performance and include overhead, trumpet, behind head, over belly, behind back, out to sides, arrest, arms to sides and forearm supination (see Appendix A). For example, hand to back of neck position is relevant to hair care, hand to small of back reflects position required for dressing tasks, and hand to mouth positioning relates to eating.

Photographs were taken in a private exam room free of distractions. The participant was positioned in front of a standard white, one-inch grid sewing board hung on the wall with its baseline (of 0) 17 ½ inches from the floor. Participants stood with their heels against the wall in front of the board. A Nikon camera was used to photograph participants, centered with the grid on a tripod 84 inches away from the wall and the height of the camera was varied according to each participant’s height. The nine positions were modeled by the occupational therapist conducting the assessment. If the participant could not independently get into the position, hands-on guidance by the occupational therapist was used, but the participant was requested to independently hold the maximally attained position for photography. Photos were stored in PDF format.

At the time that the photographs were taken, no method had been established to quantify the participants’ functional end-range composite movement in each of the nine positions. Therefore, the FCMS was developed over a six month period to analyze retrospective pre- and post- still photos of participants in nine functional end range positions, resulting in a quantitative
measure of the movement required to reach the position observed in each photograph. The FCMS is based on a 0 to 5 scoring system with pre-determined criteria (see Appendix B). The scale for each position was designed to not only reflect similarity to functional movement, but also to clearly demarcate differences between numerical scores by specifying clear criteria for specific joint positions of the upper extremity being measured that are required for each of the nine positions. In addition to the numerical scale, movement compensation information is recorded for each position that meets the criteria for scores between the 2 to 5 range. Whole numbers (2, 3, 4, & 5) indicate that no visible compensation in the trunk or shoulder girdle is present in the position (e.g., neck flexion, shoulder height discrepancy, lateral or forward flexion of the trunk), whereas a 0.5 score deduction indicates visible compensation in one of these areas. For example, if a participant meets the upper extremity positioning criteria for a score of 5, but visible trunk lateral flexion is observed, he or she receives a score of 4.5 for that position. A participant’s pre-intervention and post-intervention scores are to be totaled separately, with a maximum possible score of 45 for each.

Draft criteria for the FCMS were refined and revised through inter-rater reliability checks conducted by the three research team members using 90 sample photos of 10 individuals (not related to this study) in the 9 functional positions. When discrepancies between researcher ratings occurred, the researchers viewed each discrepancy as a potential weakness in the wording of the scale criteria or the criteria itself. Evolution of the FCMS occurred based on these ongoing inter-rater reliability checks and discussions among the research team and occupational therapy faculty. For the purpose of this study, small-scale inter-rater reliability for the final draft of the FCMS was determined by taking an additional five sets of non-participant photos. Each of the three researchers separately scored the photos, and criteria was modified until the researchers
came within greater than 80% agreement before analyzing the actual data from the mCIMT camp. Future development of this tool will require more extensive inter-rater reliability and validity investigations, and the development of precise criteria for photographing the nine positions.

**Procedure**

The authors received approval from both the MultiCare Health System and University of Puget Sound Institutional Review Boards. Written consent to use the photos for future research studies was granted by the parents of the participants prior to the start of the mCIMT camp; written, verbal, or visual (nodding) assent for use of the photos was also granted by each participant (see Appendix C.) The photos remained in electronic format for analysis and did not include participant names, but were identified by a letter and pre- post- designation. To ensure privacy for the participants, all identifiable aspects of the face and torso were covered with a black circle prior to being distributed to the researchers. Prior to analysis, Berg electronically filed the photos into pre- and post- measure categories and placed them on a password protected flash drive. The photos were randomly divided among the three researchers for scoring; each set of nine photos took ten or fewer minutes to score. Each photo was scored by two of the three researchers to ensure reliability of the measure (all photos assessed by Researcher 1, were also assessed by Researcher 2; all photos assessed by Researcher 2 were also assessed by Researcher 3; and all photos assessed by Researcher 3 were also assessed by Researcher 1). When disagreements between individual picture scores arose, the researcher not involved in that specific analysis was brought in as a tiebreaker. Researchers had a 93.6% agreement rate within a window of 1.0 on the FCMS. The photos were stored electronically on the password-protected personal computers of the primary researchers.
Data Analysis

Data analysis consisted of calculating the FCMS scores for pre- and post- photos, and entering the scores into SPSS to statistically assess the data for changes. The FCMS uses ordinal data; the dependent $t$-test was used to determine if there were statistically significant changes between the mean of the group’s combined average pre-FCMS scores and the mean of the group’s combined average post-FCMS scores. This test was used to determine whether statistically significant changes occurred between group pre- and post- scores for the average of each individual FCMS position. Dependent $t$-tests were run to investigate the possible effect of demographic data on FCMS score changes. Subgroups were based on age (session), affected side, and sex. Changes were examined separately for pre- to post- average FCMS scores for the morning session, afternoon session, females, males, and right or left affected side. Independent $t$-tests were used to analyze differences between the mean change in FCMS score combined average scores for the morning vs. afternoon sessions, females vs. males, as well as for right vs. left affected side.

