CONSTRAINT INDUCED MOVEMENT THERAPY WITH ARMEO® SPRING PEDIATRIC TRAINING FOR CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY: A COMPARATIVE STUDY

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DEDICATION

To my parents, Diane and John Boyne and Michael Wachtel, thank you for your love, support and encouragement.

To my husband, Dr. Aaron Roberts,
thank you for your continuous support, patience,
and unconditional love.

To my little ones, Annabel and Benjamin,
thank you for your inspiration and endless
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ABSTRACT

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CONSTRAINT INDUCED MOVEMENT THERAPY WITH ARMEO®SPRING PEDIATRIC TRAINING FOR CHILDREN WITH HEIMIPLEGIC CEREBRAL PALSY: A COMPARATIVE STUDY

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Constraint Induced Movement Therapy (CIMT) is a therapeutic intervention using constraint of the non-involved limb while a child engages in intense training with hemiplegic extremity. No studies to date have examined the effectiveness of CIMT combined with the Armeo®Spring Pediatric, a robotic device, in the pediatric hemiplegic cerebral palsy (hCP) population. The Armeo®Spring combines virtual reality games with repetitive upper limb movements. The games aim to increase motivation to complete repetitive tasks required to improve function. The purpose of this study was to examine the effectiveness of hand function of CIMT compared to CIMT with Armeo®Spring and the perceived experience of using the Armeo®Spring compared to fine motor tasks.

Twelve children with hCP (age 6-11yr, 8 M, MACS Level I= 2, II= 9, III= 1, right hCP= 7) were recruited at a pediatric hospital. Eight subjects completed CIMT camp 6 hours for 10 days; 4 subjects completed CIMT camp with Armeo®Spring daily for 30 minutes. Primary outcome measure, Assisting Hand Assessment (AHA), and secondary outcome measures, Melbourne Assessment of Unilateral Upper Limb Function (MUUL), Canadian Occupational Performance Measure (COPM), Tone (MAS and Tardieu), Range of Motion, grip strength, proprioception, and stereognosis were compared before and post intervention. Perceived observations on motivation, engagement, enjoyment and frustration were recorded during Armeo®Spring and fine motor activities.

Clinically significant gains were observed in the augmented CIMT group on the AHA, COPM, and grip strength. The CIMT group demonstrated improvements on the AHA, MUUL, COPM, and grip strength. The augmented group demonstrated significant improvement on the AHA. Mean scores for motivation, engagement, and enjoyment were higher on the Armeo®Spring than fine motor tasks.

The Armeo®Spring is a novel therapy that improves functional outcomes for children with hCP. Compared to CIMT alone, CIMT with Armeo®Spring appears to provide more intensive training. Based on particpant comments, its robotic features and videogame interface also appeal to the children leading to increased motivation, engagement and enjoyment while providing the just right challenge of the affected limb. This study provides a framework supported by evidence-based data for non-invasive treatment of children with hCP.

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CHAPTER I

INTRODUCTION

Statement of the Problem

Cerebral palsy (CP) is one of the most common and disabling conditions occurring in infancy (Odding, Roebroeck, & Stam, 2006). CP is not a progressive disease process. However, CP frequently presents the child and family with a lifetime of significant challenges (Boyle, Decoufle, & Yeargin-Allsopp, 1994). CP may affect all four extremities (quadriplegia), just the lower extremities (diplegia), or the upper and lower extremities on one side of the body (hemiplegia). CP often compromises the individual's ability to engage in typical activities of daily living. While there is much in the literature on intervention, there is a paucity of research on evidenced-based interventions that have been demonstrated to be effective in promoting an optimal level of independence.

Constraint Induced Movement Therapy (CIMT) is recognized as an intervention that offers promise in remediation of hand function and use in children with hemiplegic CP (Gordon, Charles, & Wolf, 2005; Huang, Fetters, Hale, & McBride, 2009; Novak et al., 2013). CIMT involves restraining the non-involved limb for a specified period of time and providing intense training activities for the affected limb. A novel approach to utilizing activity-based interventions is the use of robotic devices and virtual reality. Robotic devices like the Armeo®Spring Pediatric offer repetitive movement resulting in increased quantity and improved quality of movements. Virtual reality games increase the motivation to complete these repetitive tasks required to improve outcomes (Zariffa et al., 2012). However, no studies to date have examined the use of Armeo®Spring Pediatric for upper limb rehabilitation in the pediatric CP population.

Combining the use of the Armeo®Spring Pediatric with CIMT in a camp setting provides an even greater level of intensity of training for the involved limb. Both the Armeo®Spring and CIMT are based on the principles of motor learning theory. Massed practice and repetitive movements are required to improve function of the affected limb. Without increasing the demands of the therapist, the exoskeleton of the Armeo®Spring increases the number of desired movements and repetitions of the upper extremity.

Statement of the Purpose

The aim of this research was to determine the effects of a two-week modified constraint induced movement therapy (mCIMT) camp that incorporated Armeo®Spring training for children with hemiplegic CP. The overarching research objectives were divided into three parts and are discussed below.

Hypotheses

Part A: Clinical Effectiveness of a Modified CIMT Camp with Armeo®Spring Pediatric Training

A prospective study was completed examining the clinical effectiveness of a mCIMT intervention that included spring loaded arm support therapy using the Armeo®Spring Pediatric for children with hemiplegic CP.

Hypothesis 1. Hand function and participation in children with hemiplegic CP will improve following a mCIMT intervention augmented with the Armeo®Spring *in a camp setting.*

This hypothesis was tested by examining the children's scores both pre- and post-camp participation using an assessment protocol which included outcome measures that have been validated for use in children with hemiplegic CP.

Part B: Comparative Study Examining Effects of the Armeo®Spring Pediatric within a mCIMT Camp

A comparative study was designed to examine the differences in hand arm function and participation of children who completed a mCIMT intervention in a camp like setting with Armeo®Spring training compared to those who completed a mCIMT intervention who did not receive Armeo®Spring training.

Hypothesis 2. Hand function and participation will demonstrate greater improvements in children with hemiplegic CP who received the augmented mCIMT intervention with the Armeo®Spring Pediatric *training*.

This study was completed by gathering data from the 2014 mCIMT camp and comparing it to data gathered during previous mCIMT camps (2012 and 2013) via a retrospective chart review.

Part C: Observed Experiences of Participants

A qualitative study was designed based on the observed experience of participants while engaged in Armeo®Spring Pediatric training in comparison with other fine motor activities during the mCIMT camp.

Hypothesis 3. Participants will display increased engagement, motivation, and enjoyment and decreased frustration during use of the Armeo®Spring compared to the fine motor stations of the augmented mCIMT intervention.

This study was completed by collecting observations of the participants during the Armeo®Spring Pediatric training and fine motor stations during the mCIMT camp.

Significance

Many treatments for improving function in children with hemiplegic CP involve either medication or invasive, irreversible procedures. Previous research has found that CIMT is a promising, non-invasive treatment for improving function of the affected hand in children with hemiplegic CP. Combining the Armeo®Spring with mCIMT in a camp like setting offers a novel approach to treating children with hemiplegic CP. The device provides a greater level of intensity of practice with the involved upper extremity. It also addresses the assumption that the Armeo®Spring Pediatric is more enjoyable and motivating therefore children are more engaged and more involved in intensive training thus having greater therapeutic effect than a traditional mCIMT camp. The outcomes from this study have relevance to occupational therapists, physicians, and the medical community at large. The study provides a framework supported by evidence-based data for non-invasive treatment of children with hemiplegic CP. Dissemination of the results in peer-reviewed publications and presentations will provide occupational therapists with new evidence-based data that will help provide a novel therapy that is more likely to improve functional outcomes for children with hemiplegic CP.

Definitions

The following definitions are provided to ensure uniformity and understanding of these terms throughout the study.

Constraint Induced Movement Therapy (CIMT): short term, intensive training of an involved upper extremity by the application of a restraint to the non-involved upper extremity to be worn 90% of the waking hours for 21 days. Shaping and individualized training for the involved limb will take place for up to 6 hours during the day (Taub, Ramey, DeLuca, & Echols, 2004).

Hemiplegic Cerebral Palsy (hCP): paralysis of one side of the body resulting from injury to the brain (Odding et al., 2006)

Modified Constraint Induced Movement Therapy (mCIMT): modifications made to the above definition of CIMT (DeLuca, Echols, Law, & Ramey, 2006). Participants in this research wore the restraint to the non-involved extremity for 6 hours a day for 10 days. Shaping and individualized training for the involved limb took place for 6 hours a day for 10 days.

CHAPTER II

LITERATURE REVIEW

Cerebral palsy (CP) is not a progressive disease process. However, CP frequently presents the child and family with a lifetime of significant challenges. The root cause of CP is not clearly delineated. CP results from a brain lesion that occurs either in utero or early childhood that causes the child to experience impaired neurological signals to motor and sensory nerves. This produces impaired movement. CP is frequently classified according to the body parts that are affected. Quadriplegic CP involves all four extremities; diplegia is applicable to lower extremities, and hemiplegia refers to CP affecting the arm and leg on same side of the body. Thirty six percent of children with CP have hemiplegia (Stanley, Blair, & Alberman, 2000). This study will be focused on children with hemiplegic CP.

The World Health Organization's International Classification of Functioning, Disability and Health (ICF), has been adopted internationally as a way to discuss health and disability (WHO 2013). Children with CP experience problems within all levels of the classification system. Impairments at the Body Structure/Function level (abnormal muscle tone, decreased range of motion, seizures) lead to dysfunction at the Activity and Participation level (loss of function- activities of daily living, participation in school activities). There may also be a decrease in quality of life (Livingston, Rosenbaum, Russell, & Palisano, 2007).

Children with CP encounter challenges every day when using their hands during play and self-care activities. The hand is used for nearly all activities of daily living; dressing, bathing, eating, and playing. Children with hemiplegic CP tend to develop individualized adaptations in how and when they use their affected hand due to the abnormal muscle tone and weakness that they experience. The result may range from total neglect of the affected hand to only minor difficulty in performing daily activities. Despite the degree of severity, the child with hemiplegic CP will typically experience difficulties with both activities of daily living and leisure participation.

The Manual Abilities Classification System (MACS) describes how children with cerebral palsy use their hands during activities of daily living (Eliasson et al., 2006). The classification system reflects the typical performance of the children's hand use throughout the day, rather than "their best effort". There are five different levels to the classification system. Level I is the least involved and children perform activities quite normally. Level V is the most severe with children having no hand function and therefore must rely on others for all care. The majority of children with hemiplegic cerebral palsy are classified as Level I, II or III (Stanley et al., 2000).

Overview of CP Treatment and Effectiveness

Many treatment methods and techniques have been developed for children with CP. These include occupational therapy, physical therapy, exercise, virtual reality, constraint-induced movement therapy, medication, selective dorsal rhizotomy, and orthopedic surgery (Tilton, 2009; Sakzewski, Ziviani, & Boyd 2009; Tuatla et al., 2013). Christiansen and Lange (2008) and Bower, Mitchel, Burnett, Campbel, and McLellan (2001) found physical therapy and exercise improved gross motor skills as measured by the Gross Motor Performance Measure (GMFM) in children with CP. Oral medication is useful when the goal is to reduce tone globally throughout the body. Muscle injections with botulinum toxin type A (BoNT) are used to reduce tone to a specific muscle group. However, neither of these approaches translates to improved function (Tilton, 2009). There is a small but growing body of evidence demonstrating BoNT combined with occupational therapy improves hand function (Wong, 2002; Yang, Fu, Kao, Chan, & Chen, 2003). Selective dorsal rhizotomy (SDR) offers the best results for those with CP that are most affected in their lower extremities (Chicoine, Parks, & Kaufman, 1997). Orthopedic surgery is used when muscle contractures have occurred and often involves tendon releases and transfers. Children are typically older and closer to skeletal maturity when these procedures are considered. Both the SDR and orthopedic surgery are invasive and non-reversible treatments (Tilton, 2009).

Constraint Induced Movement Therapy

Overview. Constraint Induced Movement Therapy (CIMT) is a non-invasive, focused alternative to medication and surgery for treatment of children with hemiplegic CP. Children with hemiplegic CP have impairment on one side of the brain hemisphere causing "developmental disregard" (Hoare, Imms, Carey, & Wasiak, 2007) of the impaired extremity. Developmental disregard is defined "as a failure to use the potential motor functions and capacities of the affected arm and hand for spontaneous use in daily life" (Houwink, Aarts, Geerts, & Steenbergen, 2011). CIMT involves restraining the non-involved limb for a period of time and providing structured practice that incorporates the concept of "shaping". Shaping is a strategy wherein tasks are introduced at a rate that promotes success while the difficulty of the task is slowly increased with the ultimate goal of increasing the use of the affected limb (Eliasson, Krumlinde-Sundholm, Shaw, & Wang, 2005).

For interventions for CP to have long-term benefits, the therapy must result in changes in the neural pathways. Thus, the intervention must result in adjustments in the brain and neural pathways to accommodate the injury. These adjustments and changes in neurophysiology are commonly referred to as neuroplasticity (Johnston, 2004). Previous studies using transcranial magnetic stimulation to examine neural pathways have demonstrated that the use of CIMT results in changes in brain plasticity in adults impaired by cerebrovascular accident (Kuhnke et al., 2008; Liepert et al., 1998). Furthermore, studies utilizing functional magnetic resonance imaging (fMRI) in children with CP have demonstrated changes in brain plasticity following treatment with CIMT (Fehlings, Sutcliffe, & Longan, 2009; Huang, Fetters, Hale, & McBride, 2009; Juenger et al., 2007). These findings suggest that CIMT, by altering neuroplasticity, offers potential long-term benefits as a non-invasive treatment option for children with hemiplegic CP.

