CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

Effects of Aquatic Exercise on Balance in Children with Cerebral Palsy

A thesis submitted in partial fulfillment of the requirements

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in Kinesiology

By

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Dedication

To my Lord, my Savior, Jesus Christ

For all that I do is for Him. "Whatever you do, work heartily, as for the Lord and not for men, knowing that from the Lord you will receive the inheritance as your reward. You are serving the Lord Christ. For the wrongdoer will be paid back for the wrong he has done, and there is no partiality." (Col 3:23-25)

To my parents, Mike and Kris

For their unconditional love, support, and encouragement in all that I do

To my family and friends,

For their continued encouragement and enthusiasm throughout this journey

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Abstract

Effects of Aquatic Exercise on Balance in Children with Cerebral Palsy

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The effects of aquatic exercise on various physiological and psychological outcomes have been well documented in children with cerebral palsy (CP) in recent years. However, few research specifically addressed how balance is affected by aquatic exercise. The purpose of this study was to investigate the effects of aquatic exercise on balance in children with CP. A case study approach with multiple data points was employed for this study. Three children with spastic CP (age seven to 14, GMFCS level I and II) participated in a 40-minute aquatic exercise three times a week for seven weeks. Each session included warm-up, static and dynamic balance training, mobility exercise, and cool-down. Balance outcomes were measured four times including pre, midcheck, post, and seven-week follow-up intervention. Biomechanical balance tests were administered on a computerized posturographic equipment (Smart Balance Master, Neurocom International, Clackamas, OR, 2010), which utilized dynamic dual forceplates with rotation capabilities and a movable visual surrounding. Comprehensive balance assessments were performed using various test protocols in the equipment, which were Sensory Organization, Motor Control, and Adaptation tests. The tests examined multifaceted changes in static and dynamic balance, based on postural sways profiles, ground reaction force data and automatic postural response time under various conditions. Results were analyzed using visual analysis of trend graphs from each case. There were improvements observed in each participant that varied individually. The results suggest that children with CP can improve balance and balance-related motor adaptation skills through a seven-week aquatic intervention program. The interpretation of our study outcomes must be limited for generalization due to the nature of case study, as well as the large variability of physical conditions among children with CP.

Introduction

Cerebral palsy (CP) is a nonprogressive, permanent, group of disorders that occur in the fetal to infant brain that affect the child's motor development and posture (Rosenbaum, Paneth, Leviton, Goldstein, & Bax, 2007). There are four types of CP: Ataxic, dyskinetic, mixed, and spastic, with spastic CP being the most common type. Spastic CP is characterized by an increase in muscle tone in the body, specifically showing muscle stiffness in the extremities (Prevention, 2011). Each child with CP has a unique combination of characteristics that can vary throughout the child's life. Therefore, management is needed in children with CP to help them maintain functional independence ("*Cerebral Palsy: Hope Through Research*", 2011).

In previous studies, researchers have compared static and dynamic balance outcomes between children with CP and typically developing children (TD). The studies testing static balance, balance required while the child stands quietly with hands to their sides on a force plate, demonstrated that children with CP have greater postural sway than TD children and demonstrate different postural control strategies to adjust for the increase in postural sway. These strategies included the use of bigger muscle groups to make the necessary postural adjustments (Cherng, Su, Chen, & Kuan, 1999; Donker, Ledebt, Roerdink, Savelsbergh, & Beek, 2008; Ferdjallah, Harris, Smith, & Wertsch, 2002; Rose et al., 2002). Dynamic balance, balance that is required while the force plate (or subject) is moving, in studies also showed that children with CP had different balance mechanisms during recovery balance. Results suggested that after training and testing on the same machine, there was a decrease in balance recovery time (Shumway-Cook, Hutchinson, Kartin, Price, & Woollacott, 2003; Woollacott et al., 2005). Though a moveable postural force plate system (Neurocom® International, Inc, Oregon, USA) was used to improve balance, a more practical way to improve balance strategies was needed.

Land exercise based intervention programs have been studied in children with CP, with results including improved outcome measures for overall fitness, including balance (Blundell, Shepherd, Dean, Adams, & Cahill, 2003; Fragala-Pinkham, Haley, & Goodgold, 2006; Verschuren et al., 2007; Wiley & Damiano, 1998). Verschuren et al. (2007) results showed improvement in many outcome measures including agility, though the improvements seen were not present at the follow-up measurement. Overall, the study showed that group circuit training is an effective way to train children with CP. In addition, group fitness in a mixed group of children with disabilities, including children with CP, was feasible in the Fragala-Pinkham et al. (2006) study. Improvements were seen in all outcome measures that were still present at post-training; however, 31 falls were reported in this study with 29 of the falls occurred in the children with CP (Fragala-Pinkham et al., 2006). A safer environment for group exercise is needed for children with CP.

Aquatic exercise programs have been suggested to create a safe, low impact, and beneficial environment for children with CP (Chrysagis, Douka, Nikopopoulos, Apostolopoulou, & Koutsouki, 2009; Dorval, Tetreault, & Caron, 1996; Maria Fragala-Pinkham, Stephen M. Haley, & Margaret E. O'Neil, 2008; Hutzler, Chacham, Bergman, & Szeinberg, 1998; Thorpe & Reilly, 2000; Thorpe, Reilly, & Case, 2005). A case study by Thorpe and Reilly (2000), showed strength improvements in the trunk and lower extremity muscles in children with CP (Thorpe & Reilly, 2000). In a pilot study of similar design, Thorpe, Reilly, and Case (2005) showed a significant decrease in time in the Time Up and Go (TUG) test and an increased distance in Functional Reach Test (FRT) (Thorpe et al., 2005). Both studies showed maintained improvements at follow-up measurements (Thorpe & Reilly, 2000; Thorpe et al., 2005). Lastly, Fragala-Pinkham, Haley, and O'Neal (2008), demonstrated that a group aquatic class is feasible, provides a safe and dynamic environment, creating a camaraderie that is unique from land exercise programs (M. Fragala-Pinkham, S. M. Haley, & M. E. O'Neil, 2008).

Previous studies examined the effects of aquatic exercise on various physiological and psychological conditions in children with CP (Chrysagis et al., 2009; Dorval et al., 1996; Maria Fragala-Pinkham et al., 2008; Hutzler et al., 1998; Thorpe & Reilly, 2000; Thorpe et al., 2005). However, few have investigated balance parameters, none as a mainoutcome, for a seven-week group aquatic exercise program for children with CP. Therefore, the purpose of this study is to investigate the effect of aquatic exercise on balance in children with CP.

Literature Review

CP

Definition, incidence, prevalence, and medical costs for treatment

CP is a nonprogressive, permanent, group of disorders that occur in the fetal to infant brain that affect the child's motor development and posture (Rosenbaum et al., 2007). There are about 8,000 new cases diagnosed in infants and babies and an additional 1,200-1,500 cases recognized in pre-school aged children per year (Palsy). Overall, CP is prevalent in 3.3 per 1000 people in the United States. Of the people that have CP, 56% can walk without an assistive device. Approximately 58% of children with CP are White, non-Hispanic, 29% are African American, non-Hispanic, and are 9% Hispanic. CP occurs about 1.2 times more in boys than girls (Kirby et al., 2011). The average cost per person living with CP in a lifetime is $921,000 (Prevention, 2006).

Pathology and characteristics in children with CP

There are four types of CP: Ataxic, dyskinetic, mixed, and spastic, with spastic CP being the most common type affecting about 80% of people with CP. Spastic CP is characterized by an increase in muscle tone in the body, specifically showing muscle stiffness in the upper and lower extremities. The three types of spastic CP are spastic diplegia, spastic hemiplegia, and spastic quadriplegia. Spastic diplegia is characterized by increased muscle tone in the lower extremities with the upper extremities minimally affected, if affected at all. Spastic hemiplegia is characterized by increased muscle tone affecting one side of the body, with the arm being typically more affected. Spastic quadriplegia is the most severe type of CP because it affects both upper and lower extremities, the face, and the trunk of the person ("Cerebral Palsy (CP)," 2011). CP is not a disease, it is a disorder caused by damage to the motor unit of the brain that can be diagnosed in pregnancy through two years of age. As a result of the damage to the brain, children with CP have problems controlling their movement and posture. Children with CP can show a wide variety of characteristics including lack of coordination, random involuntary movement, exaggerated reflexes, and stiffness in muscles. Each child with CP can have a unique combination of symptoms that can vary throughout the child's life. In addition, there are a variety of different treatments to help manage the symptoms including physical therapy, occupational therapy, speech therapy, and many others to help make children with CP as independent as possible. These types of therapies can help the children learn new ways of completing activities ("*Cerebral Palsy: Hope Through Research"*, 2011). A continual management of characteristics is needed in children with CP to help them maintain functional independence.

Static versus dynamic balance

Static balance in children with CP compared to TD

Numerous studies have compared static balance strategies between children with CP and TD children (Donker et al., 2008; Ferdjallah et al., 2002; Rose et al., 2002). In one study Rose et al. (2002), took 23 children with spastic diplegia CP between the ages of five and 18 were compared with 92 TD children in standing balance under two conditions: eyes open while fixed on a subject and eyes closed. The participants were asked to stand barefoot on a forceplate five times for 30 seconds under both conditions if the participants were between five and six years old, children seven years old and older completed each condition 10 times. The results showed that children with CP had decreased standing stability when compared to TD children in their age group. Children with CP had higher path length values (a velocity measurement of the distance a person traveled per second throughout the total testing trial), average radial displacement (average movement of the radius throughout trial), and diffusion coefficients (average rate the center of pressure will likely change in the time trial) by two standard deviations when compared to TD children. The study also showed there was no difference in eyes open and closed values in children with CP, indicating that children with CP do not depend more heavily on visual feedback when standing (Rose et al., 2002).

In a similar study, Ferdjallah, Harris, Smith, and Wertsch (2002) examined a greater reliance on balance strategies due to the increased postural sway seen in children with CP. A forceplate was used for each foot, as opposed to a single forceplate seen in the previous study, which allowed the observation of transverse rotation, movement that reduced center of pressure due to each extremity moving in opposite directions. Transverse rotation and limb protraction and retraction, techniques that primarily use the hip to possibly reduce ankle adjustments for posture, were seen in both children with CP and TD children. However, results suggested that children with CP relied more on limb protraction and retraction and had more transverse rotation to compensate for the increased postural sway observed during both conditions when compared TD children (Ferdjallah et al., 2002).

Donker et al. (2008) suggested that children with CP exhibit greater postural sway and have differences in organizing postural control than compared to TD children. This study differed from other studies' results that showed an increase in postural sway because this study allowed the children to wear shoes, leg braces, and insoles for leg length discrepancies instead of being barefoot as seen in the previous studies. Both groups showed improvements when their center of pressure was shown on a screen in front of the child (Donker et al., 2008). This study showed that postural sway exists in children with CP whether their posture was artificially corrected by assistive device or not.

Static balance has also been studied in children with CP under altered sensory environments including moveable surrounding and an unstable surface created by placing foam onto the forceplate. In one study, Cherng, Chen, and Kuan (1999) examined the static standing balance in children with CP compared to TD children. They tested six conditions that included eyes open, eyes closed, and moveable surrounding while standing on a forceplate or a foam surface. The results showed that children with CP have decreased stability than TD children only under the conditions with the unstable foam surface. The study also showed that children with CP and TD children preformed the same when standing on the stable forceplate in all visual conditions (Cherng et al., 1999). Visual feedback was not relied on as heavily in children with CP, as also seen in the Rose et al. (2002) study (Cherng et al., 1999; Rose et al., 2002).

Dynamic balance and efficiency of balance recovery in children with CP

Balance was further researched by comparing children with CP with dynamic forceplates, plates that can have anterior and posterior perturbations and have anterior and posterior tilts, and altered sensory environments. The addition of dynamic forceplates introduced recovery of stability, the time it takes for a child to regain balance after a perturbation or tilt of the forceplate, as another outcome variable. These studies have used dynamic forceplates as training strategies to improve balance in children in CP. In 2003, Shumway-Cook, Hutchinson, Kartin, Price, and Woollacott studied recovery stability in six children with spastic diplegia and spastic hemiplegia CP through training and testing on a dual moveable force plate system designed to move as one unit (Neurocom® International, Inc, Oregon, USA). Testing measurements were taken before, immediately after training, and 30 days post-training with training that consisted of five consecutive training session days of 100 forward and backward perturbations of the force plate each day while the child watched a video. The results showed that after the training period, all participants showed a decrease in recovery time of stance balance with the improvements still present at post-training data collection. Based off of these results, the researchers suggested that children with CP could adjust their postural control (Shumway-Cook et al., 2003).

In a pilot study modeled after Shumway-Cook et al. (2003), researchers looked further into the mechanism used by children with CP that improved their reactive balance. The study showed that each child used different combinations of balance mechanisms to improve their reactive balance (Shumway-Cook et al., 2003; Woollacott et al., 2005).