Due to missing data, pre- and post- average scores were calculated for each participant. Position number eight was eliminated from data analysis due to eleven missing photos.

Results

Demographics

The average age of all 13 participants was 7.85 years, and participants ranged in age from 4.5 to 12.4 years. The average age of participants in the morning session ($n = 7$) was 5.2 years, while the average age of participants in the afternoon session ($n = 6$) was 10.0 years. Of the 13 participants, 54% ($n = 7$) were affected on the left side; four of these individuals were in the morning session. Exactly 54% of participants ($n = 7$) were males, four were in the morning
session. Participant L had a diagnosis of triplegia, while the remaining 12 participants were diagnosed with hemiplegia. Demographic information is reported in Table 1.

**Findings**

Table 2 shows average FCMS scores and overall differences in FCMS scores by participant, and reveals eight participants had an increase in average scores, three participants had a decrease in average scores, and two participants showed no change in average score when considering individual changes in pre- to post- average scores on the FCMS. Participant L demonstrated the largest improvement in average FCMS increasing from a pre-score of 3.56 to a post-score of 4.0, a difference of +0.44, which reveals the ability of this participant on average to achieve more of the desired positions without using compensation. Contrarily, participant H had the largest decrease in average scores, as she went from an average FCMS pre-score of 3.81, to an average post-score of 3.56, a difference of -0.25 (see Table 2). This decrease in FCMS means the participant had to use more compensation to achieve the positions at the conclusion of the camp. The oldest participant, M, began with the highest average FCMS pre-score ($\bar{x} = 4.25$), and ended with the highest average post-score ($\bar{x} = 4.44$).

The mean change in average pre- to post- FCMS scores, across all participants was positive ($\bar{x} = 0.06$), with the average FCMS score of all participants improving from a pre-score of 3.65 to a post-score of 3.71 (see Table 3). The overall change in average FCMS scores for participants in the afternoon session ($\bar{x} = 0.08$) was greater than the average change in FCMS scores for participants in the morning session ($\bar{x} = 0.05$); however, this difference between sessions was not statistically significant. The average pre-score for the morning session was 3.59, with an average post-score of 3.64. For the afternoon session, the group had an average pre-score of 3.72, which increased to 3.80 for their average post-score. There was no difference in
combined average FCMS pre- to post- scores for females ($\bar{x} = 0.06$) versus males ($\bar{x} = 0.06$). Females started with an average pre-score of 3.71, and ended with an average post-score of 3.77, while the males were at 3.60 for an average pre-score and increased to 3.66 as their average post-score. The males had an average post-score ($\bar{x} = 3.66$) that was lower than the females average pre-score ($\bar{x} = 3.71$), although these differences were not statistically significant (see Table 3). Participants who were affected on the left side had a greater average gain in pre- to post- FCMS scores ($\bar{x} = 0.11$) than those affected on the right side ($\bar{x} = 0.00$), however this difference was not statistically significant (see Table 3). Participants affected on the left side had a lower average post-score ($\bar{x} = 3.71$), than the average pre-score for the participants affected on the right side ($\bar{x} = 3.72$), although the right affected participants had no changes in their average FCMS score from pre- to post- intervention. When considering pre- to post- changes for each FCMS position, there was an overall increase in scores for positions 1, 2, 5, 6, and 7 (see Table 4). Data analysis resulted in one statistically significant finding among all comparisons when an alpha level of .05 was used (see Table 4). There was a statistically significant difference in pre- to post- group average FCMS scores for the overhead position, $t(12) = 2.483, p = .029$. While not statistically significant, the out to sides position had the second lowest $p$ value when considering pre- to post-group average FCMS scores $t(11) = 2.10, p = .060$. The overhead position and the out to sides position each required full elbow extension against gravity.

**Discussion**

Due to the high prevalence of CP (CDC, 2006, para. 4) and the associated impact on function (Boulet et al., 2009; Case-Smith et al., 2012; Martin et al., 2008), the ability to assess gains in functional movement of the upper extremity will assist in guiding treatment interventions for this population, which may lead to a decrease in caregiver burden and a
reduction in the overall financial impact of CP. CIMT has been found to be a successful intervention for the treatment of adult patients with stroke-induced hemiplegia (Taub et al., 1993) and mCIMT is becoming more widely used for addressing the impact of CP in the pediatric population. However, as discussed by Sheehan (2012), current assessments are not adequate to record the complexities of the combined movements of the joints of the upper extremity. Sheehan (2012) suggested that outcome measures for mCIMT should reflect Areas of Occupation, Performance Skills, and Body Function domains of the Occupational Therapy Practice Framework. The FCMS demonstrates potential to close the current gap in assessments by addressing composite movements of the upper extremity and considering compensation in an individual’s physical movement. Additionally, it shows promise at assessing gains in functional movement resulting from treatment that may be generalized to ADL.