CIMT approaches. Several studies have documented positive benefits of CIMT in children (Eliasson et al., 2005; Charles, Wolf, Schneider, & Gordon, 2006; Charles & Gordon, 2007; Huang et al., 2009; Hoare et al., 2007; Aarts, Jongerius, Geerdink, Van Limbeek, & Geurts, 2010; Nascimento, Gloria, & Habib, 2009; Sakzewski et al., 2011; Smania et al., 2009). Many of these studies focused on improvements at the body structure level (range of motion and tone) without carry over to participation (hand function and activities of daily living). Recent research reports evidence of improvements at the activity/participation level (Case-Smith, DeLuca, Stevenson, & Ramey, 2012; Huang et al., 2009). Though these studies offer promise of improved hand function, there is no conclusive evidence that demonstrates the "right ingredients" for long-term positive outcomes following CIMT (Novak et al., 2013). There is a great deal of variation from study to study in the types of constraint worn, the duration the constraint is worn and the outcome measures used to determine the effectiveness. For example, many studies examining children with CP have used instruments such as the Peabody, the Bruininks-Oseretsky Test of Motor Proficiency, or the Jebsen Taylor Hand Function Test to determine the effectiveness of CIMT (Brandao, Mancini, Vaz, de Melo, & Fonseca, 2010; Charles et al., 2006; Stearns, Burtney, Keener, Qualls, & Phillips, 2009; Taub, Ramey, DeLuca, & Echols, 2004). However, none of these assessments are validated for children with CP. The literature supports that additional studies are needed that incorporate measures with demonstrated validity for assessing children with CP.

Types of constraints. A number of studies have been completed testing various constraint-type interventions. However, the variance in treatment approaches and research methods makes it difficult for clinicians to identify best practices for use of CIMT interventions for hemiplegic CP. The various types of constraints include: hand holding and verbal cues (Naylor & Bower, 2005); a sling (Charles et al., 2006), a mitt (Eliasson et al., 2005; Wallen, Ziviani, Herbert, Evans, & Novak, 2008), and bi-valve casts or splints (Brandao et al., 2010; Charles et al., 2006; Psychouli, Burridge, & Kennedy, 2010; Taub et al., 2004).

Duration. In addition to various types of constraints, published studies also vary on the time/duration the constraint was worn. The wear time of constraint ranges from being constrained twenty-four hours a day (Taub et al., 2004) to no restraint as the therapist "held" the affected arm (Naylor & Bower, 2005). Therapy duration ranged from two-weeks (Brandao et al., 2010; Charles et al., 2006; Cope et al., 2010; Stearns et al., 2009) to two months (Eliasson et al., 2005). The length of therapy also differs from one hour a day (Naylor & Bower, 2005) to six hours a day (Taub et al., 2004). Another study compared the results of three hours versus six hours per day of CIMT over a time frame of twenty-one days and both groups demonstrated statistically significant gains suggesting a shorter duration of restraint might be used (Case-Smith et al., 2012).

Armeo®Spring Pediatric

The Armeo®Spring combines the use of an exoskeleton device with virtual reality technology to practice repetitive movements the child needs to acquire improved functional use of his/her upper extremity. There is great adjustability to the Armeo®Spring, allowing the therapist to customize the device to the needs of the individual child. The Armeo®Spring has five different degrees of freedom; shoulder flexion/extension, shoulder abduction/adduction, elbow flexion and extension, forearm pronation/supination and grip strength. The therapist can choose to lock out different motions or work on all motions at the same time depending on the needs of the individual child. In addition, adjustments can be made to the amount of gravity assistance the exoskeleton provides depending on the strength of the upper extremity.

Several virtual reality games for each desired range of motion are available for the child to choose. For example, in the soccer game the child must supinate his/her forearm to block the shot on goal. In the raindrop game, to facilitate elbow flexion and extension the child has a cup he/she must reach towards to catch a falling raindrop. The therapist has the ability to adjust the speed of the falling raindrops and the size of the cup to create the "just right challenge". This exoskeleton device provides an engaging environment to achieve the required repetitive practice the upper extremity needs for improved function. Children on average play video games thirteen hours a week (Gentile, 2009). Thus, the therapist can use the "video game" virtual reality interface of the Armeo®Spring as a desirable activity for use with children.

There is a paucity of literature on the effectiveness of virtual reality for upper limb improvements. Tautla et al. (2013) completed a systematic review of the use of virtual reality in children and adolescents with cerebral palsy and its effects on outcomes. Eight studies were found using the American Academy for Cerebral Palsy and Developmental Medicine (AACPMD)'s guidelines for systematic reviews. Only one the studies examined the upper extremity others focused on the lower extremity. The one upper extremity study found no statistically significant effects of upper limb function when virtual reality (Sony Eye-Toy) was used. Rostami et al. (2013) conducted a randomized control trial with children with hemiparetic CP using virtual reality, CIMT, CIMT and virtual reality, and a control group. Participants that received virtual reality in combination with CIMT had statistically significant improvements on the speed and dexterity subtest of the Bruininks-Oseretsky Test of Motor Proficiency and increased use of extremity according to the Pediatric Motor Activity Log (PMAL).

In summary, published studies support the use of CIMT as an effective, positive treatment for children with hemiplegia. Positive outcomes include decreased muscle tone, increased spontaneous use, and improved hand function. However, although a number of CIMT studies have been implemented, the marked variance in techniques and methodologies makes it difficult for the clinician to identify the optimal type of constraint or frequency and duration of treatment. The Armeo®Spring is a novel tool that combines robotic assistance and virtual reality to provide a new, unique way to engage children in the required repetitive motions required for motor learning. The evidence for virtual reality as an effective treatment for children with hemiplegia is conflicted and inconsistent. Studies are called for that incorporate greater rigor in design using outcome measures that are appropriate and valid for children with CP.

CHAPTER III

METHODS

Part A: Clinical Effectiveness of a Modified CIMT Camp with Armeo®Spring Pediatric Training

A study was completed to determine the clinical effectiveness of a modified CIMT camp (mCIMT) with Armeo®Spring training at a local children's hospital, Texas Scottish Rite Hospital for Children (TSRHC, Dallas, Texas). The goal was to examine the clinical effectiveness of a mCIMT camp augmented with the Armeo®Spring Pediatric on upper extremity function in children with hemiplegic CP.

Participants

Participants for the augmented mCIMT camp were recruited though the Motor Control Clinic (neurology) at an internationally known children's hospital in the southwestern central part of the United States. Children were eligible to participate if they: (1) had a diagnosis of hemiplegic CP aged between 5 years and 12 years, (2) were classified as MACS level I, II, or III (3) spoke English fluently enough to follow one step directions and (4) indicated they were able to attend camp every day. Children were excluded if they: (1) did not meet age range or above criteria, (2) had significant visual impairment or (3) had uncontrolled seizures. The principal investigator (PI) determined which participants were appropriate for recruitment and met the inclusion criteria. A minimum of three participants and maximum of ten participants were to be recruited.

The protocol was approved by the Institutional Review Boards of the University of Texas Southwestern Medical Center (#042014-013) and Texas Woman's University (# 17734). Informed consent was obtained from the parents and informed assent from all children over 10 years old.

Procedure

The mCIMT camp was designed on past clinical trials and clinical reviews (Aarts el al., 2012; Boyd et al., 2010; Case-Smith et al., 2012; Hoare et al., 2006; Huang et al., 2009; Nascimento et al., 2009; Novak et al., 2012). After enrollment, each participant was assessed using the standardized protocol for baseline performance and post intervention performance. This was the same assessment protocol used for the 2012 and 2013 camps. The PI completed all assessments.

Upon completion of the assessment protocol, the PI determined which joints were affected and had the greatest potential for rehabilitation. The PI then determined how many degrees of freedom were to be used with each child on the Armeo®Spring Pediatric. The child was then able to choose the games he/she participated in during the designated time on the Armeo®Spring Pediatric. The participants completed thirty minutes of training on the Armeo®Spring Pediatric daily during the mCIMT camp.

Participants attended the augmented mCIMT camp with the use of the Armeo®Spring Pediatric for two successive weeks (Monday through Friday 9am-3pm) for six hours a day (60 hours total) held at TSRHC in the summer of 2014. This model of intensity was chosen because of its positive outcomes seen in other studies (Charles et al., 2006; Huang et al., 2009). In addition, this was the intensity used with the 2012 and 2013 camps. The participants wore the constraint for five and half hours and used the Armeo®Spring for thirty minutes during each camp day. Post assessment utilizing the same assessment protocol was completed at the conclusion of camp.

Development of the Augmented Modified Constraint Induced Movement Therapy Camp

A camp manual was organized for the mCIMT camp allowing for consistency in the delivery and presentation of the mCIMT camps. A theme-based approach was used to promote participants' motivation and desire to be engaged in the activities. In this case, the camp incorporated a pirate theme. The PI and another trained OT with more than twenty years combined experience working with children with CP designed camp activities. Participants participated in a combination of gross and fine motor activities that were all related to the camp theme (see Appendix A Gross and Fine Motor Activities).

A schedule was created for camp (Appendix B Schedule). Each day followed the same routine with different types of activities incorporated into the schedule. Camp activities were provided in both individual and small group context. Snack time included edibles that promoted hand use. These activities were utilized because they elicited a specific response and were gradable (Appendix C Snack List). These are the same activities that were conducted during the 2012 and 2013 camps.

The day began at 9 am and concluded at 3 pm. The day started with a camp opening where the campers were welcomed. Staff and campers were introduced and name tags provided. Constraints were applied by the PI or other staff. On the first day, staff volunteers (university students who were interested in a healthcare profession) performed a pirate skit to review rules and introduce the theme of camp.

A token system, with "pirate coins" and visits to the "pirate chest", was incorporated to promote motivation. The PI explained to campers that they would receive a pirate coin when they completed an activity. Staff was instructed to provide coins when incentives were needed to complete task or for motivation. At end of each day campers took their treasure boxes with their coins and exchanged them for prizes.

Participants utilized the Armeo®Spring Pediatric for thirty minutes a day as suggested by Gordon and Okita (2012). This provided the high level of repetition required to promote change in the upper extremity. Each camper was escorted to a different part of the hospital where the Armeo®Spring Pediatric was located (in the occupational therapy department). The PI determined activities specific to each child based upon that child's impairment.

The PI and another Occupational Therapist (OT) with more than five years of experience working with children with CP directed the camp, coordinated the interventions including the Armeo®Spring Pediatric, and trained the volunteers who assisted in camp activities. These two therapists will be identified as the experienced therapists throughout the remainder of the dissertation.

Volunteer Training

Volunteers were contacted from requests of students to obtain volunteer hours. Contacts were emailed information about mCIMT camp and sent a TSRHC volunteer application. Each interested volunteer completed the TSRHC volunteer application which included proof of immunizations from the Volunteer Services Department. This was reviewed by the PI and then sent to the Volunteer Service Coordinator for further review. Once cleared, the PI was given permission for the volunteer to work.

A mandatory volunteer training was completed in the occupational therapy department at TSRHC (Appendix D Volunteer Training Agenda). This training provided the volunteers with a viewing of the HIPAA video, an overview of mCIMT and the Armeo®Spring Pediatric, introduction to the theme of camp, roles and responsibilities, and a tour of the hospital, bathrooms and outdoor space. The daily schedule was reviewed. Volunteers participated in three sample camp activities using their non-dominant hand. Different ways to “grade” the activities were discussed as well how to motivate the campers and to watch for frustration.

Description of the Constraint

The material was 1/16-inch aquaplast and secured with vel-foam strapping (Brandao et al., 2010; Charles et al., 2006; Taub et al., 2004). The constraint consisted of a long arm ulnar gutter splint that started under the shoulder and extended to the fingertips, with the elbow flexed at 90 degrees. The splint was applied by the PI, OT or the trained volunteers at the beginning of each camp day and removed for toileting needs, during use of the Armeo®Spring Pediatric, and at the conclusion of each camp day.

Assessment Protocol

The following presents the assessment protocol that was used for the augmented mCIMT study with Armeo®Spring Pediatric added as a new intervention. (Note: the 2012 AND 2013 mCIMT participants were assessed using the identical protocol.) (Appendix E Assessment Protocol). Participants in the 2014 Augmented mCIMT Camp were assessed at baseline and post intervention (at the conclusion of camp). Each evaluation period included a standardized protocol incorporating evaluation procedures. The PI administered assessments in the Occupational Therapy Department at Texas Scottish Rite Hospital for Children. The PI also scored and recorded all assessments.

The Assisting Hand Assessment (AHA) was the primary outcome measure utilized. The AHA (Krumlinde-Sundholm & Eliasson, 2003) is a valid and reliable 22-item measure that assesses the assisting or affected hand in carrying out bimanual activities for children with cerebral palsy or obstetric brachial plexus palsy aged 18 months to 12 years. The AHA was selected to measure bi-manual performance (Krumlinde-Sundholm & Eliasson, 2003). This test demonstrates high inter-rater and intra-rater reliability (Krumlinde-Sunholm, Holmefur, & Eliasson, 2007). Raw scores were converted to 0 to 100 logit-based AHA Units (Krumlinde-Sundholm, 2012). The smallest detectable difference (SDD) is 5 AHA units to reflect a true change or clinical difference in bi-manual performance *(*Krumlinde-Sundholm, 2012*).*

Administration and scoring of this assessment requires certification. The PI completed a 2½ day training course on test construct, testing procedures and scoring practices. The PI also completed 8 calibration cases with satisfactory results achieving certification to administer and score the AHA.