Exercise interventions

Land exercise programs with children with CP

In a large study, Verschuren et al. (2007) examined 86 children with CP who were divided into a training group or a control group. The main outcomes included aerobic and anaerobic capacity and secondary outcomes included agility, gross motor function, muscle strength, and others. The training group circuit trained for 45 minutes, twice a week, while focused on anaerobic or aerobic capacity. The study showed that in addition to significant improvement seen in aerobic and anaerobic capacity, there was also a significant increase in agility. The improvements seen in the results show that group circuit training is an effective way of training children with CP. In addition, it was stated that children with CP have difficulty with agility, being defined as the ability for a person to change direction or shift the direction of movement in a quick or abrupt manner while maintaining balance. Though the results were optimal for this study, the outcome measures were only partially maintained when tested again during the follow-up measurement four months post training (Verschuren et al., 2007).

In another study, a four week, twice a week, hour session of group circuit training with functional exercises designed to improve strength, control of limbs, balance in children with CP, including standing balance exercises that encouraged the child to crouch down to pick up an object at their limit of stability. The results of this study showed improvement in lower extremities strength and functional measures, all of which were maintained at the eight-week post-intervention measurement (Blundell et al., 2003). The maintaining improvements differed from the study previously mentioned; however, this study had a significantly smaller sample size, no control group, and much younger and narrower age group, and a different type of exercise intervention (Blundell et al., 2003; Verschuren et al., 2007).

Fragala-Pinkham, Haley, and Goodgold (2006) studied whether a community-based group fitness program for a group of children with neuromuscular and developmental disabilities was feasible. Their study demonstrated improvements in isometric muscle strength, walking energy expenditure, functional mobility, and fitness. However, though improvements were seen in all outcome measures, it should be mentioned that 31 falls were reported in this study, with 29 of them being from three children in the study who had CP (Fragala-Pinkham et al., 2006). A safer environment is needed for group exercise, especially when taking in consideration the results of Wiley and Damiano (1998), who concluded that children with spastic CP have significant muscle weakness in their lower extremities and varying strength ratios in their joints that cause joints to be imbalanced (Wiley & Damiano, 1998).

Aquatic exercise programs for children with CP

Previous studies have suggested that aquatic exercise programs are beneficial for children with CP, and that an aquatic setting creates a safer, low-impact exercise environment for children with disabilities (Chrysagis et al., 2009; Dorval et al., 1996; Maria Fragala-Pinkham et al., 2008; Hutzler et al., 1998; Thorpe & Reilly, 2000; Thorpe et al., 2005).

In a case study, Thorpe and Reilly (2000) suggested that the buoyant and resistive properties of the water have been suggested to be the safest environment for a person with CP completing a strengthening program. The participant in the study showed an increase in trunk and lower extremity muscles after a three times a week, 45-minute aquatic session that lasted for 10 weeks. Strength improvements were seen immediately after the ten weeks and at the 11-week post-intervention data collection (Thorpe & Reilly, 2000). In a pilot study with a similar intervention design completed by Thorpe, Reilly, and Case (2005), seven participants with CP between the ages of seven and 13 used TUG test, with components of the test being related to balance, and the FRT, a test where the participant is asked to keep feet planted while reaching forward as far as they can, as an outcome measure for functional balance. After three, 45-minute one-on-one sessions with the participant and trainer, three times a week, for 11 weeks, there was a significant decrease in TUG test times and an increasing trend in reach distance FRT when comparing pre-intervention, post-intervention, and 11-week follow-up times. In addition, the majority of the participants in the study subjectively stated that they preferred to workout in a group aquatic setting (Thorpe et al., 2005).

Fragala-Pinkham, Haley, and O'Neal (2008) completed a twice a week group aerobic aquatic exercise program for 16 children, that were six to 11 years old, with different disabilities, including CP, for 14 weeks. In the aquatic sessions, children were asked to maintain their heart rate within their target heart rate zone while completing a variety of exercises, including swimming and games, such as relay races. The results showed improved cardiorespiratory endurance in the children. In addition, no child reported any injuries or had pain throughout the aquatic program, which differs from a similar study that was completed on land (Maria Fragala-Pinkham et al., 2008; Fragala-Pinkham et al., 2006). This study demonstrated that group aquatic classes provide class dynamics and camaraderie that differs from a gym, allowing people with different functional abilities and age to be in the same class, which is good preparation for participation in a community-based fitness program (M. Fragala-Pinkham et al., 2008).

Summary

CP is the most common motor disability in children with about 80% of those children having spastic CP. CP affects the motor control of the brain, which causes unique characteristics in each child that may include increased muscular tone, abnormal posture, random involuntary movement, and exaggerated reflexes. These characteristics can change throughout the child's life (Rosenbaum et al., 2007).

When comparing children with CP and TD children of the same age, children with CP have increased postural sway, recruit larger muscle groups to help adjust for the sway, and rotate their body more to compensate for the lack of balance; however, both groups rely equally on visual feedback (Cherng et al., 1999; Donker et al., 2008; Ferdjallah et al., 2002; Rose et al., 2002). Two dynamic balance studies, that used the same machine for training and testing, found that children with CP learned new strategies to maintain their balance when there were altered sensory environments and unstable surfaces (Shumway-Cook et al., 2003; Woollacott et al., 2005). Further studies are needed to see if the same results were obtainable outside of a lab setting.

Group land based exercise programs resulted in an increase in aerobic and anaerobic capacity, strength, functional measurements, and agility; however, some of these results were not present at follow-up measurements (Blundell et al., 2003; Fragala-Pinkham et al., 2006; Verschuren et al., 2007). In one study, 31 falls were reported, 29 of the falls occurred with the children with CP, compared to a group aquatic exercise program where no falls were reported (Fragala-Pinkham et al., 2006). Aquatic exercise studies showed increased strength in the trunk and lower extremities, cardiorespiratory endurance, and functional balance tests. The results were seen in follow-up measurements (M. Fragala-Pinkham et al., 2008; Thorpe & Reilly, 2000; Thorpe et al., 2005).

Aquatic exercise programs provide a dynamic environment of constant change that is safe, practical, and beneficial for children with CP. Group aquatic exercise programs are more appropriate for children with CP because they provide opportunity for children to build camaraderie with people of different ages and ability. In addition, this prepares the children for community-based fitness programs (M. Fragala-Pinkham et al., 2008). Therefore, it is hypothesized that children with CP will have an improvement in balance after the group aquatic exercise program and there will be a decrease in postural sway in all participants.

Methods

Participants

All procedures were approved by the Institutional Review Board at California State University, Northridge (CSUN). Written informed child/adolescent assent forms and parent consent forms were obtained before the initial data collection. There were three participants in this study between the ages of seven to 14 years old. Data were collected four times: pre-intervention, midcheck, post, and seven-week follow-up. Participants were recruited through flyers and word of mouth. Inclusion criteria were: medical diagnosis of spastic CP, ability to follow verbal instructions, ability to stand independently for 10 seconds without an assistive device, ability to communicate in English, and ability to exercise for at least 50 minutes on land and in the water. Exclusion criteria included: surgery or treatment for spasticity (Botox or Selective Dorsal Rhizotomy) in the last six months, open wound or infection, current participation in an aquatic program, fear of water, and unstable seizures.

Procedures

General

The three participants were recruited from the San Fernando Valley by word of mouth and flyers. The participants were contacted and scheduled for preliminary data collection. Upon arrival to the Center of Achievement (COA), CSUN, the participants and their family members were given a detailed explanation of the nature of the study, data collection, and intervention procedures. They were given the opportunity to ask questions and were informed that they could withdrawal from the study at any time. The parents were asked to sign a Parent Consent Form and the participants were asked to sign a Child Assent Form or Adolescent Assent Form depending on their age. There was preliminary data collection to obtain baseline data. The intervention began and continued for seven weeks, three times a week, for 40 minutes. Data were collected three more times at midcheck, post, and seven-week follow-up.

Instrumentation

The Neurocom Balance Manger (Smart Balance Master, Neurocom International, Clackamas, OR, 2010) is a computerized posturalgraphic balance assessment machine. The Neurocom Balance Manager consists of dual dynamic forceplates and a moveable surrounding that can correlate with the movement of the forceplates or over exaggerate the movement on the forceplates. There were three tests completed in the following order for all data collections: Sensory Organization Test (SOT), Motor Control Test (MCT), and Adaptation Test (AT).

The SOT consists of six conditions designed to emphasize the human body's three major balance systems: somatosensory, visual, and vestibular system. Three trials per condition were performed. The test consists of six conditions that use a combination of: eyes open, eyes closed, moveable forceplate, and moveable surrounding, and combination of the conditions. The first three conditions are different variations of static standing. Condition One requires the participant to stand quietly while facing forward with their eyes open, while Condition Two requires the participant to keep their eyes closed. During Condition Three, the participant was asked to stand on the stationary forceplate with eyes open and while looking forward at a moving visual surrounding. The last three conditions the participants rely on dynamic balance during different combinations. Condition Four required the participant to stand on a moveable forceplate with their eyes open on a stationary visual surrounding. During Condition Five, the participant was asked to keep their eyes closed throughout the trial while standing a moveable forceplate. Lastly, Condition Six had a combination of eyes open, moveable forceplate, and moveable visual surrounding.

The MCT and AT were designed to measure the participant's involuntary reaction to an unexpected movement of the forceplate. The MCT required the participant to react to three unexpected anterior and posterior translations of the forceplates. The AT was designed to see if the participants can adapt through fixed unexpected upwards, anterior, and downwards, posterior, tilts of the forceplates.

The moveable floor pool at the COA, CSUN was used for the aquatic intervention. The water depth was adjusted between participant's waist and chest height before the warm-up began. The average temperature of the pool was 92 degrees.

Outcome measures

Primary Outcome Measures

The primary outcomes were Equilibrium Score, Latency, and Sway Energy.

Equilibrium Score (SOT)

The Equilibrium Score was a score that was calculated by using the participant's maximum anterior and posterior sway throughout each trial of the SOT conditions and divided that number by the maximum sway possible, which was multiplied by 100 to create a percentage. The equation was as follows:

$$\text{Equilibrium Score} = \frac{12.5-(\text{Max AP COG Dis} - \text{Min AP COG Dis})}{12.5} * 100$$

AP = Anterior to Posterior
COG Dis = Center of Gravity Displacement
(Smart Balance Master, Neurocom International, Clackamas, OR, 2010)

Latency (MCT)

Latency was the involuntary reaction time from the unexpected movement of the forceplate either during anterior or posterior translations of the forceplate.

Sway Energy (AT)

Sway Energy was a non-dimensional measurement of the amount of force and sway the participant must apply to maintain on the forceplate during both conditions. The equation was as followed:

$$\text{Sway Energy} = C1 * \text{Velocity(RMS)} + C2 * \text{Acceleration(RMS)}$$

C1,C2 = weight constants
RMS = root mean square
(Smart Balance Master, Neurocom International, Clackamas, OR, 2010)

Secondary outcome measures

Center of gravity (COG) (SOT)

The COG was the voluntary weight distribution between each foot during the SOT conditions.

Weight symmetry

Weight symmetry was the involuntary distribution of weight on each foot during an unexpected movement of the forceplate in either anterior or posterior translations of the forceplate.

Data collection

The participants and their parents arrived for data collection at the COA, CSUN. Before pre-data collection, the participant's height was measured in a supine position with shoes and leg braces removed. The Neurocom Balance Manager determined the participant's foot placement system based of the participant's height. Before the participant stepped onto the forceplates, each participant was fitted with a safety harness. The participant was then asked to step onto the forceplates. The participant's feet were placed on the forceplate and a tape outline of the participant's foot was added to ensure consistent foot placement in the event the participant exceeded their limits of stability. The safety harness was clipped onto the Neurocom Balance Manager, the slack was adjusted to ensure that safety was being maintained and the harness was not adding additional support, and the active spotter was standing behind the participant. The participants were removed from the assessment tool as needed and were asked to take seated breaks. The data were not recorded if the participant lost their balance by moving their foot, holding their harness, and/or touching the wall throughout the trials. If the participants moved their foot, their foot was moved back to the designated placement before the next condition began. The researcher ensured that participants were standing with proper foot placement, their safety harness was attached, and active spotter was in place prior to the trials.

All participants preformed the SOT test first. All six conditions were completed each data collection in numeric order. The second test was the MCT. This test consists of two conditions. The participants were asked to keep their balance while the forceplate unexpectedly moved posterior for three trials followed by three trials of unexpected anterior translations of the forceplate. The last test was the AT. The test consists of two conditions. First, the participants were asked to maintain their balance during posterior tilts for five trials. Second, the participant was asked to maintain their balance during five trials of anterior tilts of the forceplate. The testing protocol took approximately 30-minutes.