When analyzing session (age), affected side, and sex, participants tended to fall into equally sized subgroups, allowing for comparable outcomes. The findings from the overhead position resulted in a statistically significant average pre- to post- gain, suggesting that participants made functional improvements in shoulder range of motion, a movement that is a critical component to many ADL/IADL that are a part of a child’s daily life, such as hair washing, upper body dressing, and raising the hand in class. A positive change of 0.5 on the FCMS indicates the ability of an individual to achieve a desired position without visible compensation. This type of gain was noted for the overhead position, indicating an increase in the participants’ ability to complete overhead functional activities with normal movement patterns. Normalcy of functional movements may increase acceptance by peers, increase self-confidence, and independence in ADL.

The overall increase in scores for positions 1 (overhead), 2, (trumpet), 5 (behind back),
6 (out to sides) and 7 (arrest) may have been a result of the frequency that these motions were used in daily routines during the camp or as a result of these movements being emphasized in camp activities. Of particular note, activities during camp which required full elbow extension against gravity may have influenced the low $p$ values of the overhead and out to side positions. Regular practice using the affected side in daily functional activities may increase the tendency for an individual to perform activities with normal movement patterns. Position 3 (behind head), position 4 (over belly), and position 9 (forearm supination) resulted in slight negative changes, potentially due to the fact that set criteria were not used to define each desired position when taking pre- and post-photos. These slight nuances in positioning variation highlight potential sensitivities of the FCMS scale itself. For example, the FCMS scale requires at least slight elbow flexion to achieve a full score for forearm supination (position 9). It is possible that had some children been asked to increase elbow flexion for the photograph, a higher score could have been awarded; therefore better reflecting their true abilities.

A lack of statistical significance for difference in gains for those in the morning session versus those in the afternoon session indicates that the structure of this particular mCIMT camp was not unequal for both of the age groups represented. The negligent difference in gains based on sex reveals that the camp was no less effective for male participants than for female participants as shown by the FCMS scores.

Although the difference in gains noted for children affected on their left side versus those affected on their right was not statistically significant, the difference in change is worthy of mention. The scores for children affected on the right remained relatively the same from pre- to post- measurements; however, children affected on the left side had 34.6 times the increase in scores as children affected on the right. We hypothesize that this may be due to living in a right-
handed world, which forces all people to use their right upper extremities more than their left during daily activities and in the community. Children who are affected on their right side may have more practice incorporating their affected extremity into daily activities than those children affected on their left, because there is much less environmental press to use the left extremity.

**Implications for Occupational Therapy**

This study has implications for occupational therapists who are interested in using mCIMT in a clinical setting. At the time of this pilot study, there were no other studies that used photography in conjunction with mCIMT intervention. The use of photography is a promising way to monitor progress over the course of a mCIMT intervention providing that a proper protocol is established prior to data collection. Photography is a quick, efficient way of collecting data about a client, and is an objective way to capture visual changes in functional movement. The FCMS additionally provides a means to observe the impact of compensation on functional movement. It is believed that using the FCMS in combination with other data collection processes will make it a more useful clinical tool. The researchers have found it to be a more consistent assessment tool when one therapist was rating photographs.

**Limitations**

There were numerous limitations related to this study that may affect its reliability and validity. First, the photos taken were not originally intended for use in a particular research study, that is, they were not taken in a prescribed manner. There were no recorded notes of what was said or done during photography, including verbal and/or physical cuing used to assist children or how each child was “prep” by the occupational therapist. Children may have been nervous about having their photos taken in an unfamiliar room or in the nine positions. Incomplete data required one position to be removed from the data set. Additionally, as
numerous t-tests were performed during the analysis, one needs to be aware of Type I error accumulation impacting the findings.

The “behind back” or “behind head” photos were taken from a forward facing position which made it difficult to distinguish where the participant’s hands were on the posterior part of their body. No photos were taken of each participant’s typical relaxed standing position, which made it challenging to distinguish if there was movement towards the desired position or inherent body compensation in their typical posture.

Finally, the FCMS was developed for this study to assist the primary researchers in scoring the photos taken for this particular camp. Generalizability of the FCMS to other diagnoses or age groups is not known without further research.

**Suggestions for Further Research**

The FCMS was developed as a tool to help the researchers assess change in function in pediatric participants who received mCIMT and were photographed in nine functional positions. It would be beneficial for future researchers to develop a protocol to be used during mCIMT intervention if photography will be used as an assessment tool. It is recommended that future studies using photography with the FCMS use a checklist to ensure all participants be photographed in each of the nine positions before and after the intervention. A best-practice protocol for photographing participants would allow them to demonstrate their full ability to replicate the nine desired positions illustrated on the FCMS and thus receive the highest scores. Additionally, it is believed there is potential for the FCMS to be used with videography, although it has not been tested. This would allow therapists to score the participants accurately on the FCMS even if they are unable to sustain holding the position long enough for a photograph, and may give other subjective or objective information that could be useful in clinical
documentation. Additionally, videography could allow therapists using the FCMS to see if a child uses momentary compensation to achieve the position, even if this compensation does not appear in a photograph (e.g. using the uninvolved side to help put affected arm behind head). Finally, use of the FCMS with adult clients receiving mCIMT could be explored.