Secondary outcomes measures included body function/structure measures (Range of Motion, the Modified Ashworth Scale, The Modified Tardieu Scale, Proprioception, Stereognosis, and Grip Strength) and three other activity and participation measurements (The Melbourne Assessment of Uni-lateral Hand Function, The Canadian Occupation Performance Measure, and The Children's Assessment of Occupation and Enjoyment).

Assessment of Body Function/Structure

Modified Ashworth Scale. The Modified Ashworth (MAS) quantifies increased muscle tone as the degree of resistance to passive stretch on an ordinal scale of 0-4 (lower score represents less tone) (Bohannon & Smith, 1987). The muscle groups that were tested included the elbow flexors and the wrist flexors of the involved upper extremity. The PI completed hospital based training provided by Dr. Mauricio Delgado to enhance intra- and inter-rater reliability of the MAS.

Modified Tardieu Scale. The Modified Tardieu Scale measures spasticity by comparing passive stretch at two velocities (fast and slow) providing the rater with a spasticity angle and spasticity grade. The spasticity grade is rated on an ordinal scale of 0-4 (lower score represents less spasticity) (Gracies et al., 2010). The muscle groups tested included elbow flexors and wrist flexors of the involved upper extremity. The PI completed hospital based training by Dr. Mauricio Delgado to enhance intra- and inter-rater reliability of the Modified Tardieu Scale.

Active and Passive Range of Motion. Active and passive range of motion was measured with a standard goniometer at the following joints: wrist (flexion and extension 0-70 degrees), forearm (supination and pronation 0-80 degree), elbow (flexion and extension 0-150 degrees) and shoulder (flexion/extension/abductions/adduction 0-180 degrees). The involved upper extremities were tested.

Proprioception. The PI evaluated proprioception using five trials each of passive movement of the index MCP joint and the wrist with the participant's vision occluded (Cope et al., 2010). The involved upper extremity was tested.

Stereognosis. Stereognosis was evaluated using 10 common objects (ball, spoon, coin, paper clip, paintbrush, rubber band, scissors, crayon, toothbrush and block). With vision occluded, participants were asked to identify the object using their hand (Klingels et al., 2010; Feys et al., 2005). The involved hand was assessed.

Grip Strength. Grip strength was measured using a JAMAR hand dynamometer model number (Model PC-5030J1) according to the manufacturer's instructions. Participants were assessed for a maximum voluntary contraction during three trials for hand grasp with the arm adducted and elbow flexed and 90 degrees. Bilateral hands were assessed.

Activity and Participation

The Melbourne Assessment of Unilateral Upper Limb Function (MUUL). The MUUL (Johnson et al., 1994) is a valid and reliable tool for evaluating quality of upper limb movement including movement range, accuracy, dexterity and fluency in children with neurological conditions (cerebral palsy) aged 2.5-15 years. The MUUL was chosen to assess quality of unilateral hand function (Johnson et al., 1994). This is a videotaped assessment. Only the involved upper extremity was evaluated. A change score of twelve points or more represents a clinically significant change in uni-manual performance (Randal, Johnson, & Reddihough, 1999).

Canadian Occupation Performance Measure (COPM). The COPM (Law et al., 1990) is an individualized, client-centered outcome measure designed for use by occupational therapists to detect change in a subject's self-perception of occupational performance over time. The COPM is a valid and reliable tool designed for use with participants with a variety of disabilities and across all developmental levels. The PI interviewed the participant and the family to identify up to five goals from participating in the augmented mCIMT camp. The subject then ranked his/her performance and satisfaction of each identified goal at baseline and at the conclusion of the augmented mCIMT camp. A change score of 3 points or more represents a clinically significant change in the participant's performance and satisfaction.

Children's Assessment of Participation and Enjoyment (CAPE). The CAPE (King et al., 2004) is a questionnaire-based assessment completed by self-report or by interview that measures various aspects of participation and engagement in activities for clients aged 6-21 years. The activities are organized into five activity types including recreational, active-physical, social, skill based, and self-improvement. The CAPE can be used for intervention planning and measuring outcomes. The family of the participants completed the questionnaire by self-report. The CAPE was only given at baseline due to assessment recommendation not to assess again until at least four months later. The results of the CAPE were used to identify activities and interests of the participants to be used during the camp.

Part B: Comparative Study Examining Effects of the Armeo®Spring Pediatric within a mCIMT Camp

A comprehensive review of existing data that was charted on eight patients with hCP that completed the 2012 and 2013 CIMT camps at TSRHC was completed. The retrospective data that was reviewed was charted and approved for research purposes under an IRB approved protocol with Dr. Mauricio Delgado as the PI (#032012-001). The charts were reviewed for date of birth, age during camp, sex, side of hemiplegia, cause for hemiplegia, seizure history, MACS level, and baseline and post assessment results. Data fields were determined based on previous CIMT studies (Aarts et al., 2010; Brandao et al., 2010; Case-Smith et al., 2012).

A comparative study was designed using the data collected in the study of the augmented CIMT camp (2014) with Armeo®Spring Pediatric and the retrospective chart review of mCIMT camps from 2012 and 2013. Results from the 2012/2013 and 2014 camps were compared to examine outcomes. The end points of comparison were measures assessed at the body structure/function level using: (1) the Modified Ashworth Scale, (2) the Modified Tardieu Scale, (3) active and passive range of motion, (4) proprioception, (5) stereognosis and (6) grip strength. The measures at the activity and participation level included: (1) AHA, (2) MUUL, and (3) COPM (Appendix E

Assessment Protocol). The goal of this study was to examine the impact of using the Armeo®Spring Pediatric combined with CIMT on upper extremity function in children with hemiplegic CP.

Part C: Observed Experiences of Participants

The data from the 2012 and 2013 mCIMT camps were limited to scores from standardized assessment tools. The 2014 mCIMT camp included an additional qualitative component. The PI recorded observations on four different areas during the participants' use of the Armeo®Spring Pediatric and fine motor stations of the CIMT camp (Patton, 2002). The fine motor stations provided similar intensity of use of the affected arm as the Armeo®Spring Pediatric.

Observations were based on motivation to participate, engagement in the activity, enjoyment, and frustration. The Likert-type scale (Clarson & Dormody, 1994) included one = not at all, two = only a little, three = some, and 4 = a lot. Any comments the participant made about the specific fine motor activities and the Armeo®Spring Pediatric during the observation period were also documented (Appendix F Observation Tool). Observations were recorded on Tuesday and Thursday each week of camp. Two observations each week provided sufficient data and took in account for consideration of novelty effect of the Armeo®Spring Pediatric. In order to control for validity, a second OT (who co-lead the camp with the PI) also documented her observations at the same time of the PI. Prior to camp, the PI and OT reviewed the Likert-type scale in order to establish an understanding of the terms. The goal of this study was to examine the participant's experiences (motivation, engagement, enjoyment and frustration) while using the Armeo®Spring Pediatric compared to experiences while performing the fine motor stations.

Data Analysis

Part A: Clinical Effectiveness of a Modified CIMT Camp with Armeo®Spring Pediatric Training

The purpose of Study A was to examine the effectiveness of the Armeo®Spring with mCIMT on bi-lateral hand/arm function and participation in children with hCP. To examine pre-test and post-test scores on the AHA, Melbourne, COPM Performance, COPM Satisfaction, Grip Strength and Stereognosis, descriptive statistics (mean and standard deviation) were generated. A Wilcoxon signed-rank test was conducted to test for differences. A Wilcoxon signed –rank test was chosen due to the small sample size (Zhan & Ottenbacher, 2001). All statistical analyses were conducted with IBM SPSS Statistics19.0 (SPSS, Inc.). The significance level was $p < .05$.

Part B: Comparative Study Examining Effects of the Armeo®Spring Pediatric within a mCIMT Camp

The purpose of Study B was to examine the effectiveness of the 2012/2013 mCIMT camps (without Armeo®Spring) on bi-lateral hand/arm function and participation in children with hCP. To examine pre-test and post-test scores on the AHA, MUUL, COPM Performance and Satisfaction, Stereognosis, and Grip Strength, descriptive statistics (mean and standard deviation) were generated, and a Wilcoxon signed-rank test was conducted to test for differences. A Wilcoxon signed –rank test was chosen due to the small sample size (Zhan & Ottenbacher, 2001).

A second purpose of Study B was to determine whether use of the Armeo®Spring resulted in greater improvement in bi-lateral hand/arm function and participation in children with hCP attending a mCIMT camp compared to those attending a mCIMT camp without Armeo®Spring. A Mann Whitney U test was used to compare the improvement in pre/post test scores for the AHA, MUUL, COPM Performance and Satisfaction, Stereognosis, and Grip Strength between children that received Armeo®Spring training with mCIMT and those that received only mCIMT. All statistical analyses were conducted with IBM SPSS Statistics19.0 (SPSS, Inc.). The significance level was $p < .05$.

Part C: Observed Experiences of Participants

Descriptive statistics were used to analyze the observational data. Mean scores were determined from Likert-type scales of the Armeo®Spring. Mean scores were also examined on the fine motor station activity component of the 2014 augmented mCIMT camp. Participants' comments were reviewed and summarized for content.

CHAPTER IV

RESULTS

Part A: Augmented mCIMT Camp with Armeo®Spring Pediatric

Participants

One hundred twenty-one children diagnosed with hemiplegic CP were available in the facility's active patient database. Twenty-nine children met the previously stated inclusion criteria and were contacted. Twenty-one families expressed interest in attending the 2014 augmented mCIMT camp. Families reported various reasons for not being able to attend the 2014 augmented mCIMT camp (driving distance to the hospital, vacation schedules, logistics of picking up/dropping off with other siblings and not being able to commit to the full two weeks of camp). Four children met the inclusion criteria and enrolled in the study to participate in the augmented 2014 mCIMT camp with Armeo®Spring Pediatric (Table 1).

Table 1

Participant Demographics of the Two Groups

Variable	**2014 Augmented mCIMT Group**	**2012/2013 mCIMT Group**
Number	4	8
Mean Age (Age Range)	8y6m (6-11y)	10y2m (8-11y)
Boys	2	6
Right Side Affected	4	3
History of Seizures	1	3
Etiology		
Periventricular Leukomalacia (PVL)	1	1
Prematurity	1	0
Unkown	1	1
Cerebral Artery Infarct	0	1
Hemispheric Infarct	0	1
Hemispherectomy	0	1
Hypoplastic hemisphere	0	1
Congenital Brain Malformation	1	0
MACS Level 1	0	2
MACS Level II	3	6
MACS Level III	1	0

Note. MACS = Manual Abilities Classification System.

The mean age of the participants for the augmented group was 8 years 6 months (range 6-11 years). All four had a right-sided hemiplegia. There were two males and two females. According to the MACS (Eliasson et al., 2006), none of the children were classified as MACS Level I, three were Level II, and one was Level III. Etiology of their hemiplegia included periventricular leukomalacia (PVL), prematurity, unknown, and congenital brain malformation. One participant had a history of seizures.

Compliance

All four children participated in the full mCIMT camp receiving ten days of treatment with ten daily 30 minutes sessions on the Armeo®Spring Pediatric.

Primary Outcome Measure

The Wilcoxon signed-rank test was conducted to examine differences in the mean pre-test and post-test scores on the AHA in children who attended the 2014 augmented mCIMT camp with Armeo®Spring. The Wilcoxon signed rank test revealed no significant changes on the AHA (Z = -1.826, p = .06). However, the mean difference on the AHA between baseline and after intervention was 7.00 units (SD = 1.83). According to the AHA testing manual (Krumlinde-Sundholm, 2012), a clinically significant change in the AHA is a change ≥ 5 logits. Thus, these results indicate a clinically significant change in bi-manual performance following mCIMT camp with Armeo®Spring. These results should be interpreted with caution due to small sample size.

Secondary Outcome Measures

The Wilcoxon signed-rank test was conducted to determine differences between mean pre-test and post-test scores for Grip Strength and Stereognosis in children who attended the 2014 augmented mCIMT camp with Armeo®Spring. No statistically significant changes were found in Grip Strength (Z = -1.83, p = .06) or Stereognosis (Z = -1.34, p = .10). Upper extremity range of motion, tone, and proprioception remained largely unchanged in all participants and therefore are not described in detail but can be found in Table 2.