Aquatic intervention

Participants came to the COA, CSUN three times a week for 40-minute aquatic sessions for seven weeks. The aquatic session took place in the moveable floor pool. Each session had two supervisors to keep time of each exercise, oversee the entire pool area, and assisted participants when needed. The participants entered the pool by walking on the raised pool floor that was even-level with the pool deck and stayed in the middle of the floor with assistants until the water level was adjusted to the proper height. Each aquatic session began with a 10-minute group warm-up that consisted of exercises such as: forward walking, backwards walking, sidestepping, marching, hamstring curls, and flexibility of the lower extremities. The next 20 minutes were divided into 10-minute breakout groups focusing on gait and balance. Participants were divided into two groups and assigned which breakout group to begin with. After 10 minutes, the lead supervisor would announce for each group to switch. The balance group's exercises consisted of exercises such as: balance board sitting, matt climbing, noodle sitting, spinal flexion and extension exercises, and sit and reach. The gait exercises consisted of exercises such as: toe walking, heel walking, sidestepping, backwards walking, tandem walking, and other exercises of this nature. The last 10 minutes was a group cool down that consisted of games including: Simon Says, Shark Tag, Hot Potato, What Time is it Mr. Bear, noodle horse races, volleyball, water polo, and basketball. After the 40-minutes, the participants and assistants gathered back into the center of the pool floor and waited as the floor was raised back to deck level.

Results

Participant #1

Participant #1 was a 14-year-old female with spastic, left hemplegia CP. She showed increased Equilibrium Score during the SOT in two conditions, Condition Five and Condition Six. There was a 7.14% increase in Equilibrium Score from baseline score of 42 to post score of 45 in Condition Five (Figure 1e). She was unable to complete any trials for score at baseline for Condition Six; however at post data collection scored a 53.0 (Figure 1f). There were decreases in Equilibrium Score in Condition One, Condition Two, Condition Three, and Condition Four. Participant #1 had a 10.60% decrease from baseline score of 94.3 to post score of 84.3 data collection in Condition One (Figure 1a). There was a 14.69% decrease in Condition Two from baseline score of 92.6 to post score of 79.0 data collection (Figure 1b). During Condition Three, Participant #1 showed an 11.60% decrease in Equilibrium Score from a baseline score of 93.3 to a post score of 82.5 (Figure 1c). Lastly, a 30.89% decrease in Equilibrium Score was reported from baseline score of 61.5 to post score of 42.5 in Condition Four (Figure 1d).

Participant #1 had an 11.11% decrease in latency time from baseline time of 180 milliseconds to post time of 160 milliseconds during right anterior translations of the forceplate (Figure 2a). A greater decrease in latency time was observed during right posterior translations of the forceplate with a 43.48% decrease in time observed in Participant #1 (Figure 2b). There were no latency times measured on the participant's left leg. Participant #1 showed improvements during the AT. During the anterior tilt condition, Participant #1 was unable to complete the test at baseline, but was able to complete two tilts for score at post data collection. Participant #1 was unable to complete any trials during anterior condition; however, was able to successfully maintain on the forceplate for three trials at post data collection.

In secondary outcomes during the MCT, there were improvements in weight symmetry in anterior and posterior translations of the forceplate. During anterior translations of the forceplate, Participant #1 had a decrease on the right side by 29 points and achieved equal weight distribution at post data collection (Figure 3a). In addition, improvements were observed during posterior translations of the forceplate. Participant #1 decreased her dependence on her right leg by 11 points (Figure 3b). In strength symmetry measurements, Participant #1 maintained right side full dependence during posterior translations of the forceplate from baseline to post (Figure 4a). She increased strength by 58 points to full right side dependence during anterior translations from baseline to post data collection (Figure 4b).

Participant #2

Participant #2 was a 10-year-old female with spastic hemiplegia CP. She had improvements in two SOT conditions, Condition One and Condition Four. Condition One had a 10.49% increase in Equilibrium Score from a baseline score of 71.5 to a post score of 79.0 (Figure 5a). There was a 20.37% increase in Equilibrium Score from baseline score of 54.0 to post score of 65.0 in Condition Four (Figure 5d). Participant #2 had decreases in Equilibrium Score in Condition Two, Condition Three, Condition Five, and Condition Six from baseline to post data collection. In Condition Two, there was a 1.85% decrease in Equilibrium Score from baseline score of 81.0 to post score of 79.5 (Figure 5b). Participant #2 had a 9.64% decrease from baseline Equilibrium Score of

83.0 to post score of 75.0 in Condition Three (Figure 5c). In Condition Five (Figure 5e) and Condition Six (Figure 5f), Participant #2 decreased from trials completed in baseline measurement to no score being obtained at post data collection.

In the MCT, Participant #2 increased latency time in all conditions: right side anterior translation by 7.69% from baseline time of 130 milliseconds to post time of 140 milliseconds (Figure 6d), left side anterior translation by 13.33% from a baseline time of 150 milliseconds to 170 milliseconds at post (Figure 6c), right side posterior translation by 37.5% from baseline time of 160 milliseconds to 220 milliseconds at post (Figure 6b), and left side posterior translation by 31.25% from baseline time of 160 milliseconds to 210 milliseconds at post (Figure 6a). There were also improvements seen in the AT. During the anterior tilt condition, Participant #2 showed a 21.6% decrease in Sway Energy score from baseline to post data collection. She was only able to complete baseline trial for posterior tilt condition and did not score for midcheck or post.

There were also improvements in secondary measures of the MCT. Participant #2 improved weight symmetry during posterior translation of the forceplate by one closer to equal symmetry from baseline to post data collection (Figure 7a). She decreased in weight symmetry during anterior translations by three points from baseline to post data collection (Figure 7b). In strength symmetry, Participant #2 maintained from baseline to post equal distribution between each leg during posterior translations of the forceplate (Figure 8a). There was an improvement in strength symmetry noted from baseline to post, decrease of 14 points closer to equal strength distribution, during forward translations. At post data collection, Participant #2 had equal distribution in both legs for a score of 100 (Figure 8b).

Participant #3

Participant #3 was a nine-year-old male with spastic left hemiplegia CP. Participant #3 had improvements in all conditions from baseline to post data collection. There was a 24.72% improvement in Condition One from baseline Equilibrium Score of 59.33 to post score of 74.0 (Figure 9a) and a 34.76% improvement in Condition Two from baseline score of 54.67 to post score of 73.67 (Figure 9b). He improved from baseline Equilibrium Score of 50.33 to post score of 71.5 for a 42.05% improvement in Condition Three (Figure 9c) and 38.46% improvement observed in Condition Four from baseline score of 13 to post score of 18 (Figure 9d). Participant #3's largest improvement was noted in Condition Five with a 67.16% improvement from baseline score of 33.5 to post data collection score of 56 (Figure 9e). In Condition Six, he was unable to complete baseline measurements for score at baseline; however, at post data collection scored an Equilibrium Score of 29 (Figure 9f). In the MCT, Participant #3 achieved a 23.81% decrease in latency time on his right leg during posterior translations of the forceplate from baseline time of 210 milliseconds to a time of 160 milliseconds measured at post data collection (Figure 10a). No scores could be measured on his left leg during posterior translations of the forceplate. During anterior translations of the forceplate from baseline time of 200 milliseconds to post data collection time of 180 milliseconds, a 10% decrease in latency time was reported on his right side (Figure 10b) and a 10% increase in latency time measured on his left leg (Figure 10c). Improvements were seen in the AT. Participant #3 improved from no score in baseline data collection to a decrease in score from midcheck and post in posterior tilt condition. In addition, Participant #3 was not able to score in baseline and midcheck data collection during anterior tilt condition; however, was able to get to measurements at post data collection.

There were observations noted in secondary measures. Participant #3 shifted his weight distribution from the right leg to the left in anterior translations (Figure 11a). Participant #3 also shifted weight distribution from right to left seen during anterior translations and was within seven points of equal weight distribution (Figure 11b). Participant #3 increased to full right dependence during strength symmetry during posterior translations of the forceplate from baseline to post data collection (Figure 12a). In addition, he maintained full right side dependence during anterior translation of the forceplate when comparing baseline to post data collection (Figure 12b).

Seven-week follow-up

Participant #1

Participant #1 had carry over effects observed at the seven-week follow-up in Condition One, Condition Two, and Condition Three. A 0.83% carry over effect in Equilibrium Score was observed during Condition One (Figure 1a). Participant #1 had a 5.91% carry over effect from baseline to post in Condition Two (Figure 1b). In addition, a 5.85% carry over effect in Equilibrium Score was observed in Condition Three (Figure 1c). Withdrawal training effects were seen in Condition Six with a 16.98% decrease in Equilibrium Score from post to the seven-week follow-up (1f). She had a 31.25% carry over effect in latency was observed from post to seven-week on the right side during anterior translations of the forceplate (Figure 2a); however, a 15.38% withdrawal effect in latency was observed during right side posterior translations of the forceplate (Figure 2b). Participant #1 had withdrawal effects observed in the AT at the seven-week follow-up measurement of the anterior condition. At post data collection she was able to maintain standing on the forceplate for two tilts, but was unable to maintain standing during any tilts at the seven-week follow-up. She also had withdrawal effects seen during the posterior condition of the AT with three trials successfully completed at post data collection with only completion of two trials observed at the seven-week follow-up.

In secondary measures, there were withdrawal effects observed at the seven-week follow-up during anterior translations of the forceplate with a shift from equal weight distribution between both feet to a relying on the left leg by seven points away from equal distribution (Figure 3a). Participant #1 had carry over effects of nine points with continued decreased reliance on the right leg and moved closer to equal weight distribution in posterior translations of the forceplate (Figure 3b). Participant #1 maintained full right side dependence in strength symmetry measurements during posterior translations from post to seven-week follow-up (Figure 4a). During anterior translations of the forceplate, there were withdrawal effects observed from post, full right side dependence, to seven-week as Participant #1 decreased right side strength by 50 points (Figure 4b).

Participant #2

There were carry over effects observed in Participant #2 in Conditions One and Condition Two. In Condition One, there was a 1.27% carry over effect in Equilibrium Score noted from post to seven-week follow-up (Figure 5a). Participant #2 had a 5.70% carry over effect from post to seven-week follow-up measured in Condition Two (Figure 5b). In addition, withdrawal effects were observed in Condition Three and Condition Four. In Condition Three, there was continued 2% decrease in Equilibrium

Score observed from post to seven-week follow-up (Figure 5c). In Condition Four, there were withdrawal effects of a 20.37% decrease in score from post to seven-week follow-up (Figure 5d). A 21.43% carry over effect was observed in latency time from post to seven-week follow-up during anterior right translation of the forceplate. In at the AT, withdrawal effects were observed at the seven-week follow-up condition during the anterior tilt condition. Participant #2 decreased from baseline, to midcheck, to post, but was not able to stay within her limits of stability to score during the seven-week follow-up. Participant #2 maintained not being able to score during the posterior tilt condition at the seven-week follow-up.

Both carry over and withdrawal effects were observed in weight symmetry scores of the MCT at the seven-week follow-up data collection. Participant #2 had carry over effects, three points closer to equal weight distribution, during posterior translations of the forceplate (Figure 7a) and withdrawal effects, one point different between post and seven-week follow-up, observed during anterior translations of the forceplate (Figure 7b). A withdrawal effect of 33 with increase in right side favored was also noted from post to seven-week in strength symmetry score during anterior translation of the forceplate (Figure 8b).

Participant #3

Participant #3 had withdrawal effects measured from post to seven-week follow-up in four out of the six SOT conditions. In Condition One, there was a 19.82% withdrawal effect in Equilibrium Score observed (Figure 9a). He had a 4.52% withdrawal observed in Condition Two from post to seven-week follow-up (Figure 9b). Participant #3 scored an Equilibrium Score of 56 during post data collection and was unable to complete a trial for score at the seven-week follow-up. In addition, a 7.69% carry over effect was observed in Condition #3 from post to the seven-week follow-up (Figure 9c). In latency times, no changes were observed in posterior translations of the forceplate. Participant #3 maintained a time of 160 milliseconds in posterior right translation of the forceplate (Figure 10a). No time could be measured in the left leg during posterior translation. There were withdrawal effects observed during anterior translations of the forceplate in the right and left leg. There was an increase in latency time from post to seven-week follow-up for a 38.89% withdrawal during anterior right translations of the forceplate (Figure 10b). In addition, a 13.64% withdrawal effect was observed from post to the seven-week follow-up during anterior left translations of the forceplate (Figure 10c). Withdrawal effects were also observed in posterior and anterior tilt conditions of the AT, with no scores at the seven-week follow-up.

Carry over effects was observed in secondary measures. In MCT weight symmetry, Participant #3 had carry over effects observed in anterior and posterior translations of the forceplate. Participant #3 had a carry over effect of six points closer to equal weight distribution in posterior translations of the forceplate (Figure 11a). During anterior translations weight symmetry, Participant #3 had a carry over effect of five points from post to seven-week follow-up moving from left side weighted closer to equal weight distribution (Figure 11b). In strength symmetry measurements, Participant #3 maintained full right side dependence from post to seven-week follow-up during posterior translations of the forceplate (Figure 12a). There was a decrease in right side strength symmetry observed in anterior translations of the forceplate from post to seven-week data collection (Figure 12b).