Conclusions

While the FCMS warrants further research and development to determine its applicability to clinical practice, it shows potential to become a standardized clinical tool to assess changes in upper extremity function as a result of mCIMT intervention. A lack of statistically significant findings should not be taken as evidence of mCIMT being an ineffective intervention for children with cerebral palsy, nor should it be viewed as a failure of the FCMS. Rather, it is a reflection of the retrospective aspect of this study as the protocols for assessment were developed after the original photographs were taken. Establishment of a specific protocol for gathering data will likely further increase the precision of this tool.

It is not only a benefit to clinicians to observe progress, but to third party payers as a means to determine the effectiveness of clinical treatment. As evidenced by the statistically significant findings concerning the overhead position, quantifiable changes can be ascertained with the FCMS. This instrument is a quick and easy-to-learn tool that can be used readily by an entry-level therapist, as rating takes less than 10 minutes for a set of nine photographs. Due to the nature of photography, grading the positions can be done outside of a client’s session, therefore freeing time spent with the client. The FCMS is a reliable, simple, quantitative assessment that necessitates further attention as a means to assess changes in function for pediatric clients participating in a mCIMT intervention program.


Appendix A

Functional Composite Movement Scale

OVERHEAD position

*Desired position: shoulders and elbows fully extended (approximately 180° extension) above head in anatomical position (no flexion, extension or rotation), wrists neutral and fingers in extended position.

TRUMPET position

*Desired position: Tips of fingers on both hands touching lips/mouth, elbows flexed into torso (Shoulder abduction ≤ 15°).

BEHIND HEAD position

*Desired position: Palmar surface of fingers touching back of head, upper extremity visibly in plane of scaption with elbow flexion.
**OVER BELLY position**

*Desired position: palmar surface of fingers touching midline at umbilicus region, elbows flexed and shoulders abducted to approximately 45°.*

**BEHIND BACK position**

*Desired position: dorsal surface of hands touching lumbar region of spine near midline, elbows flexed and shoulders abducted to approximately 45°.*

**OUT TO SIDES position**

*Desired position: shoulder horizontally abducted to approximately 90°, elbow fully extended to 180°, wrists in neutral position.*
**ARREST position**

*Desired position: shoulders abducted to approximately 80-110° (in frontal plane or plane of scaption), elbows flexed to approximately 85-95°, palms of hands facing anteriorly, in frontal plane.*

**ARMS TO SIDES position**

*Desired position: both arms fully adducted at respective sides of the body, elbows fully extended, palmar surface of both hands touching thighs.*

**FOREARM SUPINATION position**

*Desired position: shoulders fully adducted, elbows flexed in sagittal plane at approximately 80-90°, wrists are supinated >80°.*
Appendix B

**Functional Composite Movement Scale: Scoring Criteria**

**OVERHEAD**

*Desired position: shoulders and elbows fully extended (approximately 180° extension) above head in anatomical position (no flexion, extension or rotation), wrists neutral and fingers in extended position.*

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 5.0   | Client demonstrates desired position with symmetry.  
         - Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 4.5   | Client demonstrates desired position with symmetry.  
         - Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 4.0   | Shoulders and elbows fully extended, but wrists are not in neutral.  
         - Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 3.5   | Shoulders and elbows fully extended, but wrists are not in neutral.  
         - Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 3.0   | Wrist crease of affected hand are superior to the horizontal line formed at the bridge of the nose, but position does not yet qualify for a (4).  
         - Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 2.5   | Wrist crease of affected hand is superior to the horizontal line formed at the bridge of the nose, but position does not yet qualify for a (4).  
         - Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 2.0   | Wrist crease of affected hand is inferior to the horizontal line formed at the bridge of the base of the nose.  
         - Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 1.5   | Wrist crease of affected hand is inferior to the horizontal line formed at the bridge of the base of the nose.  
         - Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2- |
| 0     | No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
TRUMPET

*Desired position: Tips of fingers on both hands touching lips/mouth, elbows flexed into torso (Shoulder abduction ≤ 15°).