Table 2

Body Structures/Functions: Baseline and Post Intervention Individual Measurements of Involved Extremity

Participant ID		Shoulder		Elbow		Wrist		Forearm	
		Base-line	Post	Base-line	Post	Base-line	Post	Base-line	Post
2014 Armeo									
1	PROM	0-180	0-180	0-150	0-150	70	70	80	80
	AROM	0-180	0-180	0-150	0-150	Neutral	Neutral	45	45
	MAS			1+	1+	1+	1+		
	TS			1	1	1	1		
2	PROM	0-180	0-180	0-150	0-150	0-70	0-70	80	80
	AROM	0-180	0-180	-25-150	-10-150	20	20	45	45
	MAS			1+	1	1	0		
	TS			2 (90)	0	1	0		
3	PROM	0-180	0-180	0-150	0-150	70	70	80	80
	AROM	0-180	0-180	0-150	0-150	Trace	Trace	45	45
	MAS			1+	1	1	0		
	TS			2(90)	2 (90)	0	0		
4	PROM	0-180	0-180	0-150	0-150	70	70	80	80
	AROM	0-180	0-180	-10-150	-10-150	20	20	80	80
	MAS			1	1	1+	1+		
	TS			2 (90)	2 (90)	1	1		
2013 mCIMT									
5	PROM	0-180	0-180	0-150	0-150	70	70	80	80
	AROM	0-180	0-180	0-150	0-150	70	70	80	80
	MAS			1	1	1+	1		
	TS			1	1	2 (0)	1		
6	PROM	0-180	0-180	0-150	0-180	45	45	80	80
	AROM	0-180	0-180	-10-150	-5-150	25	25	80	80
	MAS			1	1	1+	1		
	TS			1	1	2 (0)	1		
7	PROM	0-180	0-180	-15-150	-10-150	20	20	70	65
	AROM	0-180	0-180	-25-150	-15-150	-20	-20	No Active	No Active
	MAS			1+	1+	1+	1+		
	TS			2 (90)	2 (90)	2 (45)	2 (45)		
8	PROM	0-180	0-180	0-15-	0-150	70	70	80	80
	AROM	0-180	0-180	0-150	0-150	20	25	30	50
	MAS			1+	1	1+	1+		
	TS			2 (90)	2 (90)	2 (-20)	2 (-30)		
2012 mCIMT									
9	PROM	0-160	0-160	0-180	0-180	70	70	80	80
	AROM	0-160	0-160	-30-150	-15-130	35	35	40	50
	MAS			1	1	0	0		

	TS			1	1	0	0		
10	PROM	0-180	0-180	0-150	0-150	70	70	80	80
	AROM	0-180	0-180	-20-150	-20-150	-35	-20	50	75
	MAS			1+	1	1	1		
	TS			2 (90)	2 (90)	1	1		
11	PROM	0-180	0-180	-10-150	-10-150	0-70	0-70	80	80
	AROM	0-160	0-160	-45-150	-40-150	80-Neutral	80-Neutral	Neutral	Neutral
	MAS			1+	1+	1+	1		
	TS			2 (60)	2 (90)	2 (0)	1		
12	PROM	0-180	0-180	0-150	0-150	70	70	80	80
	AROM	0-180	0-180	-5-150	0-150	-15	Neutral	-30	Neutral
	MAS			0	0	1	0		
	TS			0	0	1	1		

Note. PROM = passive range of motion; AROM = active range of motion; MAS = Modified Ashworth Scale; TS = Modified Tardieu Scale (angle where there was a catch). Participants 1-4 were included the 2014 Armeo®Spring mCIMT group. Participants 5-8 were included in the 2013 mCIMT group. Participants 9-12 were included in the 2012 mCIMT group.

The Wilcoxon signed-rank test was conducted to determine the differences between mean pre-test and post-test scores on the Melbourne, COPM Satisfaction and Performance who attended the 2014 augmented mCIMT camp with Armeo®Spring. No statistically significant changes were found on the Melbourne (Z = -1.83, p = .06), the COPM Satisfaction (Z = -1.64, p = .10), and the COPM Performance subsection (Z = -1.63, p = .10).

Due to the small sample size, statistical results should be interpreted with caution. All participants from the 2014 augmented mCIMT camp made improvements on their individual post-test scores when compared to their individual pre-test scores. However, the small sample size made it difficult to determine statistical significance in the overall means between pre-test and post-test scores. See Table 2 for detailed results of individual test scores.

Participant 1 - 2014 Camp with Armeo®Spring

Participant 1 was a 6-year-old female with right-sided-hemiplegia due to Periventricular Leukomalacia (PVL). She was classified as MACS Level II. She completed the augmented mCIMT camp including 10 thirty minute sessions on the Armeo®Spring Pediatric. A change score of six points (57-63) on the primary outcome measure, the AHA, suggested a true change in bi-manual performance. There was no clinically significant change in uni-manual performance on the MUUL (100-102). On the COPM, the Performance Subtest of her selected goals was a 3 at baseline and an 8.2 post intervention. Similarly, on the Satisfaction Subtest of the COPM, she reported a 3 and then 9.2. Both of these scores reflected a clinically significant change according to the test manual. She identified all items (10) on stereognosis at baseline and post intervention. Grip strength improved from .5 to 3.3 pounds.

Participant 2 - 2014 Camp with Armeo®Spring

Participant 2 was an 11-year- old female with right-sided hemiplegia due to prematurity and MACS Level II. On the AHA, the primary outcome measure, she improved from a 73 at baseline to 78-post camp indicating a true change in bi-manual performance (5 logit points or greater). On the MUUL, she improved 14 points (92-106), which is considered clinically significant according to the test manual. On the COPM, her Performance score at baseline was 3 and 8.4 post intervention. Her COPM Satisfaction score improved 4.2 points (5.2- 9.4). She identified 10 out of 10 items on the stereognosis test both at baseline and post intervention. Her grip strength at baseline was 8 pounds and 14 pounds following the intervention.

Participant 3 - 2014 Camp with Armeo®Spring

Participant 3 was a 10-year-old male with right-sided hemiplegia due to unknown etiology and also included a neonatal Volkman's contracture. He was classified as a MACS Level III and had a remote history of seizures. He attended the full augmented mCIMT camp. His AHA (primary outcome measure) score improved 9 points (37-46) and indicated a true change of bi-manual performance. A six-point change (77-83) on the MUUL was not considered clinically significant. Both his Performance and Satisfaction scores on the COPM (4.6-8.3, 4.6-3.4) indicated a clinically significant change of his identified goals. He identified only 3 objects on the stereognosis at baseline and post intervention identified 6. His grip strength improved from 1.5 pounds to 5 pounds.

Participant 4 - 2014 Camp with Armeo®Spring

Participant 4 was a 7-year-old male with right-sided hemiplegia due to a congenital brain abnormality. He was classified as a MACS Level II with no history of seizures. He attended all sessions of the augmented mCIMT camp. An 8-point change (62-70) on the AHA (primary outcome measure) indicated a true change in bi-manual performance. On the MUUL a 22-point change (72-94) was observed. This demonstrated a clinically significant change in uni-manual performance as well. This participant struggled with the rating scale of the COPM so his mother ranked the scores (Performance 6.4-8, Satisfaction 6.5-10). He identified 8 items on the stereognosis test at baseline and all 10 items post intervention. His grip strength improved from 0 .5 pounds to 5 pounds at the conclusion of the mCIMT camp.

Part B: Comparative Study Examining Effects of the Armeo®Spring Pediatric within a mCIMT Camp

Chart reviews from the participants in the mCIMT camp (without ArmeoSpring training included) yielded four 2012 camp participants and four in the 2013 camp. The mean age of the participants was 10 years 2 months (range 8y-11y); three had right-sided hemiplegia (3M, 0F), and five had left-sided hemiplegia (3M, 2F). Children were classified as MACS Level I (n = 2) and Level II (n = 6). Three participants had a history of seizures. Etiology of their hemiplegia was also varied. See Table 1 for additional detail.

Primary Outcome Measure

The Wilcoxon signed-rank test was conducted to examine differences in the mean pre-test and post-test scores on the AHA in children who attended the 2012/2013 mCIMT camps. The Wilcoxon signed rank test revealed significant changes on the AHA (Z = -.2.02, p = .04). The mean difference on the AHA between baseline and after intervention was 2.38 units (SD = 3.07). According to the AHA manual, this does not indicate a clinically significant change in bi-manual performance.

The Mann-Whitney U test was conducted to compare the change in pre-test and post-test scores between the augmented 2014 mCIMT camp (with Armeo®Spring training) and the 2012/2013 mCIMT camps (without Armeo®Spring training). The Mann-Whitney U test determined the improvement in the AHA was statistically higher for the 2014 mCIMT with Armeo®Spring group compared to the 2012/2013 mCIMT without Armeo®Spring group (U = 28.5, p = .03).

Secondary Outcome Measures

The Wilcoxon signed-rank test was conducted to determine differences between mean pre-test and post-test scores for Grip Strength and Stereognosis in children who attended the 2012/2013 mCIMT camps. Statistically significant increases in Grip Strength were found ($Z = -2.13$, $p = .03$). No statistically significant differences were found in Stereognosis ($Z = -1.83$ $p = .06$). Upper extremity range of motion, tone, and proprioception remained largely unchanged in all participants and therefore are not described in detail but can be found in Table 2.

The Wilcoxon signed-rank test was conducted to determine the differences between mean pre-test and post-test scores on the Melbourne, COPM Satisfaction and Performance who attended the 2012/2013 mCIMT camps. Statistically significant improvements were found on the Melbourne ($Z = -2.37$, $p = .02$), the COPM Satisfaction ($Z = -2.5$, $p = .01$), and the COPM Performance subsection ($Z = -2.56$, $p =.01$).

The Mann-Whitney U test was conducted to compare the improvements between participants in the augmented 2014 mCIMT camp (with Armeo®Spring training) and participants in the 2012/2013 mCIMT camps (without Armeo®Spring training). No statistical significant differences were found on the Melbourne (U = 28.5, $p = .28$), COPM Performance ($U = 16.5$, $p = 1$), COPM Satisfaction ($U = 11.5$, $p = .46$), Stereognosis ($U = 14.5$, $p = .81$), Grip Strength ($U = 20$, $p = .57$).

The individual scores of participants in the 2012/2013 mCIMT camp remained either unchanged or showed some improvement. There were statistically significant changes as a group on the AHA, Melbourne, COPM Performance and Satisfaction, and Grip Strength. Table 3 contains detailed individual scores for each outcome measure. The Mann-Whitney U test determined the improvement in the AHA was statistically higher for the 2014 mCIMT with Armeo®Spring group compared to the 2012/2013 mCIMT without Armeo®Spring group. The following presents the individual results for the 2012 and 2013 participants.

Table 3

Activity/Participation Outcome Measures Pre and Post Intervention

Participant ID	AHA			MUUL			COPM-Performance			COPM-Satisfaction			Stereognosis			Grip Strength (lbs)		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
2014 Armeo																		
1	57	63	6*	100	102	2	3	8.2	5.2*	3.2	9	5.8*	10	10	0	.5	3.3	2.8
2	73	78	5*	92	106	14*	3	8.4	5.4*	5.2	9.4	4.2*	10	10	0	8	14	6
3	37	46	9*	77	83	8	4.6	8.3	3.7*	4.6	7.3	2.7	3	6	4	1.3	5	3.7
4	62	70	8*	72	94	22*	1.8	6.4	4.6*	1.6	6.5	4.9*	8	10	2	.5	5	4.5
2013 mCIMT																		
5	86	86	0	117	117	0	3.7	5.7	2	3.7	8	4.3*	10	10	0	13.3	18.7	5.4
6	62	64	2	110	111	1	4.3	6.7	2.3	3.7	6.3	2.7	10	10	0	8	13.6	5.6
7	41	41	0	64	86	22*	6.7	7.5	.8	5	7.8	2.8	10	10	0	5	6	1
8	30	39	9*	74	76	2	1.7	4.3	2.6	4.3	5.7	1.3	4	8	4	2.7	3.3	.7
2012 mCIMT																		
9	57	57	0	58	72	14*	2.8	7.2	4.4*	1.2	7.4	6.2*	2	10	8	1.6	5.6	4
10	66	69	3	54	69	5	4	10	6*	4	10	6*	9	10	1	5.6	8.3	2.7
11	53	54	1	45	59	14*	2.8	7.3	4.5*	3	7.8	4.8*	4	4	0	1.3	2	.7
12	58	62	4	50	74	14*	3.4	7.6	4.2*	3	8.2	5.2*	7	10	3	8	14	6

Note. AHA; Assisting Hand Assessment, MUUL; Melbourne Assessment of Unilateral Hand Function, COPM; Canadian Occupation Performance Measure. * Represents a clinically significant change according to testing manual. Participants 1-4 were included in the 2014 Armeo®Spring mCIMT camp. Participants 5-8 were included in the 2013 mCIMT camp. Participants 9-12 were included in the 2012 mCIMT camp.

Participant 5 - 2012 mCIMT Camp

Participant 5 was a 12-year-old male with right-sided hemiplegia. He was classified as MACS Level I with an unknown etiology. He attended the mCIMT camp in 2012. Both his AHA (86) and MUUL (117) remained unchanged. On the COPM, he identified a score of 3.7 on the Performance subtest at baseline and 5.7- post intervention. His COPM Satisfaction score at baseline was 3.7 and 8 post-intervention. He identified 10 out of 10 items on the stereognosis test before and after the mCIMT camp. His grip strength improved from 13.3 pounds to 18.7 pounds.

Participant 6 - 2012 mCIMT Camp

Participant 6 was a 12-year-old male with left-sided hemiplegia due to Intraventricular Hemorrhage. He was classified as a MACS Level I. He attended mCIMT camp in 2012. He yielded a 2-point difference on AHA (62-64). His MUUL scored increased 1 point remained virtually unchanged (110-111). His Performance score on the COPM improved from 4.3 to 6.7 and his COPM Satisfaction score improved from 3.7 to 6.3. He also identified 10 out of 10 items on stereognosis assessment before and after the mCIMT camp. His grip strength improved 8 pounds to 13.6 pounds.

Participant 7 - 2012 mCIMT Camp

Participant 7 was a 12-year-old male with right-sided hemiplegia due to left middle cerebral artery infarct. He was classified as a MACS Level II with remote history of seizures. He attended all sessions of the mCIMT camp in 2012. His AHA score did not change (41), however, on the MUUL a 22-point change (64 to 86) was observed. This demonstrated a clinically significant change in uni-manual performance. His COPM Performance score was not clinically significant (6.75-7.5), however, his COPM Satisfaction score was (5-7.75). He identified 10 out of 10 items on the stereognosis both at baseline and post intervention. His grip strength remained relatively unchanged from 5 pounds to 6 pounds.