Discussion

The three participants in this study suggest that aquatic exercise can have positive effects on balance in children with spastic hemiplegia and spastic diplegia CP. Improvements were observed in static and dynamic balance during involuntary and voluntary conditions. Findings from this case study also found that some of these improvements can be maintained with some continued improvement after a seven-week break of aquatic exercise, which is in agreement with other literature that children with CP can improve posture control and maintain improvements (Shumway-Cook, 2003 #24).

Sensory organization improvements

Improvements were observed in sensory organization conditions in all three participants; however, each participant had a different combination of conditions that they improved in. Research has suggested that each child with hemiplegia and diplegia has unique characteristics that lead to improvement (Shumway-Cook, 2003 #24). Participant #1 SOT results suggest that she possibly has an overreliance on her somatosensory system and that her body cannot accurately differentiate between accurate and inaccurate visual cues, which is observed in her low Equilibrium Scores in Condition Four (Figure 1d), Condition Five (Figure 1e), and Condition Six (Condition 1f). Though there were improvements in Condition Five and Condition Six, both conditions had the lowest Equilibrium Scores. Participant #1's results in this test also could suggest that her body cannot accurately switch between balance systems from somatosensory to visual or vestibular when one becomes unreliable, such as when the forceplate is unstable. It has been suggested in previous literature that children with CP cannot accurately switch between balance systems and recognize inaccurate feedback as effectively as TD children of the same age (Cherng, 1999 #22).

Participant #2 improved in Condition One and Condition Four of the SOT. It could be suggested that she improved her oculomotor function, with both conditions having a stationary visual surrounding. She decreased in the other conditions that included combinations of moveable visual surrounding, eyes closed, and moveable forceplate. Other research has shown that compared to TD children, children with CP have decreased sway when the participant's visual feedback is on a stationary surrounding (Donker, 2008 #19). Participant #3 improved over 20% in five out of the six SOT conditions. In Condition Six, the participant was unable to complete the test at baseline data collection, but was able to complete trials in the other three data collections.

Latency improvements hemiplegia verses diplegia

The two participants with spastic left hemiplegia decreased latency times on their non-hemiplegic side during anterior and posterior translations of the forceplate. Recovery stability has been found to be possible to reduce, but vary individually and differences have been seen when comparing participants with hemiplegia and diplegia (Shumway-Cook, 2003 #24; Woollacott, 2005 #23). Participant #2, the only participant in the study with diplegia, did not have improvements in latency until the seven-week follow-up data collection. Previous literature in reactive balance has shown that children with diplegia have a slower response of improvement than children with hemiplegia (Woollacott, 2005 #23). Participant #2 had improvement from post to seven-week follow-up in latency in both, right and left legs during anterior and posterior translations, of the forceplate.

Very few latency scores were collected from the participants' hemiplegic legs. Participant #3 had latency times from his hemiplegic leg during anterior translations of the forceplate; however, the times were inconsistent. There were no times scored during posterior translations during any of the four data collections; however, weight was being distributed onto his left leg during these translations. It could be suggested that with continued exercise, latency times would be measured as the participant continued to improve because there is a delay in ankle muscle contraction in the hemiplegic leg (Woollacott, 2005 #23). Participant #1 also showed improvements in weight symmetry on her hemiplegic side where she achieved equal weight distribution during anterior translations of the forceplate. Both participants had a natural stance of more weight distributed to the right side during voluntary conditions.

Adherence

Each participant had a 100% adherence rate during the aquatic intervention. Adherence policies were addressed at pre-data collection. Before the parents agreed to participate in the study, the primary researcher informed them that their child must have an adherence rate of 90%. Throughout the intervention, there were weekly conversations with each of the parents reminding them of exercise make-up dates. When working with children, it should be considered that the parents most likely have other children that have outside activities that need to be attended which may require the parent's inability to bring their child to the exercise program on some days. Make-up days were also required due to the children missing the exercise program for school functions.

Aquatic exercise program

Every exercise program consisted of a: group warm-up, balance breakout group, gait breakout group, and group cool-down. Every warm-up included forward, backwards, and sideways walking among other exercises including marching, hamstring curls, and flexibility in upper and lower extremities. Some of the participants favorite balance activities included balance board sitting while swimming with breaststroke arms, shooting basketball, and moving around the perimeter of the pool on the wall. Another popular activity during the balance breakout group was activities using the mat. The participants enjoyed sitting on the mat while waves were created, sit and reach games were played, and abdominal crunches were completed. In addition, the participants enjoyed climbing up and over the mat. The most popular cool-down group games was "What Time is it Mr. Bear?" This game was introduced by one of the assistants in the pool. The game is played with all the participants and assistants at one side of the pool, while one of the leaders is at the other end of the pool with their back facing the participants. The participants would ask, "What time is it Mr. Bear?" and the leader would announce a time, the time would correspond to the number of steps each of the participants could take that would get them closer to Mr. Bear. At any point throughout the game, Mr. Bear could response with, "It's Dinner Time!" and the participants would have to run back to their wall before Mr. Bear would tag them.

Issues with Neurocom Balance Manager and pediatrics

When using the Neurocom Balance Manager as an assessment tool for children, it should be taken into consideration that some children do not prefer to have their backs to their parents or the researchers. All three participants had to be constantly reminded to face forward and not to turn around to talk to the parent or researcher. It should also be taken into consideration that it could be uncomfortable for the child to have their foot placement different from their natural stance. Therefore, the child wants to take a step to put them back into their natural foot placement. The researchers had to constantly recheck the participant's foot placement in between each trial. Tape was placed on the footplate around the participant's foot to ensure consistency in foot placement. Participant #2 had a large base of support and did not understand that her feet needed to stay in the proper foot placement. It was suggested by the participant's mother to trace the participant's foot in her favorite color construction paper, cut out the traced images of her feet, and tape them onto the forceplate. The mother informed the researchers that her daughter would be able to understand where her feet needed to stay if she saw her feet on the forceplate and was told to put her feet on the paper feet taped to the forceplate. When completing repeated measures, an anticipation factor should be considered with the children. Some of the participants enjoyed specific testing conditions over others because they eventually knew what was going to happen. For example, Participant #2 could not complete Condition Five (Figure 5e) and Condition Six (Figure 5f) during post measurements. In addition, though the harness is required for safety purposes, it could be suggested that the harness provided the children with a false sense of security. Participant #3 was more interested in swinging backwards into the harness than completing the trials. This was especially observed during the anterior tilt condition of the AT. These observations should be taken into consideration before designing future studies.

Future research

The nature of a case study creates the need for further investigation. Further research is needed in this area with a larger sample size to create a randomized control trial. In addition, functional balance outcomes and parent surveys should be introduced for a more holistic approach on balance. In this study, Participant #2 goes to physical therapy once a month. After one of the participant's appointments after the exercise program had begun, the physical therapist asked what the participant had been doing since the last time she saw the participant and stated that she saw an improvement in the participant's balance and walking. In addition, the participants could create a log of their outside activities because this study did not limit their activity outside of the exercise program and during the seven-week follow-up. Future studies should also consider monitoring intensity levels of each exercise throughout the exercise program. Other factors to consider in future research when using the Neurocom Balance Manager, electromyography could be added to the participants lower extremities. The researcher would be able to see if the hemiplegic leg's muscle contraction. Though the leg may not be involuntarily involved in contracting for a latency score, the EMG would be able to detect muscle activation even if the leg did not produce force that could be detected by the forceplate.

Conclusion

In summary, the results suggest that children with CP can have individualized improvements in balance and balance-related motor adaptation skills through a seven-week aquatic intervention program. The interpretation of our study outcomes must be limited for generalization due to the nature of case study, as well as, the large variability of physical conditions among children with CP. In the future, clinicians should consider the information from the three participants in this study and the improvements they made when considering an exercise program for children with CP.

References

Blundell, S. W., Shepherd, R. B., Dean, C. M., Adams, R. D., & Cahill, B. M. (2003). Functional strength training in cerebral palsy: a pilot study of a group circuit training class for children aged 4-8 years. *Clin Rehabil, 17*(1), 48-57.

Cherng, R. J., Su, F. C., Chen, J. J., & Kuan, T. S. (1999). Performance of static standing balance in children with spastic diplegic cerebral palsy under altered sensory environments. *Am J Phys Med Rehabil, 78*(4), 336-343.

Chrysagis, N., Douka, A., Nikopopoulos, M., Apostolopoulou, F., & Koutsouki, D. (2009). Effects of an aquatic program on gross motor function of children with spastic cerebral palsy. *Biology of Exercise, 5.2*, 14-25. doi: http:doi.org/10.4127/jbe.2009.0027

Donker, S. F., Ledebt, A., Roerdink, M., Savelsbergh, G. J. P., & Beek, P. J. (2008). Children with Cerebral Palsy Exhibit Greater and More Regular Postural Sway Than Typically Developing Children. *Exp Brain Res, 184*(3), 363-370. doi: 10.1007/s00221-007-1105-y

Dorval, G., Tetreault, S., & Caron, C. (1996). Impact of Aquatic Programmes on Adolescents with Cerebral Palsy. *Occupational Therapy International, 3*(4), 241-261.

Ferdjallah, M., Harris, G. F., Smith, P., & Wertsch, J. J. (2002). Analysis of Postural Control Synergies During Quiet Standing in Healthy Children and Children with Cerebral Palsy. *Clin Biomech (Bristol, Avon), 17*(3), 203-210.

Fragala-Pinkham, M., Haley, S. M., & O'Neil, M. E. (2008). Group aquatic aerobic exercise for children with disabilities *Dev Med Child Neurol* (Vol. 50, pp. 822-827). England.

Fragala-Pinkham, M., Haley, S. M., & O'Neil, M. E. (2008). Group Aquatic Aerobic Exercise for Children with Disabilities. *Developmental Mededicine & Child Neurology, 50*(11), 822-827. doi: 10.1111/j.1469-8749.2008.03086.x

Fragala-Pinkham, M. A., Haley, S. M., & Goodgold, S. (2006). Evaluation of a community-based group fitness program for children with disabilities *Pediatr Phys Ther* (Vol. 18, pp. 159-167). United States.

Hutzler, Y., Chacham, A., Bergman, U., & Szeinberg, A. (1998). Effects of a movement and swimming program on vital capacity and water orientation skills of children with cerebral palsy. *Developmental Medicine & Child Neurology, 40*(3), 176-181.

Kirby, R. S., Wingate, M. S., Van Naarden Braun, K., Doernberg, N. S., Arneson, C. L., Benedict, R. E., . . . Yeargin-Allsopp, M. (2011). Prevalence and functioning of children with cerebral palsy in four areas of the United States in 2006: A report from the Autism and Developmental Disabilities Monitoring Network. *Research in Developmental Disabilities, 32*(2), 462-469. doi: 10.1016/j.ridd.2010.12.042

Palsy, U. C. (2001). UCP: Press Room - Vocabulary Tips *Cerebral Palsy- Facts and Figures*.

Prevention, C. f. D. C. a. (2006). Economic Costs Associated with Mental Retardation, Cerebral Palsy, Hearing Loss, and Vision Impairment --- United States, 2003 *MMWR Weekly* (Vol. 55, pp. 881).

Prevention, C. f. D. C. a. (2011). CDC - Cerebral Palsy, Home - NCBDDD.

Rose, J., Wolff, D. R., Jones, V. K., Bloch, D. A., Oehlert, J. W., & Gamble, J. G. (2002). Postural balance in children with cerebral palsy. *Developmental Medicine & Child Neurology, 44*(1), 58-63. doi: 10.1111/j.1469-8749.2002.tb00260.x

Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., & Bax, M. (2007). A report: the definition and classification of cerebral palsy April 2006. *Developmental Medicine & Child Neurology, 49*, 8-14. doi: 10.1111/j.1469-8749.2007.tb12610.x

Shumway-Cook, A., Hutchinson, S., Kartin, D., Price, R., & Woollacott, M. (2003). Effect of balance training on recovery of stability in children with cerebral palsy. *Dev Med Child Neurol, 45*(9), 591-602.

Thorpe, D. E., & Reilly, M. (2000). The Effect of an Aquatic Resistive Exercise Program on Lower Extremity Strength, Energy Expenditure, Functional Mobility, Balance and Self-Perception in an Adult with Cerebral Palsy: A Retrospective Case Report. *The Journal of Aquatic Physical Therapy, 8*(2), 18-24.

Thorpe, D. E., Reilly, M., & Case, L. (2005). The Effects of an Aquatic Resistive Exercise Program on Ambulatory Children with Cerebral Palsy (Vol. 13, pp. 21-34): Journal of Aquatic Physical Therapy.

Verschuren, O., Ketelaar, M., Gorter, J. W., Helders, P. J., Uiterwaal, C. S., & Takken, T. (2007). Exercise training program in children and adolescents with cerebral palsy: a randomized controlled trial *Arch Pediatr Adolesc Med* (Vol. 161, pp. 1075-1081). United States.