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 5.0   | Client demonstrates desired position with symmetry.  
   • Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 4.5   | Client demonstrates desired position with symmetry.  
   • Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 4.0   | Affected hand touches lips/mouth with shoulders abducted 16 to 40°  
   • Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 3.5   | Affected hand touches lips/mouth with shoulders abducted 16 to 40°  
   • Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 3.0   | Affected hand touches lips/mouth with shoulders abducted 41° to 90°  
   • Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 2.5   | Affected hand touches lips/mouth with shoulders abducted 41° to 90°  
   • Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 2.0   | Affected hand touches lips/mouth with shoulders abducted 91° to 120°  
   • Trunk or neck flexion and/or shoulder height discrepancy **not visible** |
| 1.5   | Affected hand touches lips/mouth with shoulders abducted 41° to 90°  
   • Trunk or neck flexion and/or shoulder height discrepancy **visible** |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2- |
| 0     | No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
**BEHIND HEAD**

*Desired position: Palmar surface of fingers touching back of head, upper extremity visibly in plane of scaption with elbow flexion.*

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
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</thead>
</table>
| 5.0   | Client achieved desired position with symmetry  
   - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 4.5   | Client achieved desired position with symmetry  
   - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 4.0   | Affected hand touches behind head, but left and right sides are not symmetrical.  
   - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 3.5   | Affected hand touches behind head, but left and right sides are not symmetrical.  
   - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 3.0   | Wrist crease of affected hand is visibly superior to transverse plane formed at the base of the sternal notch but does not touch head.  
   - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 2.5   | Wrist crease of affected hand is visibly superior to transverse plane formed at the base of the sternal notch but does not touch head.  
   - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 2.0   | Wrist crease of affected hand is visibly inferior to transverse plane formed at the base of the sternal notch.  
   - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 1.5   | Wrist crease of affected hand is visibly inferior to transverse plane formed at the base of the sternal notch.  
   - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2- |
| 0     | No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
**OVER BELLY**

*Desired position: palmar surface of fingers touching midline at umbilicus region, elbows flexed and shoulders abducted to approximately 45°.*

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 5.0   | Client demonstrates desired position with symmetry.  
  • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 4.5   | Client demonstrates desired position with symmetry.  
  • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 4.0   | Both hands touch umbilical region of belly, but left and right arms/hands are not symmetrical.  
  • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 3.5   | Both hands touch umbilical region of belly, but left and right arms/hands are not symmetrical.  
  • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 3.0   | Affected hand touches anterior/lateral surface of abdominal region or area surrounding umbilical region (includes pelvic region).  
  • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 2.5   | Affected hand touches anterior/lateral surface of abdominal region or area surrounding umbilical region (includes pelvic region).  
  • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 2.0   | Affected hand does not touch abdominal or pelvic regions.  
  • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 1.5   | Affected hand does not touch abdominal or pelvic regions.  
  • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2-  
  • No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
**BEHIND BACK**

*Desired position: dorsal surface of hands touching lumbar region of spine near midline, elbows flexed and shoulders abducted to approximately 45°.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 5.0   | Client demonstrates desired position with symmetry.  
       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 4.5   | Client demonstrates desired position with symmetry.  
       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 4.0   | Affected hand touches the lumbar region of the back, but left and right arms/hands are not symmetrical.  
       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 3.5   | Affected hand touches lumbar region of back, but left and right arms/hands are not symmetrical.  
       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 3.0   | Affected hand touches posterior/lateral surface of back or area surrounding lumbar region (includes gluteal region).  
       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 2.5   | Affected hand touches posterior/lateral surface of back or area surrounding lumbar region (includes gluteal region).  
       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 2.0   | Affected hand does not touch back or gluteal regions.  
       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 1.5   | Affected hand does not touch back or gluteal regions.  
       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2-0. |
| 0     | No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
### OUT TO SIDES

*Desired position: shoulder horizontally abducted to approximately 90°, elbow fully extended to 180°, wrists in neutral position.*

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 5.0   | Client demonstrates desired position with symmetry.  
        - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 4.5   | Client demonstrates desired position with symmetry.  
        - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 4.0   | Both arms are *horizontally abducted* 90° (includes plane of scaption), however <30° elbow flexion and/or wrist flexion/extension is observed in affected arm.  
        - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 3.5   | Both arms are *horizontally abducted* 90° (includes plane of scaption), however <30° elbow flexion and/or wrist flexion/extension is observed in affected arm.  
        - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 3.0   | Affected arm is abducted at least 45° to 90°. Elbow or wrist flexion/extension may be observed.  
        - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 2.5   | Affected arm is abducted at least 45° to 90°. Elbow or wrist flexion/extension may be observed.  
        - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 2.0   | Affected arm is abducted <45°. Elbow or wrist flexion/extension may be observed.  
        - Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 1.5   | Affected arm is abducted <45°. Elbow or wrist flexion/extension may be observed.  
        - Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2- |
| 0     | No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
ARREST