Participant 8 - 2012 mCIMT Camp

Participant was a 12-year-old male with left-sided hemiplegia due to a hemispherectomy to reduce seizure frequency. He was classified as a MACS Level II. He attended all sessions of the mCIMT camp in 2012. He demonstrated a true change on his AHA from a 34 to 41. His uni-manual performance remained unchanged on the MUUL with a score of 74 at baseline and 76 post-intervention. His COPM scores were mixed with his Performance at 1.7 and then 4.3 (significant) and his Satisfaction score 4.3 and 5.7 which was not considered significant. He identified 4 objects at baseline and 8 post-intervention. His grip strength improved from 2.7 pounds to 3.3 pounds.

Participant 9 - 2013 mCIMT Camp

Participant 9 was an 8-year-old male with right-sided hemiplegia due to a hypoplastic hemisphere. He was classified as MACS Level II with a remote history of seizures. He attended all sessions of mCIMT camp in 2013. His AHA score (57) remained unchanged from baseline to post mCIMT camp. His score on the MUUL, however, changed from 58 to 72, which was clinically significant. His COPM Performance score at baseline was 2.8 which improved to 7.2. His COPM Satisfaction score improved from 1.2 to 7.4, which was clinically significant. He identified only 2 objects before the intervention and was able to identify all 10 objects following participation in the mCIMT camp. His grip strength improved by 4 pounds from 1.6 to 5.6 pounds.

Participant 10 - 2013 mCIMT Camp

Participant 10 was an 11 year-old female with left-sided hemiplegia due to PVL. She was classified as a MACS Level II. She attended all sessions of the 2013 mCIMT camp. She demonstrated a 3-point change on the AHA, and 13-point change on the MUUL. Her COPM Performance and Satisfaction scores changed 6 points from a score of 4 to 10 on both. She identified 9 of the items before the intervention and 10 post participation of the mCIMT camp. Her grip strength improved from 5.6 pounds to 8.3 pounds.

Participant 11 - 2013 mCIMT Camp

Participant 11 was an 8-year-old female with left-sided hemiplegia due to right-sided hemispheric infarct. She was classified as a MACS Level II. She attended all sessions of the 2013 mCIMT camp. On the AHA, her score remained relatively unchanged from a 53 at baseline to 54 post-camp. On the MUUL, she improved 14 points (54-69). On the COPM, her Performance score at baseline was 2.8 and 7.3 post intervention, and her COPM Satisfaction score improved 3 to 7.8. She identified 4 items both at baseline and post intervention on the stereognosis test. Her grip strength was 2 pounds at baseline and 1.3 pounds following the intervention.

Participant 12 - 2013 mCIMT Camp

Participant 12 was an 8-year-old male with left-sided hemiplegia due to Grade 4 Intraventricular hemorrhage. He was classified as a MACS Level II. He attended all sessions of the 2013 mCIMT camp. A 4-point change (58-62) on the AHA did not indicate a true change in bi-manual performance. On the MUUL a 24-point change (50-74) was observed. This demonstrated a clinically significant change in uni-manual performance. His rankings on the COPM indicated clinically significant changes (Performance 3.4-7.6, Satisfaction 3-8.2). He identified 7 items on the stereognosis test at baseline and all 10 items post mCIMT camp. Grip strength improved from 8 pounds to 14 pounds following the intervention.

Part C: Observed Experiences of Participants in the 2014 Camp

The PI and the previously identified experienced occupational therapist recorded observations for the 2014 mCIMT participants using the Armeo®Spring Pediatric and participating in the fine motor station component of camp. The observations were recorded on the Observation Data Collection Tool (Appendix F Observation Data Tool). The observations occurred on Tuesday and Thursday each of the two weeks of camp. Observations were completed by the PI and another occupational therapist with more than 20 years combined experience treating children having hCP. The therapists observed the participants simultaneously. There were a total of eight observations for the Armeo®Spring Pediatric and eight observations for the fine motor station component of the augmented mCIMT camp. The scores were calculated and the Mean (*M*) is reported.

(Tables 3 and 4 and Figure 1) The Likert-type scores range from 1= Not at all, 2 = A little, 3 = Some, 4 = A lot. Due to small sample size, each participant's results are presented in the following:

Table 4

Average Scores (Mean) of Observation Individual Scores: Armeo®Spring Pediatric

Subject ID	Motivation	Engagement	Enjoyment	Frustration
1	4	4	4	1.5
2	2.8	3.2	2.5	2
3	3.9	3.9	3.9	2.4
4	4	4	4	1.6

Note. Likert Scale 1= Not at all, 2 = A little, 3 = Some, 4 = A lot Scores are averages from two therapists based on 4 observations throughout camp.

Table 5

Average Score (Mean) Observation Individual Scores: Fine Motor Tasks

Subject ID	Motivation	Engagement	Enjoyment	Frustration
1	3	3.9	3.5	1.7
2	3.6	3.8	3.6	1.4
3	3	3	2.3	2.3
4	2	2.5	2.3	1.8

Note. Likert Scale- 1= Not at all, 2 = A little, 3 = Some, 4 = A lot
Scores are averages from two therapists based on 4 observations throughout camp.

Participant 1 - 2014 Camp with Armeo®Spring

Participant 1's mean scores on the Observation Data Tool were high on Motivation (*M* = 4), Engagement (*M* = 4), and Enjoyment (*M* = 4). Her frustration level was *M* = 1.5 which is between none and a little. She appeared to enjoy the Armeo®Spring. Her comments included, "I like this (Armeo®Spring Pediatric) a lot." "The snowflake game is my most favorite."

Her mean scores during the fine motor stations were Motivation (*M* = 3), Engagement (*M* = 3.9), and Enjoyment (*M* = 3.5). Her frustration level was *M* = 1.7 which was also between none and a little. During the fine motor stations comments included "I'm getting tired of squeezing.", "I like this bottle game", "Look at this awesome caterpillar I made with the play dough."

Participant 2 - 2014 Camp with Armeo®Spring

Participant 2's scores on the Observation Data Tool during the Armeo®Spring training were; Motivation (*M* = 2.8), Engagement (*M* = 3.2), and Enjoyment (*M* = 2.5). Her frustration level was *M* = 2. Her comments on the Armeo®Spring included "this (Armeo®Spring) is frustrating", "The puzzle is frustrating."

Participant 2's scores on the fine motor stations were a little higher than those on the Armeo®Spring Pediatric; Motivation (*M* = 3.6), Engagement (*M* = 3.8), and Enjoyment (*M* = 3.6). Her frustration level was *M* = 1.4. On the fine motor stations her comments included "I did it in less than 5 seconds".

Participant 3 - 2014 Camp with Armeo®Spring

During the Armeo®Spring Pediatric training, participant 3 scored the following; Motivation (*M* = 3.9), Engagement (*M* = 3.9), and Enjoyment (*M* = 3.9). His frustration level was *M* = 2.4, which is between a little and some. He appeared to have mixed reviews on the Armeo®Spring Pediatric with the following comments. “These games are old…This is hard, and “ I am an excellent driver. I love this racing car game so much!” “ I am awesome at video games”.

On the fine motor stations, he scored the Motivation (*M* = 3), Engagement (*M* = 3), and Enjoyment (*M* = 2.3). His frustration level was *M* = 2.4. He made no comments during the observation period on the fine motor tasks.

Participant 4 - 2014 Camp with Armeo®Spring

Participant 4 scored a *M* = 4 on the Motivation, Engagement and Enjoyment sections and a *M* = 1.6 on the Frustration section. He appeared to enjoy the Armeo®Spring Pediatric with the following comments. “I like the video games better than playing with the pennies.” “This race-car game is so much fun!”, “I love that I am so awesome at this racing game!”.

The observation mean scores for him during the fine motor station included Motivation (*M* = 2), Engagement (*M* = 2.5), and Enjoyment (*M* = 2.3). His frustration level was *M* = 1.8. During the fine motor stations he made no specific comments, but there was a note that he was engaged with the staff and not the fine motor activities.

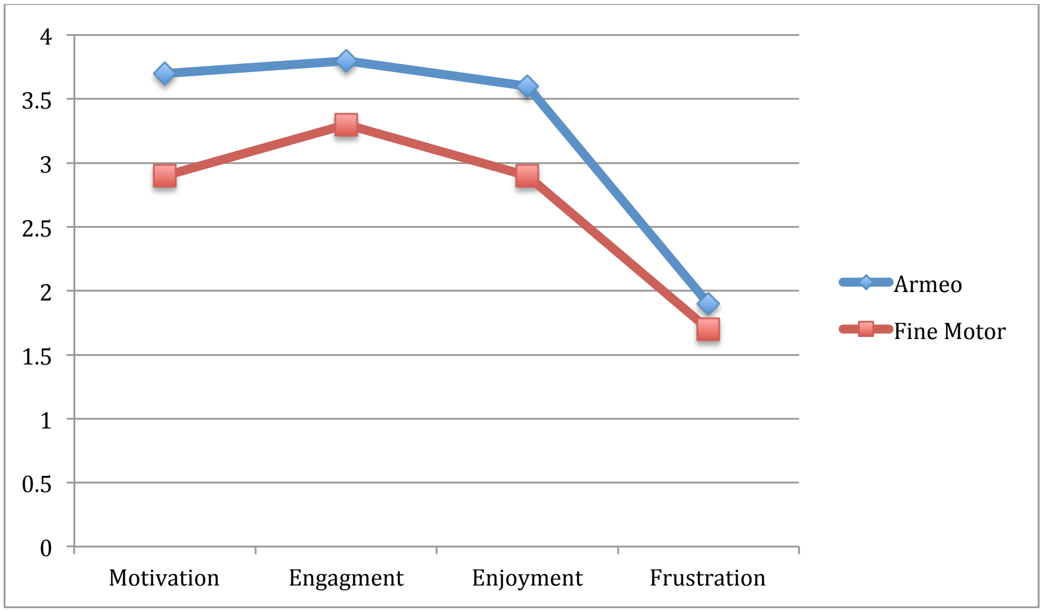

Figure 1. Group mean scores of Observation Scale of Armeo®Spring Pediatric compared to fine motor tasks

CHAPTER V

DISCUSSION

The studies in this dissertation were completed to determine the effects of a two week modified constraint induced movement therapy (mCIMT) camp that incorporated Armeo®Spring Pediatric training for children with hCP. The first hypothesis was hand function and participation in children with hemiplegic CP will improve following a mCIMT intervention augmented with the Armeo®Spring Pediatric in a camp setting. The second hypothesis was hand function and participation will demonstrate greater improvements in children with hemiplegic CP who received the augmented mCIMT intervention with the Armeo®Spring Pediatric. Finally, the third hypothesis was that participants will display increased engagement, motivation, enjoyment and decreased frustration during use of the Armeo®Spring Pediatric compared to the fine motor stations of the augmented mCIMT intervention.

Part A: Clinical Effectiveness of a Modified CIMT Camp with Armeo®Spring Pediatric Training

This dissertation is the first to report on the efficacy of the use of Armeo®Spring Pediatric training during a mCIMT camp for children with hCP. On the primary outcome measure, the AHA, all four children demonstrated clinically (a change score of 5 logits or greater) significant improvements in bimanual performance (Figure 1). These results indicate that the Armeo®Spring Pediatric may be a promising rehabilitation tool to improve bimanual performance in children with hemiplegic cerebral palsy.

Other outcome measures demonstrated a positive change. The COPM Performance and Satisfaction scores indicated clinically significant changes for all four participants. The participant and the parent participated in a semi-structured interview conducted by the PI. The participant identified goals as areas in which he/she wished to improve. The COPM goals were identified by the participants. One child needed assistance from his/her mother. The goals ranged from self-care (zipping or buttoning a coat) to leisure (jumping rope and shooting a basketball). The process of creating individualized goals that are meaningful to the participant may result in the perception of improved performance.

A positive effect on the MUUL was found in all four participants. Two participants (#2 and #4) demonstrated a change of at least 12 points. This indicates a clinically significant change in uni-lateral hand performance according to the test manual. Participant #2 and #4 were classified as a MACS Level II. Participant #2 had the highest starting score on the AHA, indicating she was the least involved. Her uni-manual performance may have improved because she had more skills to work with and the therapist was able to control how the affected hand was used. Participant #4 was observed as having the highest scores on the Arme®Spring Pediatric for motivation, engagement, and enjoyment. His increase on the MUUL could be attributed because he was engaged, focused, and motivated during his time on the machine. He may have been so immersed on the Armeo®Spring, that he was able to complete more repetitions than his peers thus improving his scores.

Grip strength improved in participants in both the 2012/2013 mCIMT camp and the 2014 augmented mCIMT camp with Armeo®Spring. Stearns et al. 2009 completed similar research on grip strength during a 2-week function based mCIMT camp. Stearns's research incorporated the same protocol for measuring grip strength that this study utilized. Stearns measured grip strength using a Jamar®Hydraulic Hand Dynamometer with three grip measures recorded then averaged. His research also used similar standard positioning of the hand/arm for measures. The research in this dissertation supports Stearns's findings and provides more evidence that mCIMT camp is an effective tool for improving grip strength in children with hCP.

Although there has been no study to date that specifically used the Armeo®Spring Pediatric, Rostami et al. (2012) conducted a mCIMT camp augmented with virtual reality games (E-Link Evaluation and Exercise Sytem by Biometrics Ltd.) for children with hCP. Rostami et al. (2012) reported higher gains in the amount of time the affected limb was used, the quality of the affected limb's movement, and the speed and dexterity of the affected limb in children who participated in the augmented camp compared to children who participated in a mCIMT camp conducted without virtual reality games. However, outcomes measures used by Rostami et al. (2012) were limited to outcome measures from the body structures/function classification and were not validated for children with hCP. The research for this dissertation utilized a virtual reality component and outcome measures that included activity/participation level in addition to body/structures classification. Furthermore, the outcome measures used in the research for this dissertation are established tools that have been validated for children with hCP.