Wiley, M. E., & Damiano, D. L. (1998). Lower-extremity strength profiles in spastic cerebral palsy. *Dev Med Child Neurol, 40*(2), 100-107.

Woollacott, M., Shumway-Cook, A., Hutchinson, S., Ciol, M., Price, R., & Kartin, D. (2005). Effect of balance training on muscle activity used in recovery of stability in children with cerebral palsy: a pilot study. *Dev Med Child Neurol, 47*(7), 455-461.

Appendix A

Figures

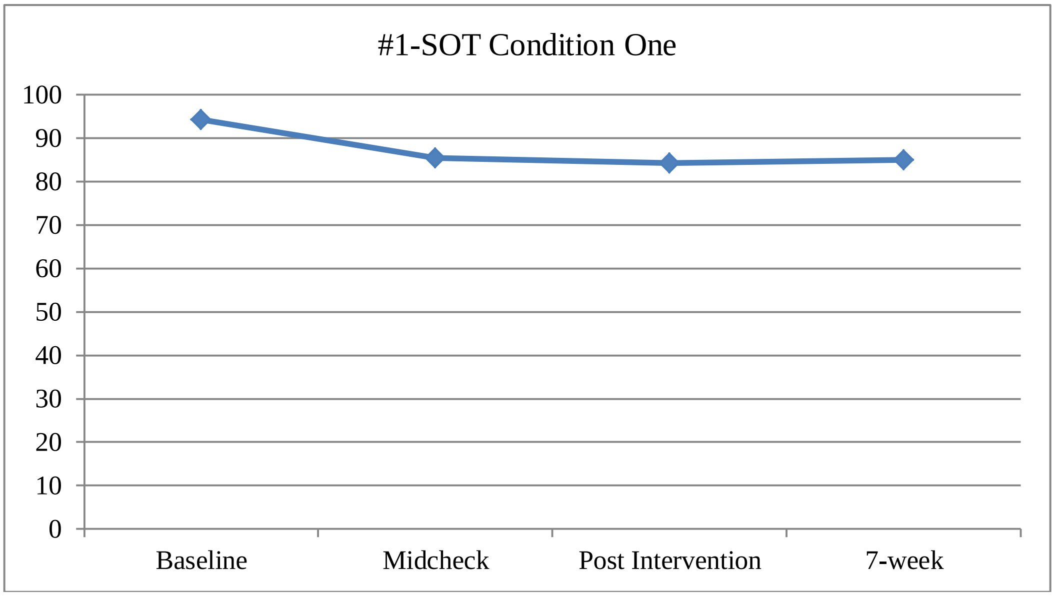

Figure 1a: Participant #1-SOT Condition One

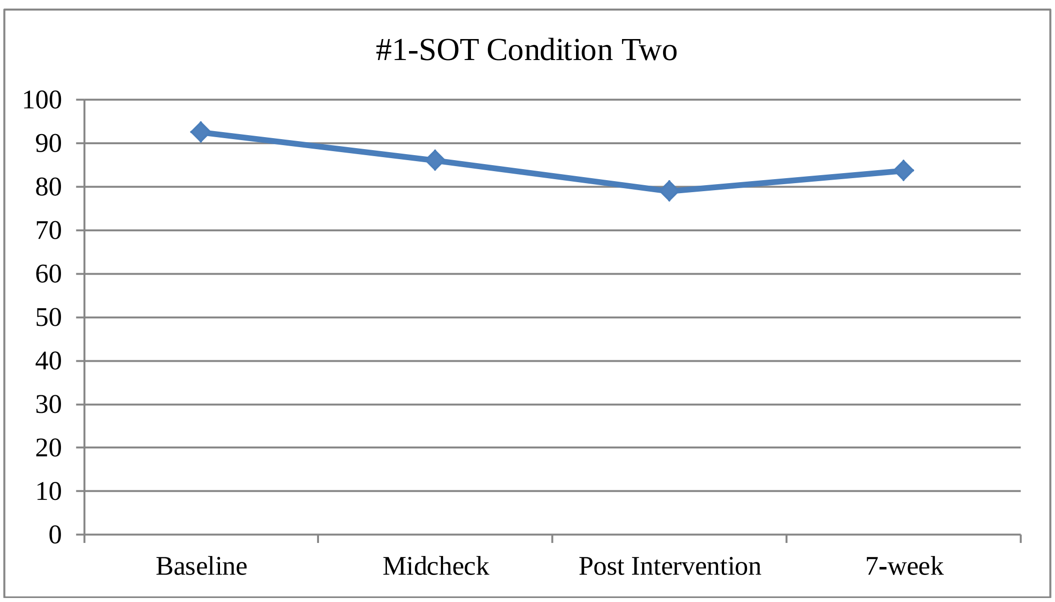

Figure 1b: Participant #1-SOT Condition Two

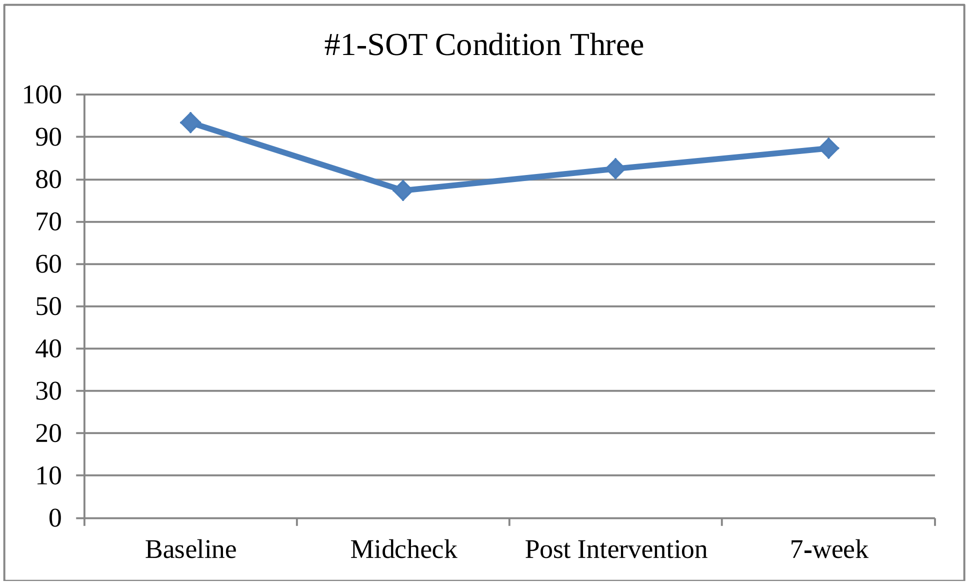

Figure 1c: Participant #1-SOT Condition Three

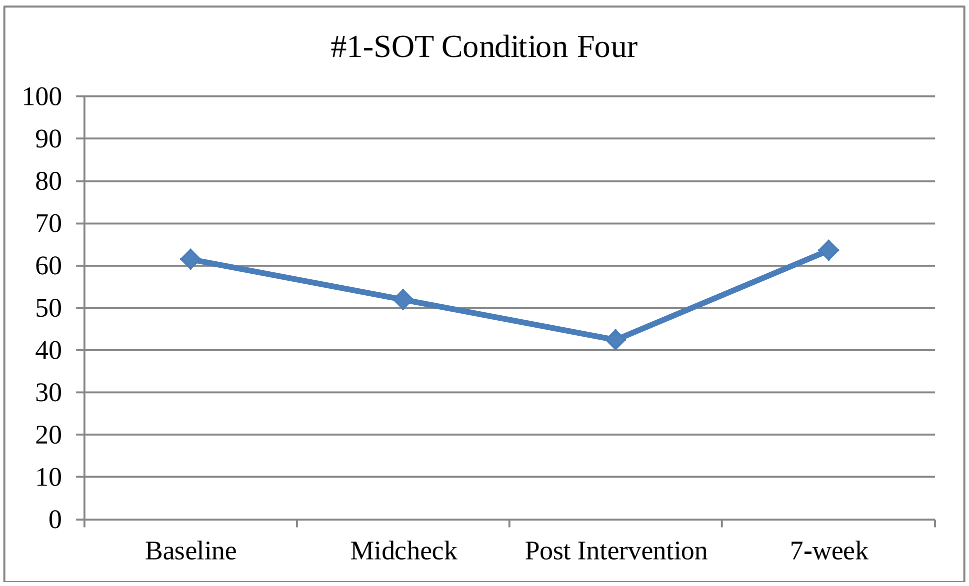