*Desired position: shoulders abducted to approximately 80-110° (in frontal plane or plane of scaption), elbows flexed to approximately 85-95°, palms of hands facing anteriorly, in frontal plane.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
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</thead>
<tbody>
<tr>
<td>5.0</td>
<td>Client demonstrates desired position with symmetry.</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>not visible</strong></td>
</tr>
<tr>
<td>4.5</td>
<td>Client demonstrates desired position with symmetry.</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>visible</strong></td>
</tr>
<tr>
<td>4.0</td>
<td>Both arms are <em>horizontally abducted</em> 80 to 110° (includes plane of scaption), however elbow flexion is &lt;85° or &gt;95°, and/or wrist flexion/extension is observed in affected arm.</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>not visible</strong></td>
</tr>
<tr>
<td>3.5</td>
<td>Both arms are <em>horizontally abducted</em> 80 to 110° (includes plane of scaption); however elbow flexion is outside of the 85 to 95° range, and/or wrist flexion/extension is observed in affected arm.</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>visible</strong></td>
</tr>
<tr>
<td>3.0</td>
<td>Wrist crease of affected hand is at or above the horizontal line formed by the base of the sternal notch, but arm/wrist position does not meet the requirements for a (4).</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>not visible</strong></td>
</tr>
<tr>
<td>2.5</td>
<td>Wrist crease of affected hand is at or above the horizontal line formed by the base of the sternal notch, but arm/wrist position does not meet the requirements for a (4).</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>visible</strong></td>
</tr>
<tr>
<td>2.0</td>
<td>Wrist crease of affected hand is below the horizontal line formed by the base of the sternal notch.</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>not visible</strong></td>
</tr>
<tr>
<td>1.5</td>
<td>Wrist crease of affected hand is below the horizontal line formed by the base of the sternal notch.</td>
</tr>
<tr>
<td></td>
<td>• Trunk or neck flexion and/or shoulder height discrepancy <strong>visible</strong></td>
</tr>
<tr>
<td>1</td>
<td>Goal directed movement observed, but movement does not meet criteria for 2-</td>
</tr>
<tr>
<td>0</td>
<td>No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations.</td>
</tr>
<tr>
<td>N/A</td>
<td>Not recorded. Missing photo, unusable photo, researcher error, etc.</td>
</tr>
</tbody>
</table>
ARMS TO SIDES

*Desired position: both arms fully adducted at respective sides of the body, elbows fully extended, palmar surface of both hands touching thighs.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 5.0   | Client demonstrates desired position with symmetry.  
      | - Trunk or neck flexion and/or shoulder height discrepancy not visible |
| 4.5   | Client demonstrates desired position with symmetry.  
      | - Trunk or neck flexion and/or shoulder height discrepancy visible |
| 4.0   | Arms are fully adducted, and elbows fully extended, but affected palm does not touch thigh.  
      | - Trunk or neck flexion and/or shoulder height discrepancy not visible |
| 3.5   | Arms are fully adducted, and elbows fully extended, but affected palm does not touch thigh.  
      | - Trunk or neck flexion and/or shoulder height discrepancy visible |
| 3.0   | Client demonstrates elbow flexion, wrist flexion/extension, and/or shoulder abduction, but affected hand lies below umbilical region.  
      | - Trunk or neck flexion and/or shoulder height discrepancy not visible |
| 2.5   | Client demonstrates elbow flexion, wrist flexion/extension, and/or shoulder abduction, but affected hand lies below umbilical region.  
      | - Trunk or neck flexion and/or shoulder height discrepancy visible |
| 2.0   | Client demonstrates elbow flexion, wrist flexion/extension, and/or shoulder abduction, and affected hand lies above umbilical region.  
      | - Trunk or neck flexion and/or shoulder height discrepancy not visible |
| 1.5   | Client demonstrates elbow flexion, wrist flexion/extension, and/or shoulder abduction, and affected hand lies above umbilical region.  
      | - Trunk or neck flexion and/or shoulder height discrepancy visible |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2- |
| 0     | No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
**FOREARM SUPINATION**

*Desired position: shoulders fully adducted, elbows flexed in sagittal plane at approximately 80-90°, wrists are supinated >80°.*

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 5.0   | Client demonstrates desired position with symmetry.  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 4.5   | Client demonstrates desired position with symmetry.  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 4.0   | Arm is adducted to side (< 20° shoulder abduction) and elbows are flexed. Affected forearm supinated 31° to 80°  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 3.5   | Arm is adducted to side (< 20° shoulder abduction) and elbows are flexed. Affected forearm supinated 31° to 80°  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 3.0   | Elbows are flexed, affected forearm supinated -30° to 30° (>20° shoulder abduction may be visible).  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 2.5   | Elbows are flexed, affected forearm supinated -30° to 30° (>20° shoulder abduction may be visible).  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 2.0   | Affected forearm supinated -60° to -31° (>20° shoulder abduction may be visible).  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *not visible* |
| 1.5   | Affected forearm supinated -60° to -31° (>20° shoulder abduction may be visible).  
|       | • Trunk or neck flexion and/or shoulder height discrepancy *visible* |
| 1     | Goal directed movement observed, but movement does not meet criteria for 2- |
| 0     | No movement. Client unable to demonstrate movement because of cognitive or behavioral limitations. |
| N/A   | Not recorded. Missing photo, unusable photo, researcher error, etc. |
### Appendix C

**CONSENT FOR PHOTOGRAPHY**

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>Name:</td>
</tr>
<tr>
<td>Phone Number:</td>
<td>Address:</td>
</tr>
<tr>
<td>e-mail:</td>
<td>Phone Number:</td>
</tr>
</tbody>
</table>

I hereby give permission for:

- myself: ____________________________
- my child or ward: __________________

NAME

NAME

to appear as a subject in videotapes and photographs produced by the **School of Occupational Therapy and Physical Therapy at the University of Puget Sound**.