Part B: Comparative Study Examining Effects of the Armeo®Spring Pediatric within a mCIMT Camp

The research presented here reports significant improvement in bi-lateral hand/arm function and participation in children with hCP following mCIMT camp. Previous studies have also reported clinical changes following mCIMT (Aarts et al., 2010; Charles et al., 2006; Charles & Gordon, 2007; Eliasson et al., 2005; Hoare et al., 2007; Huang et al., 2009; Nascimento et al., 2009; Sakzewski et al., 2011; Smania et al., 2009). Unlike other studies, the research for this dissertation utilizes measurements from the body structures/function classification and the activity/participation classification. Results from this dissertation research yielded statistically significant gains in all areas except Stereognosis for children who participated in the 2012/2013 mCIMT camps (without Armeo®Spring). However, only one participant in those camps demonstrated a clinically significant change on the AHA. This is compared to clinically significant improvement on the AHA in all four participants who received Armeo®Spring training during the 2014 mCIMT camp. This may have been due to the participants in the 2012/2013 camp having a higher beginning score on the AHA. A higher beginning score would make it difficult to gain 5 logit points needed to demonstrate a clinically significant improvement.

Participants in the augmented mCIMT camp with Armeo®Spring Pediatric training showed significantly greater improvement in bimanual performance compared to participants in the traditional mCIMT group (U = 28.5 p = .03). These results are consistent with Rostami et al. (2012) who reported higher gains in hand/arm function in a combination group of mCIMT with virtual reality games over a mCIMT group or virtual reality group only. Other outcome measures of activity level showed no statistical differences between groups. At the body structure/function level, no statistical differences between groups could be demonstrated. Therefore, this study may provide evidence that the Armeo®Spring Pediatric might provide an even greater level of intensity than a traditional mCIMT camp resulting in improved bimanual performance. However, these findings are based on a nonrandomized design and should be interpreted with caution. A randomized controlled design with a larger sample size is needed to further investigate benefits of the Armeo®Spring Pediatric.

The treatment gains obtained may have resulted from a combination of the motor learning theory and client-centered treatment. Intensive practice with shaping was given throughout the treatment in order to promote the learning of motor skills. The pirate themed camp was designed to promote the children's engagement in functional and enjoyable activities. The focus was keeping the children active and engaged in using their affected arm throughout the duration of all the mCIMT camps.

Part C: Observed Experiences of Participants in the 2014 Camp

The third piece of this dissertation incorporated a qualitative portion, where the participants were observed on the Armeo®Spring Pediatric and during the fine motor tasks. Observations were taken on motivation, engagement, enjoyment and frustration and then ranked on a Likert-type scale (1 = not at all, 2 = a little, 3 = some, 4 = a lot). The observations from the Armeo®Spring Pediatric training demonstrated higher means on the motivation, engagement and enjoyment sections. These positive observations may have been due to the Armeo®Spring Pediatric being new with fun and colorful games. Although observations were made during both weeks of camp in hopes the novelty of the Armeo®Spring would have worn off. The participants made comments about enjoying the different games, specifically the race car game and the puzzles. The use of video games, cell phones, computers is a leisure activity for children today, with the average screen time of 13 hours per week (Gentile, 2009). Using the Armeo®Spring, with its virtual reality piece, compliments children's preferred activities. The Armeo®Spring or other commercially available virtual reality games (Wii, or Kinect) may be another rehabilitation tool to use as part of child's occupational therapy program.

The frustration score on the Armeo®Spring Pediatric (M = 1.9), may indicate that "just the right challenge" was created. The Armeo®Spring's workspace, degrees of freedom, and resistance was set for each child individually, allowing the child to work within his/her own capabilities. These levels were adjusted as the children made progress throughout the camp. The Armeo®Spring was able to continually be adjusted to provide that fine balance of creating that "just right challenge". This may have fostered a sense of independence and ownership over their therapy as the therapist was not providing the feedback, it was the technology. This may suggest that Armeo®Spring Pediatric provided the intensity of repetitive practice while keeping the children motivated, engaged and happy with an activity that is important and valued to them. These scores may suggest that utilizing video gaming type technology keeps children motivated and engaged while completing the monotonous repetitive activities required for neuroplasticity.

This is the first study to use the Armeo®Spring Pediatric. This study used a very standardized approach to the delivery of the mCIMT camp. Efforts were made to standardize the camp by developing a manual with activities, type of constraint, frequency/duration of the mCIMT camp the same from year to year. The methodology of this study is rigorous, utilizing assessment tools that are validated for children with hemiplegic CP. In addition, assessments were chosen not only from the body structure/function section of the WHO, but also from the activity/participation section.

Limitations

This dissertation was not a randomized control trial. All participants were a convenient sample that was recruited through Motor Control Clinic in (neurology) at an internationally known children's hospital in the southwestern central part of the United States. The small sample size may be due to a combination of many factors. Texas Scottish Rite Hospital for Children is a tertiary referral hospital with many of its patients living four to eight hours away, making the twice daily commute for two weeks unfeasible. In addition, the age restriction on the inclusion criteria dramatically reduced the number of eligible participants. Even though the recruited number of participants for the augmented mCIMT camp with Armeo®Spring was four, this was consistent with the previous camps held in 2012 (n = 4) and 2013 (n = 4).

Due to a small sample size, the baseline starting points of the participants were not equivalent. There was variability of starting points on the AHA; the mean score of the augmented mCIMT group was 57.25 with a standard deviation of 15.06 points. The AHA of the 2012/2013 traditional mCIMT group mean of 56.63 was similar to the Armeo®Spring Pediatric group, however, also had a large SD of 16.68. The MUUL showed even greater variability with the Armeo®Spring Pediatric group mean of 85.25 and a SD of 13 points while the traditional group started at 71.5 with a SD of 27.43 points. Therefore, the results may not be generalized across the hemiplegic CP population. In addition, there is no long-term follow up of this study to determine retention of reported gains. Further research is needed to pursue long-term outcomes.

Future Research and Intervention

Treatment in the last decade of children with hCP has transitioned from a focus at the body structures level (NDT and Bobath) to the Performance and Activity Participation level (CIMT and bi-manual performance) (Novak et al., 2013). The literature provides evidence that CIMT and mCIMT improve outcomes in children with hemiplegic CP (Hoare et al., 2007; Huang et al., 2009; Novak et al., 2013). These findings demonstrate a paradigm shift in the delivery and focus of intervention. Treatment is no longer focused on posture, tone and range of motion and emerging are goals on daily activities, function and independence. This shift is in line with the theoretical principles of occupational therapy; through the use of meaningful and purposeful activities clients may engage and participate to their fullest abilities in their occupations.

According to the findings of this dissertation, there may be promise that the Armeo®Spring Pediatric improves bi-manual hand use in children with hemiplegic cerebral palsy. For future research, the long-term effects of participating in a mCIMT camp with the use of the Armeo®Spring Pediatric needs investigating. Do the children retain the skills they learned 6 months following the camp? The optimal frequency and duration of use of the Armeo®Spring Pediatric to support improved hand function needs to be further investigated. In addition, what is the optimal age for use of the Armeo®Spring Pediatric? These are just a few questions that are needed to determine what is the optimal treatment for improving hand/arm function in children with hemiplegic CP.

REFERENCES

Aarts, P. B., Jongerius, P. H., Geerdink, Y. A., van Limbeek, J., & Geurts, A. C. (2010). Effectiveness of modified constraint-induced movement therapy in children with unilateral spastic cerebral palsy: A randomized controlled trial. *Neurorehabilitation & Neural Repair, 24*(6), 509-518.

Bohannon, R.W., & Smith, M.B. (1987). Interrater reliability of a modified Ashworth scale of muscle spasticity. *Physical Therapy, 67*(2), 206-7.

Bower, E., Mitchel, D., Burnett, M., Campbel, M.J., & McLellan, D.L. (2001). Randomized control trial of physiotherapy of 56 children with cerebral palsy followed for 18 months. *Developmental Medicine & Child Neurology, 43(1),* 4-15.

Boyd, R., Sakzewski, L., Ziviani, J., Abbott, D.F., Badawy, R., Gilmore, R., … Jackson, G.D. (2010). INCITE: A randomised trial comparing constraint induced movement therapy and bimanual training in children with congenital hemiplegia. *BMC Neurology, 10*, 4-4.

Boyle, C., Decoufle, P., & Yeargin-Allsopp, M. (1994). Prevalence and health impact of developmental disabilities in US children. *Pediatrics*. 93,399-403.

Brandao, M., Mancini, M. C., Vaz, D. V., de Melo, A., & Fonseca, S. T. (2010). Adapted

Version of constraint-induced movement therapy promotes functioning in children with cerebral palsy: A randomized controlled trial. *Clinical Rehabilitation, 24*(7), 639-647.

Case-Smith, J., DeLuca, S., Stevenson, R., & Ramey, S. (2012). Multicenter randomized control trial of pediatric constraint induced movement therapy: 6-month follow up. *American Journal of Occupational Therapy, 66(1),* 15-23.

Charles, J.R., & Gordon, A.M. (2007). A repeated course of constraint induced movement therapy results in further improvement. *Developmental Medicine & Child Neurology, 49*(10), 770-773.

Charles, J. R., Wolf, S. L., Schneider, J. A., & Gordon, A. M. (2006). Efficacy of a child-friendly form of constraint-induced movement therapy in hemiplegic cerebral palsy: A randomized control trial. *Developmental Medicine & Child Neurology, 48*(8), 635-642.

Chicoine, M. R., Park, T.S., & Kaufman, B. A. (1997). Selective dorsal rhizotomy and rates of orthopedic surgery in children with spastic cerebral palsy, *Journal of Neurosurgery* (86) 34–39.

Christiansen, A., & Lange, C. (2008). Intermittent versus continuous physiotherapy in children with cerebral palsy, *Developmental Medicine and Child Neurology,* (50) 290–293.

Clarson, D.L., & Dormody, T.J. (1994). Analyzing data measured by Likert-type items. *Journal of Agriculture Education 35*(4).31-35.

Cope, S. M., Liu, X., Verber, M. D., Cayo, C., Rao, S., & Tassone, J. C. (2010). Upper limb function and brain reorganization after constraint-induced movement therapy in children with hemiplegia. *Developmental Neurorehabilitation, 13*(1), 19-30.

DeLuca, S., Echols, K., Law, C., & Ramey, S. (2006). Intensive pediatric constraint-induced therapy for children with cerebral palsy: randomized controlled, crossover trial. *Journal of Child Neurology 21*(11), 931-938.

Eliasson, A. (2005). Improving the use of hands in daily activities: Aspects of the treatment of children with cerebral palsy. *Physical & Occupational Therapy in Pediatrics, 25*(3), 37-60.

Eliasson, A., Krumlinde–Sundholm, L., Rösblad, B., Beckung, E., Arner, M., Öhrvall, A.M., & Rosenbaum, P. (2006). The Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and reliability. *Developmental Medicine and Child Neurology*, *48*, 549-554.

Eliasson, A., Krumlinde-Sundholm, L., Shaw, K., & Wang, C. (2005). Effects of constraint-induced movement therapy in young children with hemiplegic cerebral palsy: An adapted model. *Developmental Medicine & Child Neurology, 47*(4), 266-275.

Fehlings, D., Sutcliffe, T., & Logan, W. (2009). Pediatric constraint-induced movement therapy is associated with increased contralateral cortical activity on functional magnetic resonance imaging. *Journal of Child Neurology,* 24, 1230-1235.

Feys, H., Klingels, K., Desloovere, K., Huenaerts, C., Eyssen, M., & Molenaers, G. (2005).

Reliability of a clinical assessment of sensory function for the upper limb in children with hemiplegic cerebral palsy. *Developmental Medicine and Child Neurology*, 47, 20-27.

Gentile, D. (2009). Pathological video game use among youth ages 8-18. A national study. *Psychological Science,* 20, 594-602.

Gordon, A. M., Charles, J., & Wolf, S. L. (2005). Methods of constraint-induced movement therapy for children with hemiplegic cerebral palsy: Development of a child-friendly intervention for improving upper-extremity function. *Archives of Physical Medicine & Rehabilitation, 86*(4), 837-844.

Gracies, J., Burke, K., Clegg, N., Browne, R., Rushing, C., Fehlings, D., … Delgado, M. (2010). Reliability of the Tardieu Scale for assessing spasticity in children with cerebral palsy. Archives of *Physical Medicine and Rehabilitation, 3*(91) 421-428.

http://www.hocoma.com/fileadmin/user/Dokumente/Armeo/bro_AO_PE_120416_en.pdf retrieved December 23, 2013.

Hoare, B., Imms, C., Carey, L., & Wasiak, J. (2007). Constraint-induced movement therapy in the treatment of the upper limb in children with hemiplegic cerebral palsy: A cochrane systematic review. *Clinical Rehabilitation, 21*(8), 675-685.

Houwink, A., Aarts, P., Geerts, A., & Steenbergen, B. (2011). A neurocognitive perspective on developmental disregard in children with hemiplegic cerebral palsy. *Research in Developmental Disabilities,* doi:10.1016/j.ridd.2011.07.012.

Huang, H., Fetters, L., Hale, J., & McBride, A. (2009). Bound for success: A systematic review of constraint-induced movement therapy in children with cerebral palsy supports improved arm and hand use. *Physical Therapy, 89*(11), 1126-1141.

IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.

Johnson, L., Randall, M., Reddihough, D., Oke, L., Byrt, T., & Bach, T. (1994). Development of a clinical assessment of quality of movement for unilateral upper-limb function. *Developmental Medicine & Child Neurology.* (36), 965–73.