Figure 1d: Participant #1-SOT Condition Four

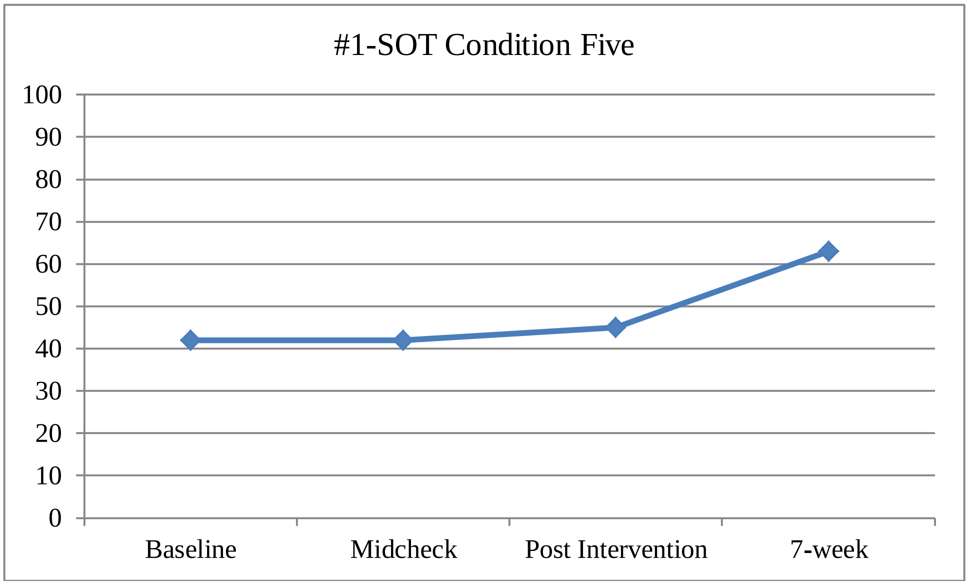

Figure 1e: Participant #1-SOT Condition Five

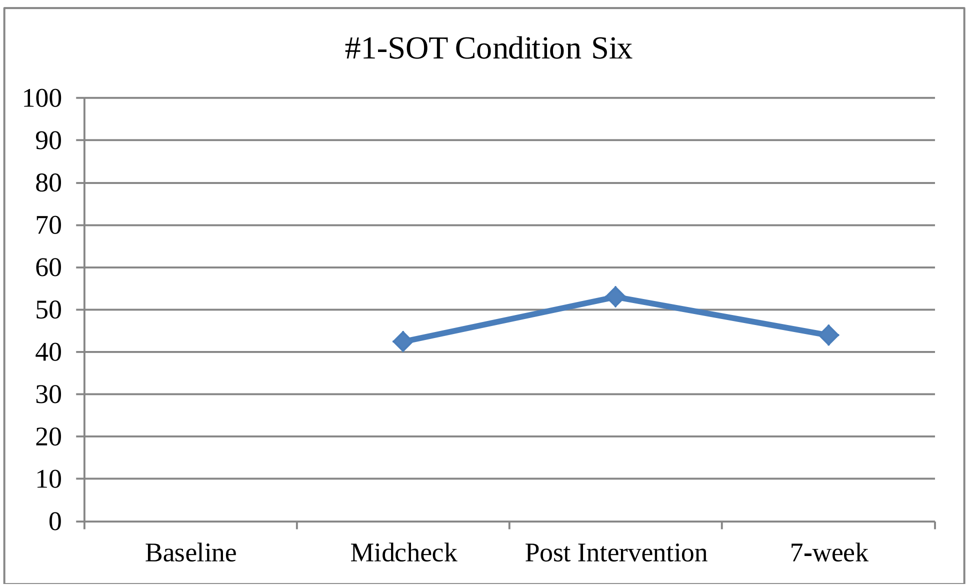

Figure 1f: Participant #1-SOT Condition Six

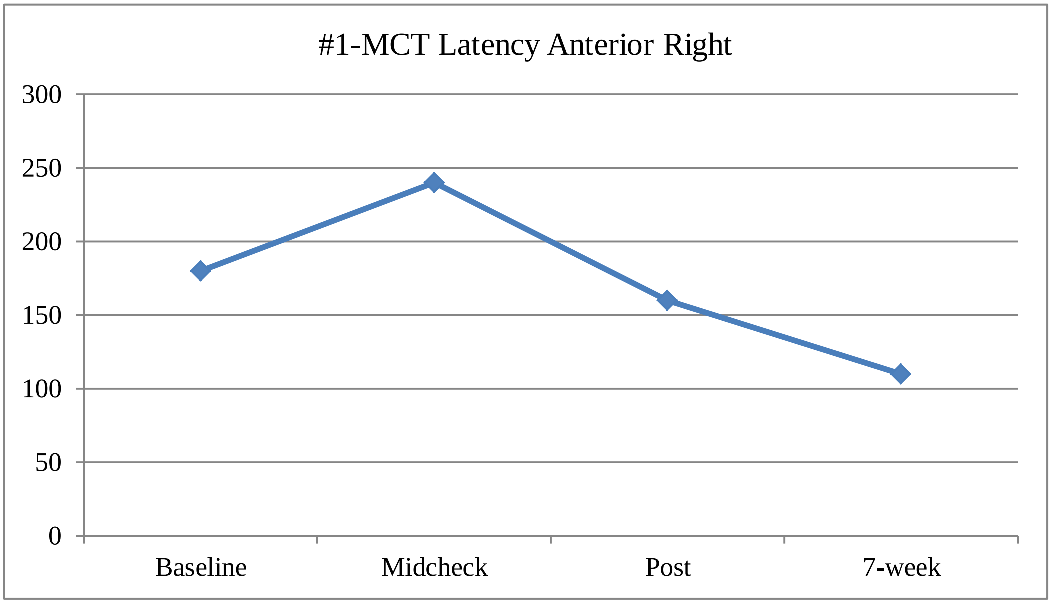

Figure 2a: Participant #1-MCT Latency Anterior Right

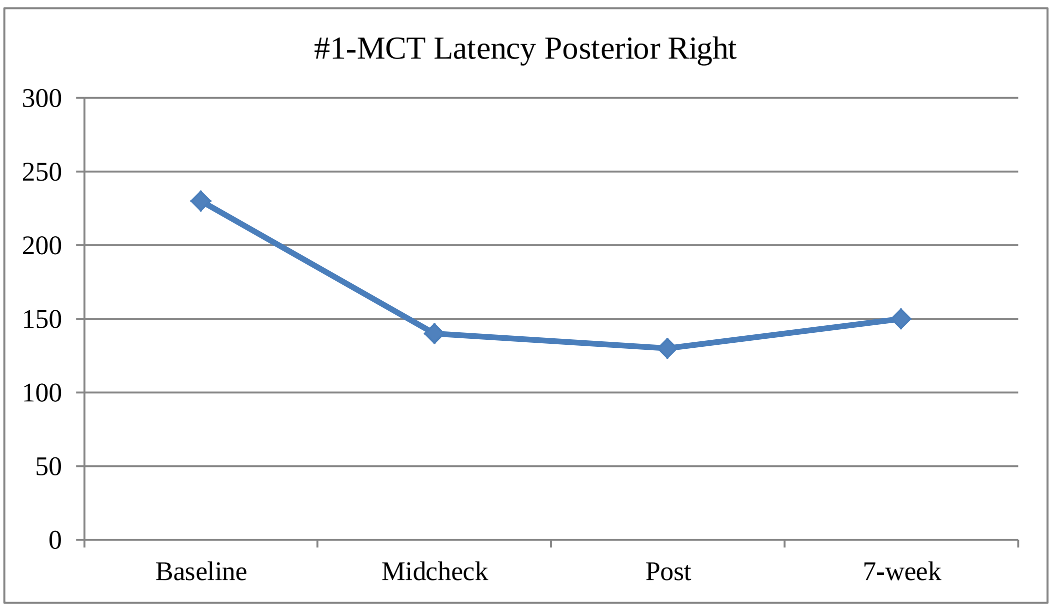

Figure 2b: Participant #1-MCT Latency Posterior Right

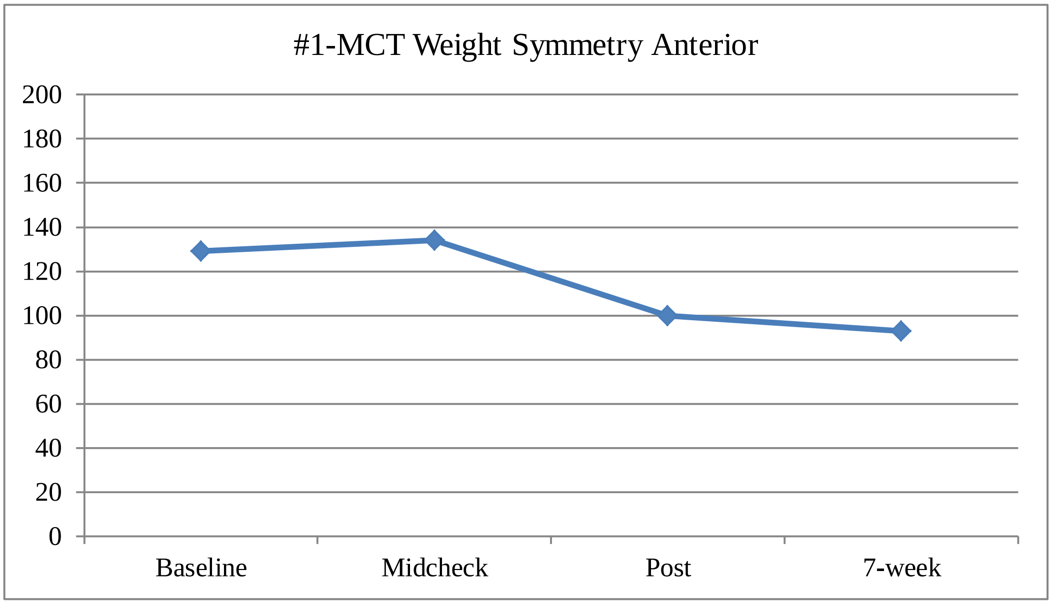

Figure 3a: Participant #1-MCT Weight Symmetry Anterior

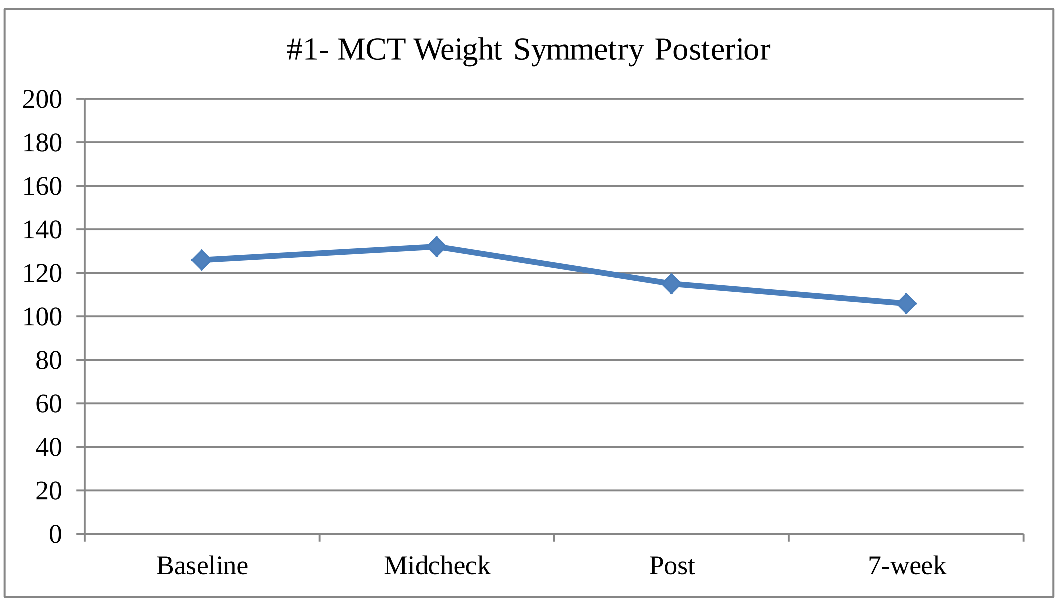

Figure 3b: Participant #1-MCT Weight Symmetry Posterior

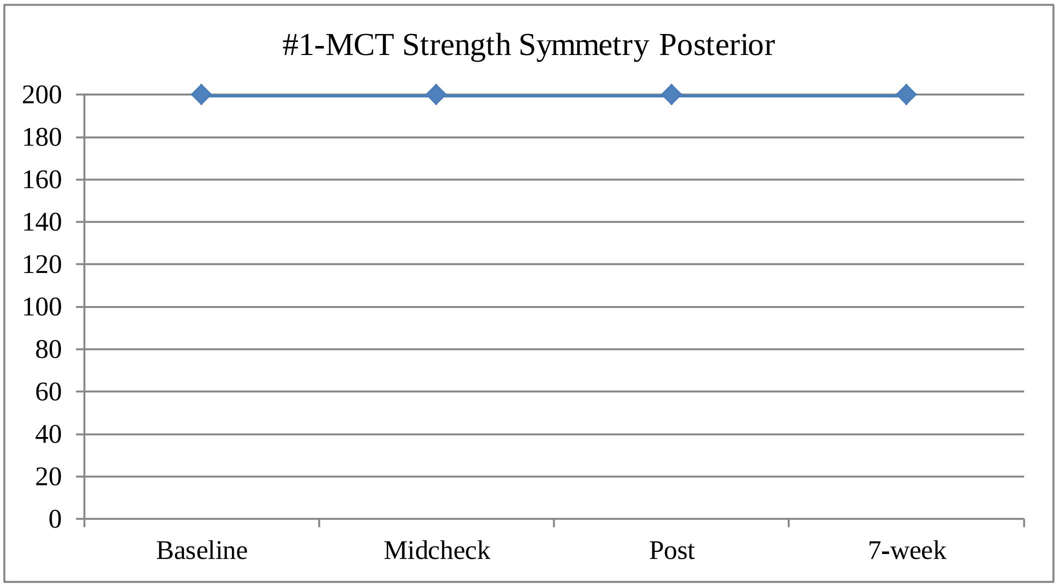

Figure 4a: Participant #1-MCT Strength Symmetry Posterior