It has been explained to me that these materials are principally to be used for documentation in my medical record but may be used for research and/or training of professionals and paraprofessionals in college, university, community college, and clinical education settings. I also understand that materials will be under the control of University of Puget Sound Faculty. Materials may also be used for papers in professional journals. In addition, I understand that this consent is specifically for:

- (Type of Study, Presentation, Brochure, etc.)

I understand that first names may be used in these materials and that the photography will in no way try to conceal the identity of the subject. I further understand that if I request, I will be given the opportunity to delete any portions that I consider objectionable and to review the final product.

I understand that the extent of eventual use cannot be fully anticipated and that it may extend for a considerable length of time. I also understand that I may cancel this consent by written notice and that this cancellation is without penalty and will in no way affect my future medical care and services, or academic standing.

I have had the opportunity to ask questions and to obtain the kind of information I need to make such a decision.

I consent to use of photo documentation in my medical records _____(initial).

I consent to use of my images for research _____(initial).

I consent to use of my images for educational purposes _____(initial).

Signature of Subject (if applicable) ____________________________ Date __________

Signature of Parent or Guardian (if applicable) ____________________________ Date __________

Signature of Faculty ____________________________ Date __________

Copies: Patient/Subject (if applicable)

- Patient File
- Faculty File
Table 1  
\textit{Demographic Information on Participants}  

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age, Month, Day</th>
<th>Sex</th>
<th>Affected Side</th>
<th>Session Attended</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4 years 6 months 13 days</td>
<td>Female</td>
<td>Right</td>
<td>Morning</td>
</tr>
<tr>
<td>B</td>
<td>5 years 2 months 26 days</td>
<td>Female</td>
<td>Left</td>
<td>Morning</td>
</tr>
<tr>
<td>C</td>
<td>5 years 10 months 15 days</td>
<td>Male</td>
<td>Left</td>
<td>Morning</td>
</tr>
<tr>
<td>D</td>
<td>5 years 11 months 4 days</td>
<td>Male</td>
<td>Right</td>
<td>Morning</td>
</tr>
<tr>
<td>E</td>
<td>6 years 2 months 7 days</td>
<td>Male</td>
<td>Left</td>
<td>Morning</td>
</tr>
<tr>
<td>F</td>
<td>7 years 5 months 18 days</td>
<td>Male</td>
<td>Right</td>
<td>Morning</td>
</tr>
<tr>
<td>G</td>
<td>7 years 11 months 14 days</td>
<td>Female</td>
<td>Left</td>
<td>Morning</td>
</tr>
<tr>
<td>H</td>
<td>9 years 3 months 6 days</td>
<td>Female</td>
<td>Left</td>
<td>Afternoon</td>
</tr>
<tr>
<td>I</td>
<td>9 years 4 months 13 days</td>
<td>Female</td>
<td>Right</td>
<td>Afternoon</td>
</tr>
<tr>
<td>J</td>
<td>9 years 6 months 4 days</td>
<td>Male</td>
<td>Left</td>
<td>Afternoon</td>
</tr>
<tr>
<td>K</td>
<td>9 years 7 months 17 days</td>
<td>Male</td>
<td>Right</td>
<td>Afternoon</td>
</tr>
<tr>
<td>L*</td>
<td>10 years 1 month 29 days</td>
<td>Female</td>
<td>Left</td>
<td>Afternoon</td>
</tr>
<tr>
<td>M</td>
<td>12 years 5 months 14 days</td>
<td>Male</td>
<td>Right</td>
<td>Afternoon</td>
</tr>
</tbody>
</table>