Johnston, M. (2004). Clinical disorders of brain plasticity. *Brain and Development, 26*(2), 73-80.

Juenger, H., Linder-Lucht M., Walther, M., Berweck, M., Mall, V., & Staudt, M. (2007). Cortical modulation by constraint induced movement therapy in congenital hemiparesis: An fMRI study. *Neuropediatrics*, 38(3): 130-136.

King, G., Law, M., King, S., Hurley, P., Hanna, S., Kertoy, M., … Young, N. (2004). *Children's Assessment of Participation and Enjoyment (CAPE) and Preferences for Activities of Children (PAC).* Harcourt Assessment, Inc., San Antonio, TX, USA

Klingels, K., De Cock, P., Molenaers, G., Desloovere, K., Huenaerts, C., & Jaspers, E. (2010). Upper limb motor and sensory impairments in children with hemiplegic cerebral palsy. Can they be measured reliably? *Disability and Rehabilitation, 32(5),* 409–416.

Krumlinde-Sundholm, L., (2012). Reporting outcomes on the assisting hand assessment. *Developmental Medicine and Child Neurology, 54* (9), 807-808.

Krumlinde-Sundholm L., & Eliasson A. (2003). Development of the assisting hand assessment: a rasch-built measure intended for children with unilateral upper limb impairments. *Scandinavian Journal of Occupational Therapy*, 10, 16–26.

Krumlinde-Sundholm, L., Holmefur, M., & Eliasson, A. (2007). Interrater and Intrarater reliability of the assisting hand assessment. *American Journal of Occupational Therapy 61*(1), 79-84.

Kuhnke, N., Juenger, H., Walther, M., Berweck, S., Mall, S., & Staudt, M. (2008). Do patients with congenital hemiparesis and ipsilateral corticospinal projections respond differently to constraint-induced movement therapy? *Developmental Medicine and Child Neurology, 50*(12), 893-903.

Law, M., Baptiste, S., McColl, M., Opzoomer, A., Polatajko, H., & Pollock, N. (1990). The Canadian occupational performance measure: An outcome measure for occupational therapy. *Canadian Journal of Occupational Therapy. (57)* 2, 82-87.

Liepert, J., Miltner, W., Bauder, H., Sommer, D., Dettmer, C., Taub, E., & Wieller, C. (1998). Motor cortex plasticity during constraint induced therapy after stroke. *Neuroscience Letters,* 250(1), 5-8.

Livingston, M., Rosenbaum, P., Russell, R., & Palisano, R. (2007). Quality of life among adolescents with cerebral palsy: what does the literature tell us? *Developmental Medicine and Child Neurology 49*(3), 225–231.

Nascimento, L. R., Gloria, A. E., & Habib, E. S. (2009). Effects of constraint-induced movement therapy as a rehabilitation strategy for the affected upper limb of children with hemiparesis: Systematic review of the literature. *Brazilian Journal of Physical Therapy / Revista Brasileira De Fisioterapia, 13*(2), 97-102.

Naylor, C. E., Bower, E. (2005). Modified constraint-induced movement therapy for young children with hemiplegic cerebral palsy: A pilot study. *Developmental Medicine & Child Neurology, 47*(6), 365-369.

Novak, I., McIntyre, S., Morgan, C., Campbell, L., Dark, L., Morton, N., … Goldsmith, S. (2013). A systematic review of interventions for children with cerebral palsy: state of the evidence. *Developmental Medicine and Child Neurology, e1-26.* Doi:10.1111/dmcn.12246

Odding, E., Roebroeck, M., & Stam, H. (2006). The epidemiology of cerebral palsy: incidence, impairments and risk factors. *Disability Rehabilitation*, 28: 183–91.

Patton, M. (2002). *Qualitative Research and Evaluation Research Methods.* Thousand Oaks, CA: Sage Publishing.

Psychouli, P., Burridge, J.K., & Kennedy, C. (2010). Forced use as a home based intervention in children with congenital hemiplegic cerebral palsy.: Choosing the appropriate constraints. *Disability & Rehabilitation: Assistive Technology, 5*(1), 25-33.

Randal, M., Johnson, L., & Reddihough, D. (1999). The Melbourne assessment of unilateral upper limb function: test administration manual. Melbourne: The Royal Children's Hospital.

Rostami, R., Arastoo, A., Nejad, J., Mahany, K., Malarmiri, A., & Goharpey, S. (2012). Effects of modified constraint-induced movement therapy in virtual environment on upper-limb function in children with spastic hemiparetic cerebral palsy: A randomized controlled trial. *Neurorehabilitation, 31*(4), 357-365.

Sakzewski, L., Ziviani, J., & Boyd, R. (2009). Systematic review and meta-analysis of therapeutic management of upper-limb dysfunction in children with congenital he hemiplegia. *Pediatrics, 123*(6), e1111-22.

Sakzewski, L., Ziviani, J., Fabott, D., Macdonnell, A., Graeme, J., & Boyd, R., (2011). Randomized trial of constraint-induced movement therapy and bimanual training on activity outcomes for children with congenital hemiplegia. *Developmental Medicine and Child Neurology, 5,* 313-320.

Smania, N., Aglioti, S. M., Cosentino, A., Camin, M., Gandolfi, M., Tinazzi, M., & Faccioli, S. (2009). A modified constraint-induced movement therapy (CIT) program improves paretic arm use and function in children with cerebral palsy. *European Journal of Physical & Rehabilitation Medicine, 45*(4), 493-500.

Stanley, F.J., Blair, E., & Alberman, E. (2000). Cerebral Palsies: Epidemiology and Causal Pathways. Clinics in Developmental Medicine No 151. London: MacKeith Press.

Stearns, G. E., Burtner, P., Keenan, K. M., Qualls, C., & Phillips, J. (2009). Effects of constraint-induced movement therapy on hand skills and muscle recruitment of children with spastic hemiplegic cerebral palsy. *NeuroRehabilitation, 24*(2), 95-108.

Taub, E., Ramey, S. L., DeLuca, S., & Echols, K. (2004). Efficacy of constraint-induced movement therapy for children with cerebral palsy with asymmetric motor impairment. *Pediatrics, 113*(2), 305-312.

Tautla, S., Sauve, K., Virji-Babul, N., Holsti, L., Butler, C., & Van Der Loos, H. (2013). Evidence for outcomes of motivational rehabilitation interventions for children and adolescents with cerebral palsy; An academy for cerebral palsy and developmental medicine systematic review. *Developmental Medicine and Child Neurology, 55*(7), 593-601.

Tilton, A. (2009). Management of spasticity in children with cerebral palsy. *Seminars in Pediatric Neurology, 16*(2), 82-89.

Wallen, M., Ziviani, J., Herbert, R., Evans, R., & Novak, I. (2008). Modified constraint-induced therapy for children with hemiplegic cerebral palsy: A feasibility study. *Developmental Neurorehabilitation, 11*(2), 124-133.

Wong, V. (2002). Open label study of botulinum toxin for upper limb spasticity in cerebral palsy. *Journal of Child Neurology*, 138-142.

World Health Organization http://www.who.int/classifications/icf/en/. Retrieved January 3, 2013.

Yang, T.F., Fu, C. P., Kao, N.T., Chan, R.C., & Chen, S.J. (2003). Effect of botulinum toxin type A on cerebral palsy with upper limb spasticity. *American Journal of Physical Medicine and Rehabilitation,* 82. 234-289.

Zhan, S., Ottenbacher, K.J. (2001). Single Subject research designs for disability.

Disability and Rehabilitation, 281-8.

Appendix A

Activity Bank

Summary- The following is a bank of sample activities that were chosen based on appeal to various ages, ability to modify and availability of supplies and space. The different activities require the children to use their involved arm in a variety of ways. The length of time each of the activities were played were dependent on group interest. These are the same activities that were completed during the 2012 and 2013 camps.

1. **Batty Bowling**. Find a number of silly or odd items that can be knocked over by a ball, such as a plastic milk carton, a candlestick, a stand-up doll, a plastic vase of flowers, a pizza box, a tower of empty cans, an umbrella stand, an empty oatmeal container, and a book. Line them up like bowling pins and let the bowlers try to knock them over with volleyballs, tennis balls, or golf balls.
2. **Name-It Ball**. Have players form a circle. Give one player a rubber ball. That player selects a category, such as "candy bars." He or she then bounces the ball to another player in the circle, who must catch the ball, state an item from the category, such as "Snickers," and keep the ball moving to the next player. If the player can't name an item, holds the ball too long, or repeats an item, he or she is out.
3. **Frisbee Tower**. Purchase a bunch of mini Frisbees and place them in a pile in the middle of the yard. Have the participants divide the Frisbees among themselves. The first player begins the activity by placing one of his or her Frisbees on the ground. Each of the following players places his or her Frisbee on top of the first Frisbee, and the action continues until someone causes the growing tower to topple.
4. **Blind Walk**. Create an obstacle path from one end of the yard to the other. Line up the participants and let them have a good look at the path. One at a time, blindfold the children and have them walk the path without looking.
5. **Cross Step**. Draw a ten-by-ten grid on the sidewalk or patio with chalk. Have each player stand on a different square. One at a time, each player must move to a new square after crossing out the square she or he was formerly standing in. The trick is that players cannot step into a square that is occupied or crossed out. If a player cannot move to a new square, he or she is out. The game continues until one player is left.
6. **Pick Pocket Tag**. Put a strip of cloth in each player's back pocket. Have the players try to grab each other's strips without having their own strip taken. The player with the most cloth strips wins the game.
7. **Drag the Body.** Divide the group into two teams. Give each team a blanket. Have one player from each team lie down on the blanket. The teams must drag the body

on the blanket from one end of the yard to the other. Whoever crosses the finish line first, wins.

8. **Parachute.** This game involves a large round parachute, preferably with handles, with people holding the parachute all around the edges. Players can just ruffle the parachute up and down a little bit, they can go all the way up and all the way down, or all the way up and then run underneath, sitting on the edge of the parachute, which can create a bubble of air with everyone inside. Players can also place light objects such as wiffle balls or beanbags on top of the parachute, and make them jump by ruffling the parachute. Also, one person can sit in the middle of the parachute and everyone ruffles it near the ground. If there is a smooth floor and a light child, the child can sit in the middle on top of the parachute and everyone else can walk partway around still holding the parachute edge. Then everyone pulls backward, spinning the child. There are countless variations.
9. **Hopscotch**: Use some sidewalk chalk and make a hopscotch grid. Number the squares from one to nine. Pick a rock that is good for tossing. Small ones can bounce too much, and larger ones are hard to throw. Start by tossing the rock onto Square 1. Hop over the rock and hop with a single foot or both feet (to follow the hopscotch pattern) all the way to the end. Turn around and come back, stopping on Square 2. Balancing on one foot, pick up the rock in Square 1 and hop over Square 1 to the start. Continue this pattern with Square 2. And so on. If you toss your rock and miss the correct square, your turn is over. This game can be played with any number of people, but only one person can go at a time. If it's raining or dark or too cold, you can get indoor hopscotch mats or foam pieces, or just find a pattern on the floor to follow, perhaps using a beanbag instead of a rock.
10. **Red Light, Green Light:** With enough room, this game can easily be played inside. One person is the traffic light at one end, and the other players are at the other end. When the traffic light faces the group, he or she says, "Red light!" and everyone must freeze. The traffic light then turns his or her back and says, "Green light!" while the group tries to get as close to the traffic light as possible. The traffic light turns around quickly, again saying, "Red light!", and if anyone is spotted moving, they have to go back to the starting place. The first person to tag the traffic light wins and gets to be the next traffic light.
11. **Mother, May I:** This game is set up in the same way as Red Light Green Light. One person in the group asks the person in the front, "Mother, may I take <insert number> steps forward?" The person at the front then says, "Yes, you may." or "No, you may not." You can vary your requests by including options such as taking baby steps, spinning steps, leaps or whatever strikes your fancy. Again, the first person to tag the person in the front wins and is the next person in the front.
12. **Simon Says:** This game can be played anywhere. One person is Simon and starts by saying, "Simon says, '<insert action here>.'" Everyone must then do the action. However, if Simon makes an action request without saying, "Simon says"

to begin the request, anyone who does that action is out. The last person still playing in the end will be Simon for the next round.

13. **Musical Chairs**: In a circle, arrange chairs facing outward to total one fewer than the number of players. An additional player needs to be in charge of the music. When the music starts, the players walk around the chairs. When the music stops, players sit down in the nearest chair as soon as they can. The one player who does not have a chair is out. One of the chairs is then removed, and the game continues in this manner. The player that sits in the final chair is the winner. This game is traditionally played inside, but it can also be played outside with outdoor furniture and a portable music player.
14. **Doggy Doggy Where's Your Bone:** A participant plays the part of the dog. He or she sat in a chair with their back to the rest of the participants. An eraser or another object is put under the chair. That is the bone. While the dog is turned around with his or her eyes closed someone would sneak up and steal the bone and hide it somewhere on his person. Then everyone would sing: Doggy, Doggy, where's your bone? Somebody's stole it from your home. Guess who it might be you. Then the dog has three chances to guess who took it. Sometimes it was left under his or her chair. If the dog guessed right then he got to do it again. If he guessed wrong than the person who had the bone got a turn as the dog.
15. **Pirate Pirate Where's Your Gold:** One child (the pirate) stands in the middle of the circle of children with eyes closed. The children chant:

    Pirate, Pirate where's your gold?
    Somebody stole it from your hold.
    Guess who? Maybe you!
    Maybe a parrot from Kalamazoo
    Now then Pirate find your gold!