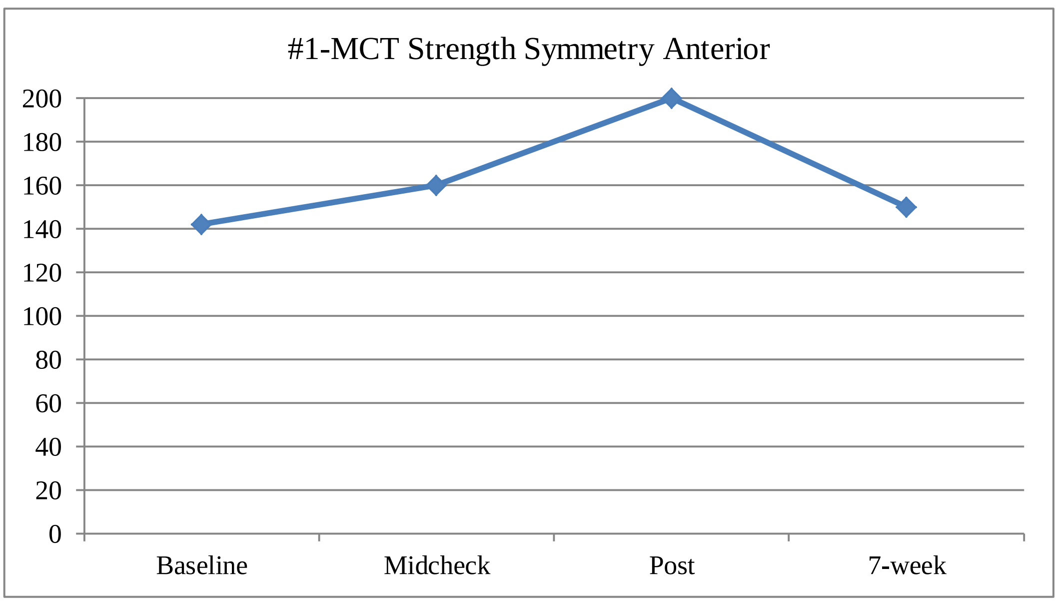

Figure 4b: Participant #1-MCT Strength Symmetry Anterior

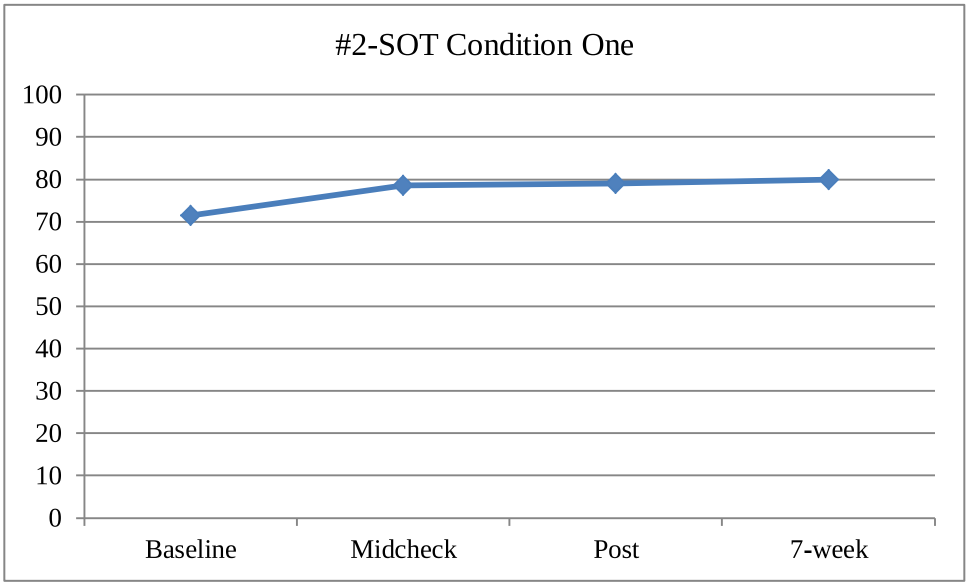

Figure 5a: Participant #2-SOT Condition One

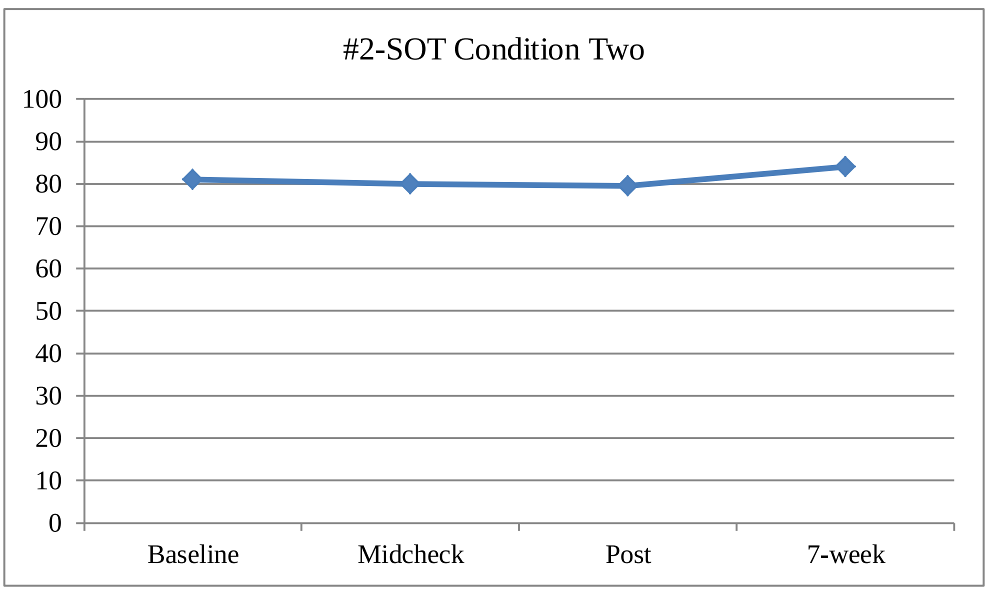

Figure 5b: Participant #2-SOT Condition Two

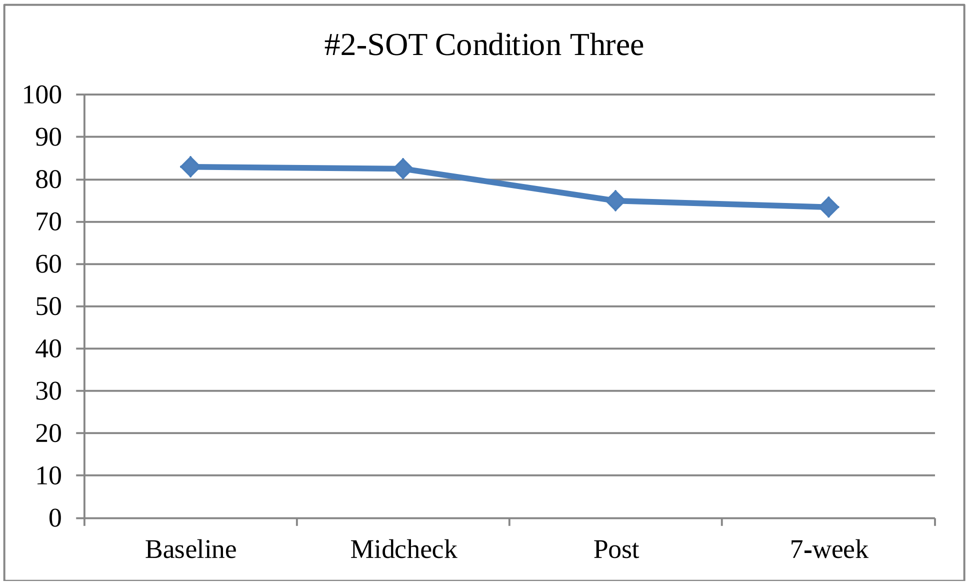

Figure 5c: Participant #2-SOT Condition Three

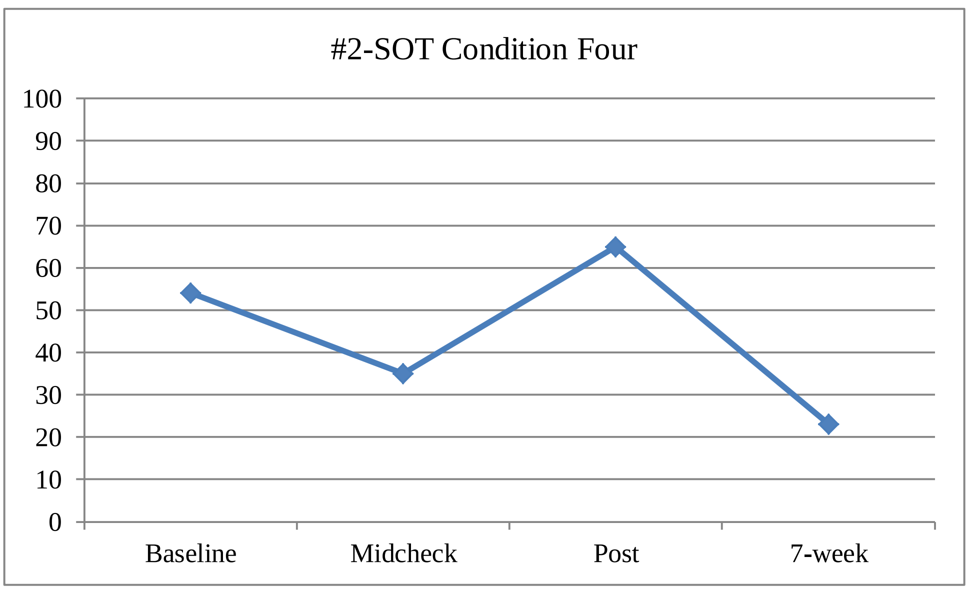

Figure 5d: Participant #2-SOT Condition Four

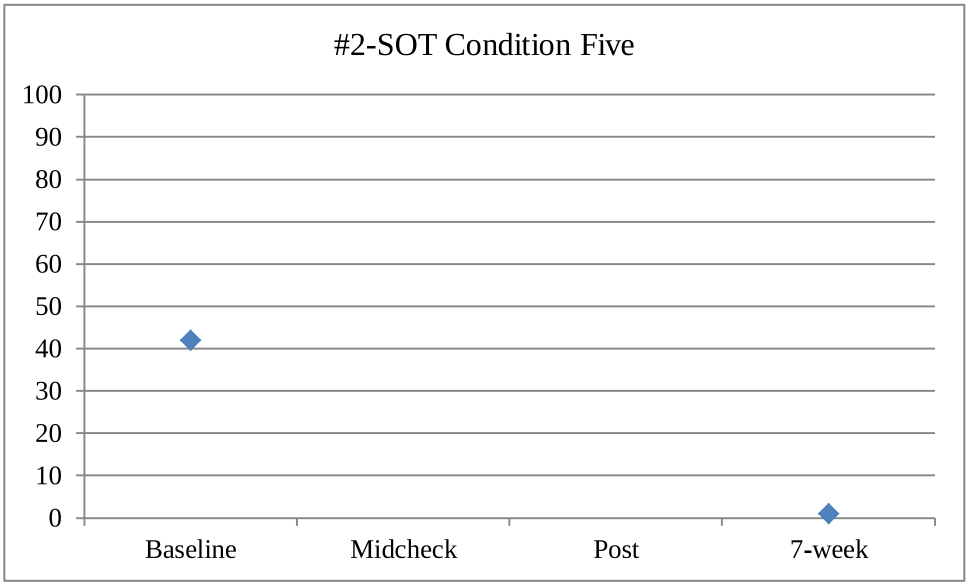

Figure 5e: Participant #2-SOT Condition Five

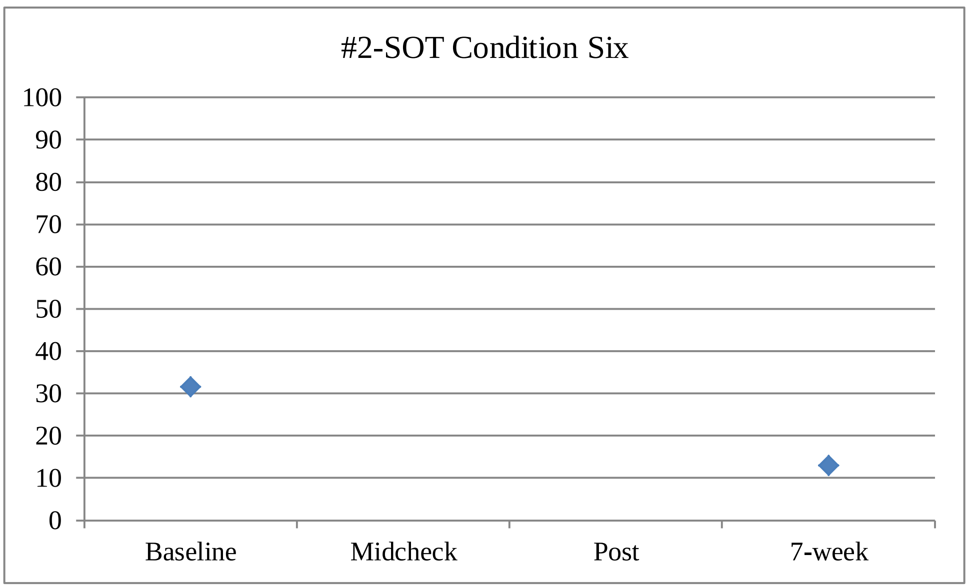

Figure 5f: Participant #2-SOT Condition Six

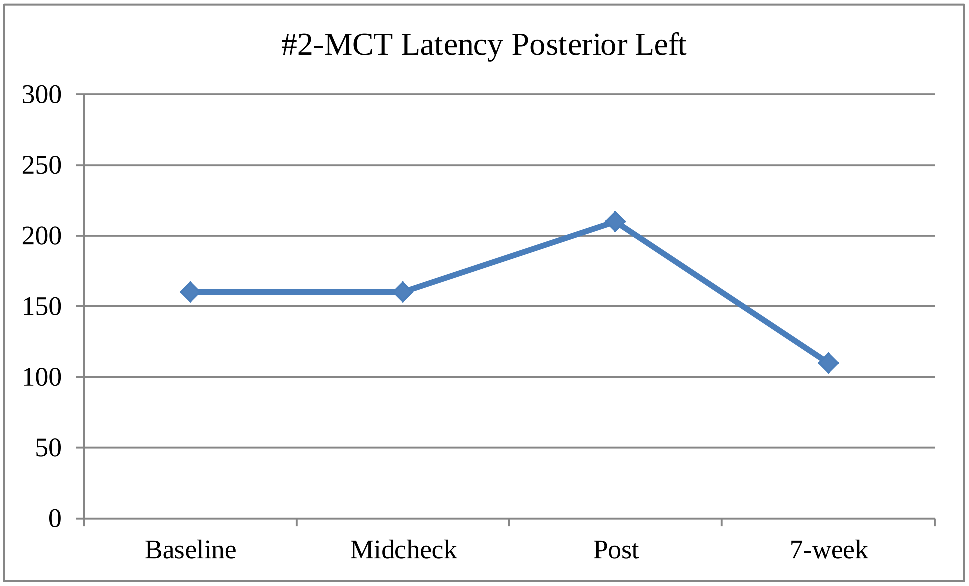

Figure 6a: Participant #2-MCT Latency Posterior Left