\textit{Note.} *Participant L had triplegia.
### Table 2

*Average FCMS Scores and Overall Differences in FCMS Score by Participant*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Average FCMS Score Pre-mCIMT</th>
<th>Average FCMS Score Post-mCIMT</th>
<th>Difference in FCMS Score (+/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.56</td>
<td>3.38</td>
<td>-0.18</td>
</tr>
<tr>
<td>B</td>
<td>3.75</td>
<td>3.88</td>
<td>+0.13</td>
</tr>
<tr>
<td>C</td>
<td>3.33</td>
<td>3.50</td>
<td>+0.17</td>
</tr>
<tr>
<td>D</td>
<td>3.69</td>
<td>3.75</td>
<td>+0.06</td>
</tr>
<tr>
<td>E</td>
<td>3.81</td>
<td>4.00</td>
<td>+0.19</td>
</tr>
<tr>
<td>F</td>
<td>3.38</td>
<td>3.21</td>
<td>-0.17</td>
</tr>
<tr>
<td>G</td>
<td>3.63</td>
<td>3.75</td>
<td>+0.12</td>
</tr>
<tr>
<td>H</td>
<td>3.81</td>
<td>3.56</td>
<td>-0.25</td>
</tr>
<tr>
<td>I</td>
<td>3.94</td>
<td>4.06</td>
<td>+0.12</td>
</tr>
<tr>
<td>J</td>
<td>3.25</td>
<td>3.25</td>
<td>0.00</td>
</tr>
<tr>
<td>K</td>
<td>3.50</td>
<td>3.50</td>
<td>0.00</td>
</tr>
<tr>
<td>L</td>
<td>3.56</td>
<td>4.00</td>
<td>+0.44</td>
</tr>
<tr>
<td>M</td>
<td>4.25</td>
<td>4.44</td>
<td>+0.19</td>
</tr>
</tbody>
</table>
Table 3

*Average FCMS Scores, Overall Differences, and t-test for FCMS score by Group*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean FCMS Score</th>
<th>Change in FCMS Score</th>
<th>Paired Samples t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre- / Post- mCIMT (+/-)</td>
<td>t (df)</td>
<td>p</td>
</tr>
<tr>
<td>All Participants</td>
<td>13</td>
<td>3.65 / 3.71</td>
<td>+0.06</td>
<td>1.22(12)</td>
</tr>
<tr>
<td>Females</td>
<td>6</td>
<td>3.71 / 3.77</td>
<td>+0.06</td>
<td>.62(5)</td>
</tr>
<tr>
<td>Males</td>
<td>7</td>
<td>3.60 / 3.66</td>
<td>+0.06</td>
<td>1.25(6)</td>
</tr>
<tr>
<td>Left Side Affected</td>
<td>7</td>
<td>3.59 / 3.71</td>
<td>+0.11</td>
<td>1.45(6)</td>
</tr>
<tr>
<td>Right Side Affected</td>
<td>6</td>
<td>3.72 / 3.72</td>
<td>0.00</td>
<td>.05(5)</td>
</tr>
<tr>
<td>Morning Session</td>
<td>7</td>
<td>3.59 / 3.64</td>
<td>+0.05</td>
<td>.77(6)</td>
</tr>
<tr>
<td>Afternoon Session</td>
<td>6</td>
<td>3.72 / 3.80</td>
<td>+0.08</td>
<td>.89(5)</td>
</tr>
</tbody>
</table>
Table 4

*Paired t-test Data Analysis by Position*

<table>
<thead>
<tr>
<th>Position</th>
<th>n</th>
<th>Pre-mCIMT Mean (SD)</th>
<th>Post-mCIMT Mean (SD)</th>
<th>Paired Samples t-test t(df)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>13</td>
<td>3.42 (.64)</td>
<td>4.00 (.84)</td>
<td>2.48(12)</td>
<td>.029*</td>
</tr>
<tr>
<td>#2</td>
<td>13</td>
<td>3.42 (.64)</td>
<td>4.00 (.84)</td>
<td>1.17(12)</td>
<td>.264</td>
</tr>
<tr>
<td>#3</td>
<td>13</td>
<td>3.81 (.43)</td>
<td>4.04 (.48)</td>
<td>-1.32(12)</td>
<td>.213</td>
</tr>
<tr>
<td>#4</td>
<td>13</td>
<td>3.85 (.47)</td>
<td>3.81 (.33)</td>
<td>-.25(12)</td>
<td>.808</td>
</tr>
<tr>
<td>#5</td>
<td>13</td>
<td>3.54 (.63)</td>
<td>3.38 (.74)</td>
<td>-.51(12)</td>
<td>.619</td>
</tr>
<tr>
<td>#6</td>
<td>12</td>
<td>3.38 (.80)</td>
<td>3.88 (.91)</td>
<td>2.10(11)</td>
<td>.060</td>
</tr>
<tr>
<td>#7</td>
<td>11</td>
<td>3.73 (.47)</td>
<td>3.77 (.47)</td>
<td>.22(10)</td>
<td>.831</td>
</tr>
<tr>
<td>#9</td>
<td>12</td>
<td>3.42 (.79)</td>
<td>3.38 (.64)</td>
<td>-.29(11)</td>
<td>.777</td>
</tr>
</tbody>
</table>

*Note.* *p < .05*
Acknowledgments

We would like to thank our research committee for helping us throughout this process. Thank you to Lucretia Berg, MSOT, OTR/L for allowing us to use the data from her 2012 mCIMT Summer Camp, as well as for being the reader of our project. Thank you to George Tomlin, PhD, OTR/L for the help with revisions, SPSS, and for being our research chair. We also extend many thanks to Anne James, PhD, OTR/L for encouragement and guidance during Fall 2013 as well as to the participants of the 2012 mCIMT Summer Camp.