    While they are chanting the leader hands a piece of "gold" (a large coin would work) to one of the children. All the kids put their hands behind their backs and then the pirate opens his eyes. He guesses who has the gold (you can either give three guesses and then he has to be pirate again if he guesses wrong or you can let them guess until they succeed). The person who had the gold becomes the new pirate.

16. **Bubble Play:** Bubble solution: Bubble-blowing tools: drinking straws, funnels, wire loops, and so on. Give each contestant a supply of bubble solution and some bubble-blowing tools. Wet the tabletop with bubble solution and have the kids get blowing. Who can blow the biggest bubble? Who can create the biggest pile of bubbles in thirty seconds? Whose bubble lasts the longest? Whose bubble is the prettiest? Who can blow a bubble within a bubble?

17. **1-2-3 Look:** Everyone closes their eyes and lowers their heads, the leader calls out 1-2-3-Look! As the leader calls "look," the campers look up at one specific person.
    *Campers cannot change who they are looking at during each round.
    If that person is looking back at him/her, both players are out. If that person is looking at a different person, the campers put their heads back down and wait for the next call of "1-2-3 Look."
    Continue the game rapidly to close the circle and eventually you'll be left with two people and the game is over.
18. **A What? Equipment:** 2 objects
    The leader of the game starts by passing the first object to the person on their right (Person A)and saying, "This is a whit."
    Person A replies, "A What?"
    The leader would then clarify, "A whit."
    Person A then turns to the person on their right (Person B) and says, "This is a whit."
    Person B, "A what?"
    Person A, turns to Leader, and asks, "This is a What?"
    Leader to Person A, "A whit!"
    Person A to Person B, "A whit!"
    Person B then turns to Person C, and the game continues...
    This game can be confused by adding an additional object called a Watt in the opposite direction. Eventually, people are receiving and passing two words at time
19. **Assassin** Sit all of the children in a circle, with legs crossed. Have all children put their heads down. one person (we always had at least one adult present) would walk around the circle and tap one child on the head. This person was the assassin. The child eliminates all other players by winking at them. If you are winked at, silently count to 10, then put your feet in the middle of the circle. We always had a few drama queens who would act as if they really had been shot, and clutch their chest, and shake and scream. very funny. if the assassin eliminates everyone, then they win. They can be "witnessed" as well. If a player thinks they know who the killer is, before they get winked at, they can say they have a suspect. Such as "I suspect that Sally is the assassin." If Sally is not the assassin, then the accusers are eliminated. A less brutal version is the sandman. same thing, except being winked at means you take a nap.
20. **Huh!** Game where you can be eliminated by laughing or motioning improperly. Everyone stands in a circle. You may not laugh. You must motion properly. The motion is having your hands flattened together and pointing either up above your head, or to another person, depending on what part of the game you are in.
    One person begins by motioning up above his/her head and saying "huh." The two

people on either side of him must then simultaneously motion to this person and say "huh." This person then must then motion to someone else in the circle and say "huh."

This begins the process over, and the new person must motion upward and say "huh" as the two on either side of him motion toward him and say "huh", and so on.

You are out if you laugh, or if you don't say "huh" or do not motion fast enough. When two people are left, they must take turns pointing upward and at each other and must get faster and faster until one messes up. The last one standing is the winner.

21. **My Aunt Loves Coffee but She Hates "T"** Everyone sits in a circle, and each person makes a statement. For example "My aunt loves ______ but she hates ______."

    The activity leader will say "true" or "false" to the statement. Go around the circle until everyone has figured out the pattern.

    The pattern is that My Aunt only likes things that don't have a letter "t" in the word.

    Things My Aunt Loves: Bread, Cars, Rain, Dogs, etc.

    Things My Aunt Hates: Trains, Thunder storms, Cats, Tennis, etc.
22. **Elbow Tag-** Everyone gets a partner and links arms. Two people are chosen to split up. One will be it and the other will be chased. Whenever the person links with a pair of players, the person on the opposite end must break off. They will now become chased. If the person gets tagged, they become it. Variation: When the person on the opposite end breaks away, they become it and must chase the person who was originally the chaser.
23. **Dumping Ground -** Make two equal size circles 50 feet apart. Divide the group into two equal teams, and have them face each other behind their circles. Place an equal number of bean bags in each teams circle. On "GO" both teams run forward. Each player takes 1 bean bag from his circle and puts it in the opposing team's circle. Players run back and forth continuing to empty bean bags into the opponents' circle. On "STOP" the team having the least number of bean bags in its circle wins.
24. **Noodle Hockey -** The name nearly says it all... It's hockey, but with noodles! Replace the hockey sticks with pool noodles, the puck with a wiffle ball, and the goal keeper sticks and gloves with a broom and go to town!
25. **Samurai Warrior -** Everyone stands in a circle around or in a line in front of one person with the Boffer (pool noodles are great!) far enough away as not to be hit. The Samurai swings at the group, either high, at head level, or low at ankle level. If he swings high, the group ducks. If he swings low, the group jumps. He is not actually supposed to hit the participants with the sword, but if someone jumps when they are supposed to duck or vice versa, they are "out" until the one left is the next Samurai.

ADAPTATIONS: For a no loser's game, the person who does the wrong thing can become the Samurai. For no losers, have two circles and person who goes wrong, switches circles

26. **Star Wars -** Divide playing space in half by Rope. Each team has one Jedi knight (with boffer), has a star base (poly-spot), and many death stars (Nerf balls). At start, both teams rush to the dividing line, gather as many death stars as possible and begin hurling them at the opponents. If a death star hits a player, they become frozen immediately. If a player catches a death star, the thrower becomes frozen instead. A player can only get back in the game if they are touched by the light saber of the teams Jedi knight. In order to "save" a frozen team player, the Jedi must leave his star base, hopping on one leg to the frozen player and tap her with the light saber. As long as the Jedi is on the star base, he is safe. If a death star hits him, he is frozen for good. The team who has players left standing and not frozen is the winner.
27. **Take it Back -** Play game in a large space. Put several sock balls in the middle of the space. Divide group into 2 groups and on the word "go", they run to the middle and throw the socks onto the other side. The object of the game is get the socks ALL on the other team's side. It is impossible to do, but very funny to watch!

Appendix B

Sample Day

Time	Activity
9:00-9:45	**Welcome Campers**
	Introduce staff and volunteers
	Name tags
	Pirate Skit- to review theme and rules
	Armeo®Spring Training
	Put splints on
9:45-10:00	**Prep for outside**- sunscreen, bug spray, water bottles
10:00-11:00	**Outside Activities-** new activities daily
	Parachute Games, Bocce Ball, Flag Tag
11:00-11:45	**Lunch**- wash hands, bathroom, eat lunch
11:45-12:15	**Craft**- rotates daily
12:15-1:15	**Fine Motor Activities-**new activities daily
	Sponge Art, Clothes Pins in a Can, Cutting dough, Armeo®Spring Training
1:15-2:00	**Gross Motor Activities-**new activities daily
	Ball throw, Bean bag hop scotch, Bowling
2:00- 2:15	**Bathroom Break**
2:15-2:45	**Snack**
2:45-3:00	**Group Game**
3:00	**Good bye**- remove splints

Appendix C

Snacks

Summary- The following presents a list of snacks for the campers to make in the afternoon. Each snack was chosen based on its appeal to children, and ability to adapt to allow every child to utilize their involved arm to help make the snack. Preparing a snack is a therapeutic group activity, life skill, and motivator.

1. **Trail Mix:** Trail mix is a versatile snack that children can make. It is ideal for picky eaters because many ingredients may be used in trail mix. Provide four or five ingredients to make up the trail mix based on your child's food preferences. Popular trail mix ingredients are dry cereal, small crackers, granola, dried fruit, nuts (use only for older children), chocolate chips and pretzels. The child can scoop each ingredient into the mixing bowl and stir them together. Trail mix is a convenient snack for kids on the go.
2. **Sandwich Kabobs:** Kabobs are a fun way to eat something ordinary. To make sandwich kabobs, the child can slide a cube of bread onto a skewer and follow the bread with cubes of meat, cheese, tomatoes and other vegetables. More bread cubes may be added between the ingredients as desired.
3. **Frozen Banana Pops**:Frozen banana pops are versatile because any toppings may be used. Cut a banana in half widthwise. The child can carefully push a popsicle stick into the banana to create a handle. Assist the child in spreading either peanut butter or honey on the banana. The child can then roll the banana in his choice of toppings. Granola, crushed cereal or chopped nuts work well. Place the banana on a plate and freeze for three hours.
4. **Pear Mouse:** Canned pear halves transform into an edible mouse in this kid's snack. Have the child place a pear half, flat side down, on a plate. The small end of the pear will serve as the mouse's head. The child places two cloves in the small end to make the eyes and a raisin below the eyes for the nose. Use two banana slices for the ears. Carefully break a toothpick in half to hold the banana slices in place. Remove the toothpicks before eating the pear mouse.
5. **Dirt Cups**: 1 pack Chocolate Pudding, instant, 2 cup Milk, 16 oz Oreos, 3 1/2 cup Cool Whip 8 Gummy Worms, Directions: Pour milk into medium bowl, add pudding mix. Beat until well blended, 1 -2 minutes. Crush Oreos and set aside. Let stand 5 minutes. Stir in cool whip and half of cookies. To assemble: place 1 Tablespoons crushed cookies in bottom of 8 oz cup. Fill cups about 3/4 full with pudding mixture. Top with remaining crumbs. Place Gummy Worms in "dirt".
6. **Bugs on a Log:** Peanut butter, Celery stalks, Chocolate chips. Directions: Take a stalk of celery and fill center with peanut butter. Place pieces of chocolate chips on top of peanut butter filled celery stalk.
7. **Peanut Butter Turtles:** Apple, 5 Grapes, 2 Tablespoons Peanut Butter. Directions: Slice an apple in half. Make several slits in each half. Fill with peanut butter or sesame butter. Attach seedless grapes with toothpicks for the head and legs and stick a carrot shaving on for a tail (tuck it in 1 of the slits).
8. **Fish Bowls and Aquariums:** Tint some cream cheese light blue. Tint some vanilla frosting light blue. Let the children spread the cream cheese on the Ritz crackers and stick on a few goldfish crackers..."fishbowls"! Spread the frosting on graham squares and add

goldfish (you can find them in graham flavor, too) for "fish tanks". Serve with glasses of "ocean water" (blue Kool-aid.)

9. **Going Fishing**: Pretzel sticks the thicker ones not the thin pretzel sticks...peanut butter and gold fishes the crackers... use the pretzel stick as the fishing pole and dip it in peanut butter and then dip into a cup of goldfishes...pull it out and there you go you have gone fishing.

10. **Possible food for party**: Goldfish crackers, Ocean with sunken treasures (blue Jell-O with diced peaches and pineapple, you can add little shark gummy treats as well), Peg legs (cucumber, carrot, celery sticks), Canon ball grapes, Red Rubies (strawberries, cranberries and cherries), Watermelon Boat (cut out a watermelon to resemble a boat, then take out all watermelon with an ice-cream spoon, and put all watermelon balls in watermelon boat as cannonballs), Octopus legs (gummy worms), Gold puffs (cheese puffs), Gold and Silver Hershey nuggets, Chocolate gold coins, Golden candies (butterscotch), Breadsticks (swords), Swords (pretzel sticks), Pirate Pellets (all kinds of jelly beans)

Appendix D

Volunteer Training Agenda

1. Introductions

2. Watch HIPAA video / turn in immunization records

3. Overview of Cerebral Palsy / hemiplegic CP

4. Overview of CIMT

5. Overview of Armeo®Spring

6. Introduce theme for camp

7. Introduce the campers: show AHA video and talk about COPM goals

8. Tour: solarium, outdoor space, bathrooms, etc.

9. Working lunch - Create a skit incorporating the Pirate theme for the first day of camp to introduce the rules of camp
   - wear your splint at all times
   - complete all activities the best you can
   - listen to instructions
   - be respectful and encourage others
   - stay with the group
   - have fun

10. Review the daily schedule: have volunteers participate in some of the activities using non-dominant hand, discuss ways to grade activities, encourage participation and watch for frustration

11. Volunteer Roles:
   - make camp fun
   - keep it positive
   - stay engaged with the campers
   - encourage participation, help when needed, but don't do it for them

12. Leading Activities:
   - responsible for giving directions for the activity to the campers
   - responsible for gathering supplies, set up and clean up of the activities

13. Review activities that you will be leading during camp and practice as needed, check that all of the supplies are available – anything missing, questions?

Appendix E

Assessment Protocol

Complete assessments in the following order:

1. Active Range of Motion
2. Passive Range of Motion
3. Modified Tardieu Scale
4. Modified Ashworth Scale
5. Proprioceptive
6. Stereognosis
7. Grip Strength
8. Canadian Occupational Performance Measure (COPM)
9. Melbourne Assessment 2: A Test of Unilateral Limb Function (MA2)
10. Children's Assessment of Participation and Enjoyment (CAPE)
11. Assisting Hand Assessment (AHA)

Appendix F

Observation Data Collection Tool

Participant #________________
Date_______________________
Please place check next to observed activity
Armeo_______Fine Motor Stations______

Following your observations please rank the participant in the following areas:

1. What is your perception of the participant's motivation during the task?

1	2	3	4
not at all	a little	some	a lot

2. How engaged is the participant during the task?

1	2	3	4
not at all	a little	some	a lot

3. How much is the participant enjoying the task?

1	2	3	4
not at all	a little	some	a lot

4. How frustrated is the participant during the task?

1	2	3	4
not at all	a little	some	a lot

Comments participant makes specifically about the activity