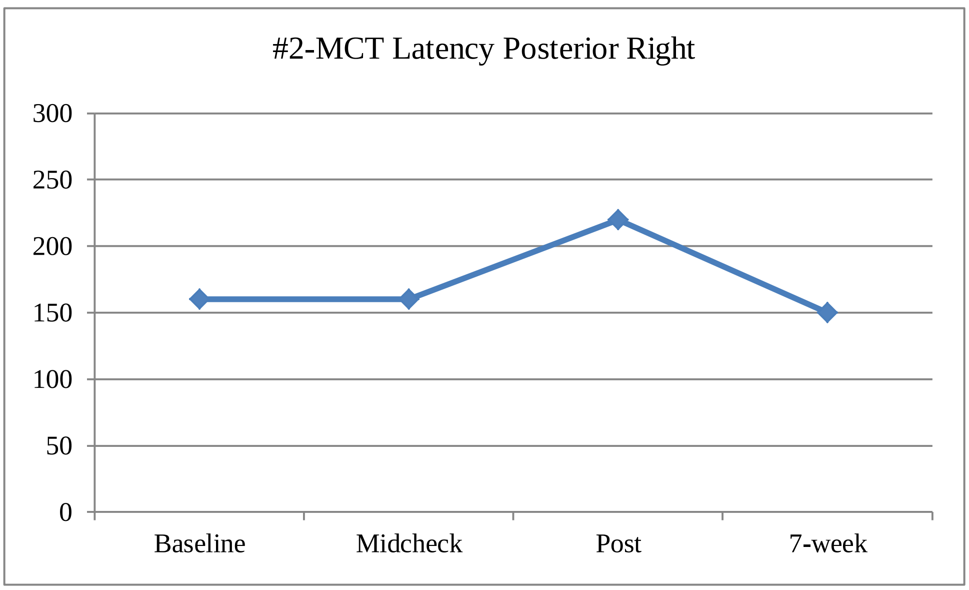

Figure 6b: Participant #2-MCT Latency Posterior Right

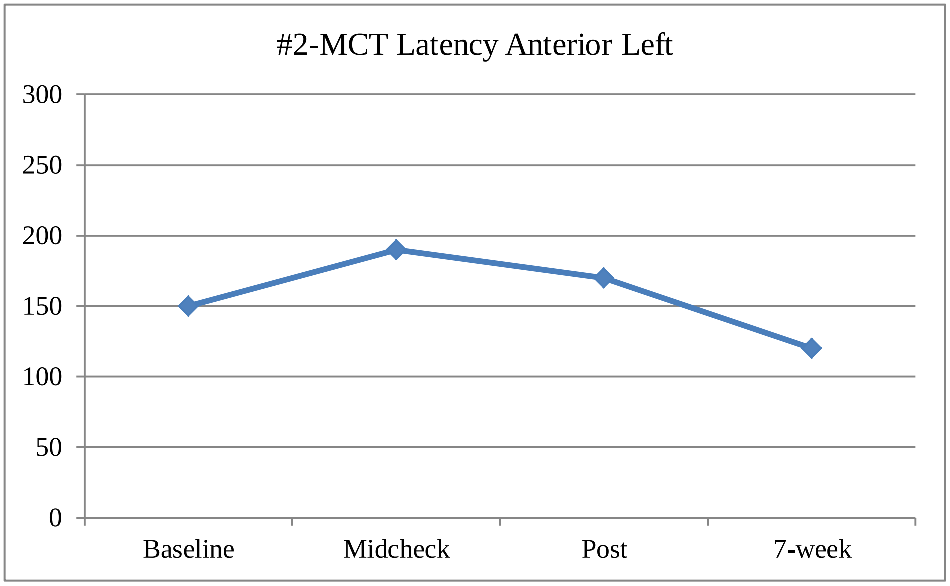

Figure 6c: Participant #2-MCT Latency Anterior Left

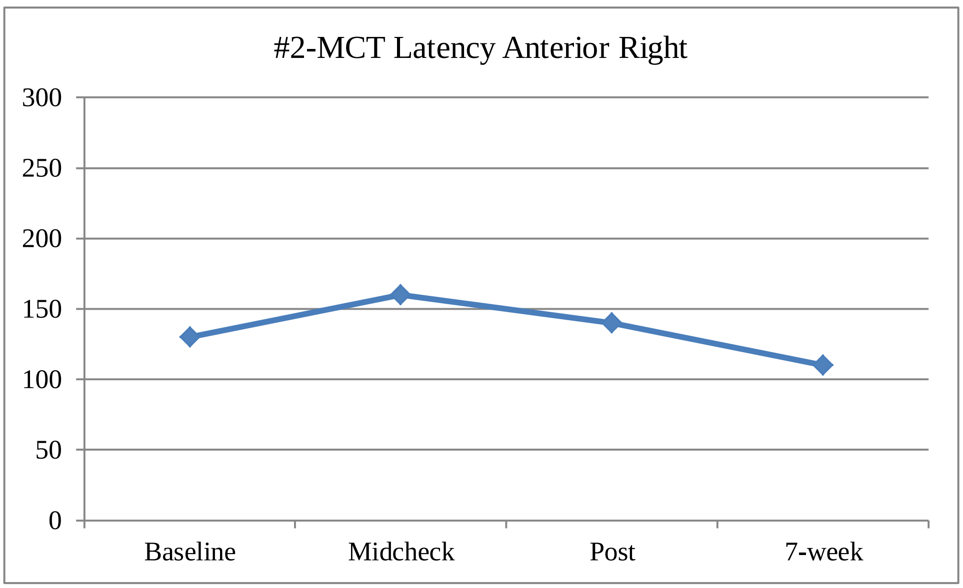

Figure 6d: Participant #2-MCT Latency Anterior Right

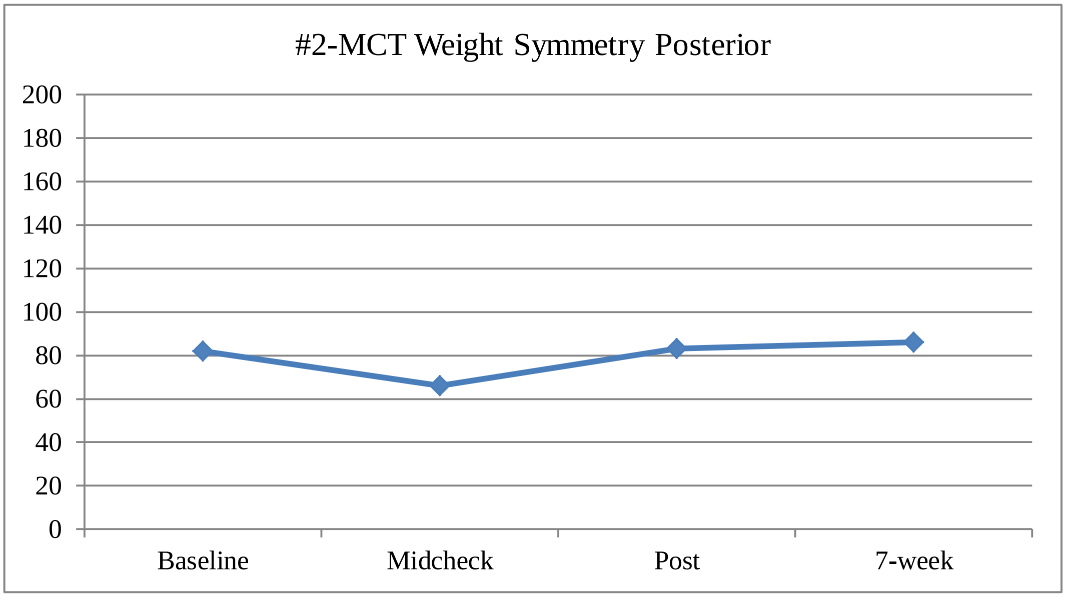

Figure 7a: Participant #2-MCT Weight Symmetry Posterior

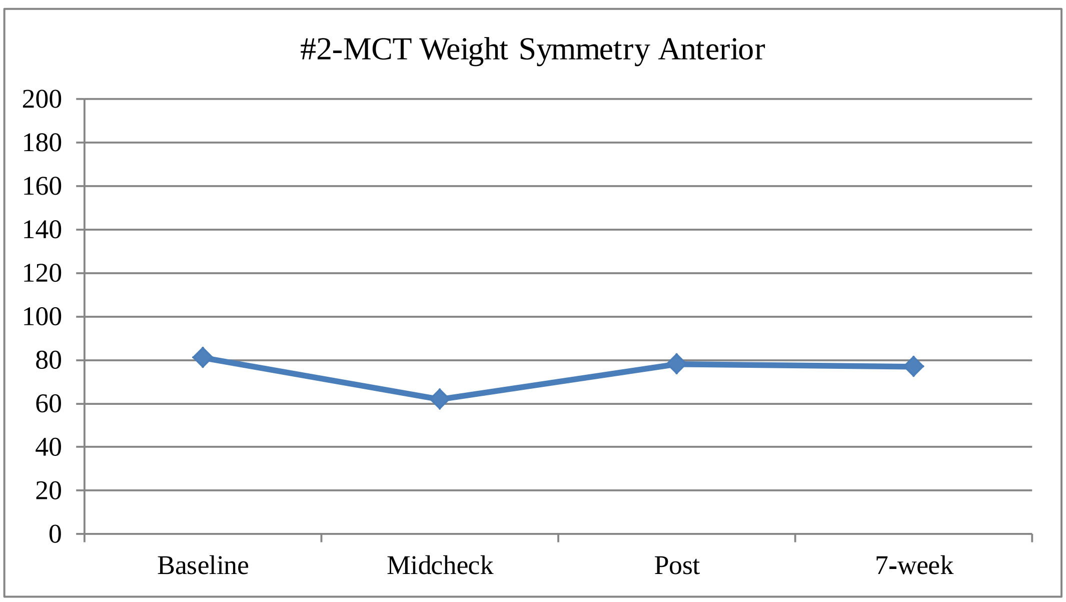

Figure 7b: Participant #2-MCT Weight Symmetry Anterior

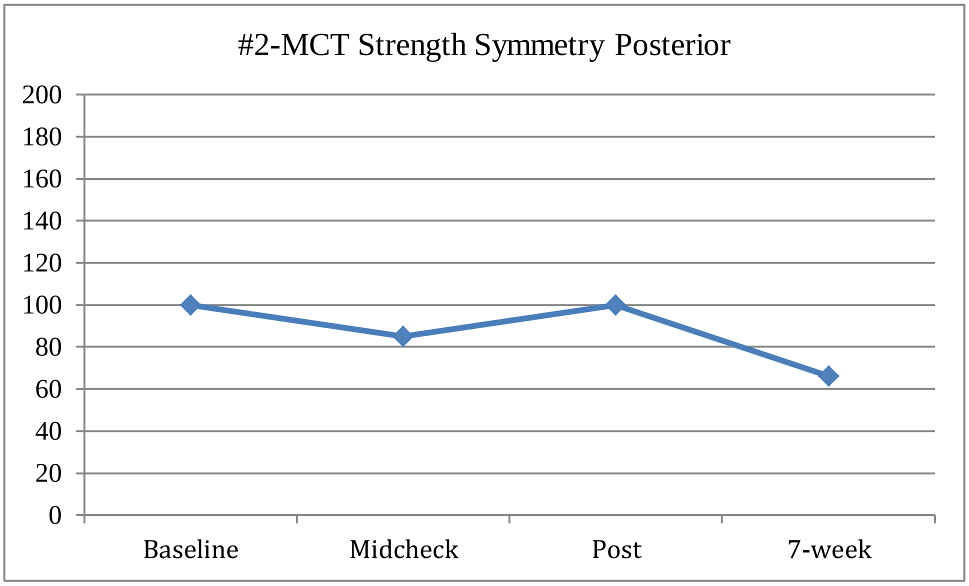

Figure 8a: Participant #2-MCT Strength Symmetry Posterior

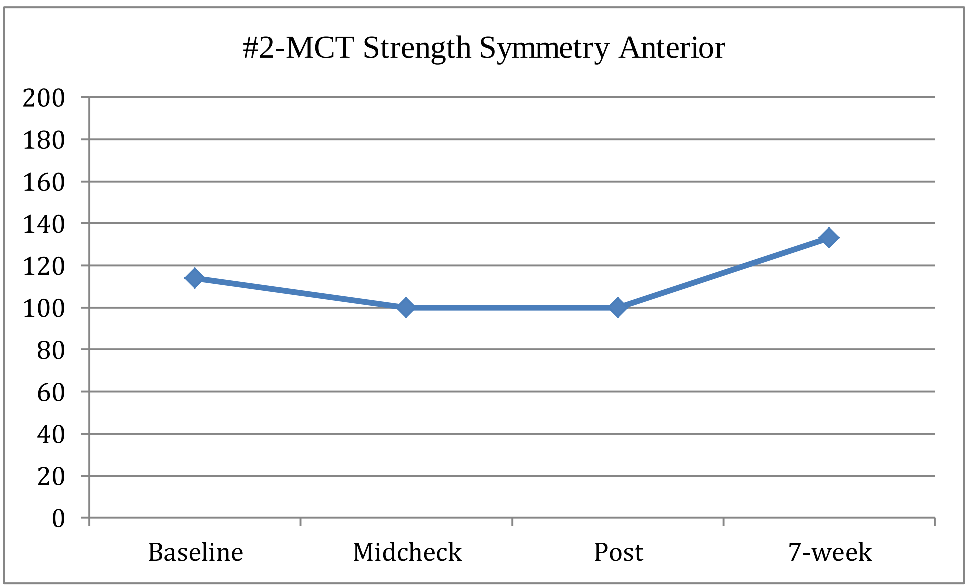

Figure 8b: Participant #2-MCT Strength Symmetry Anterior

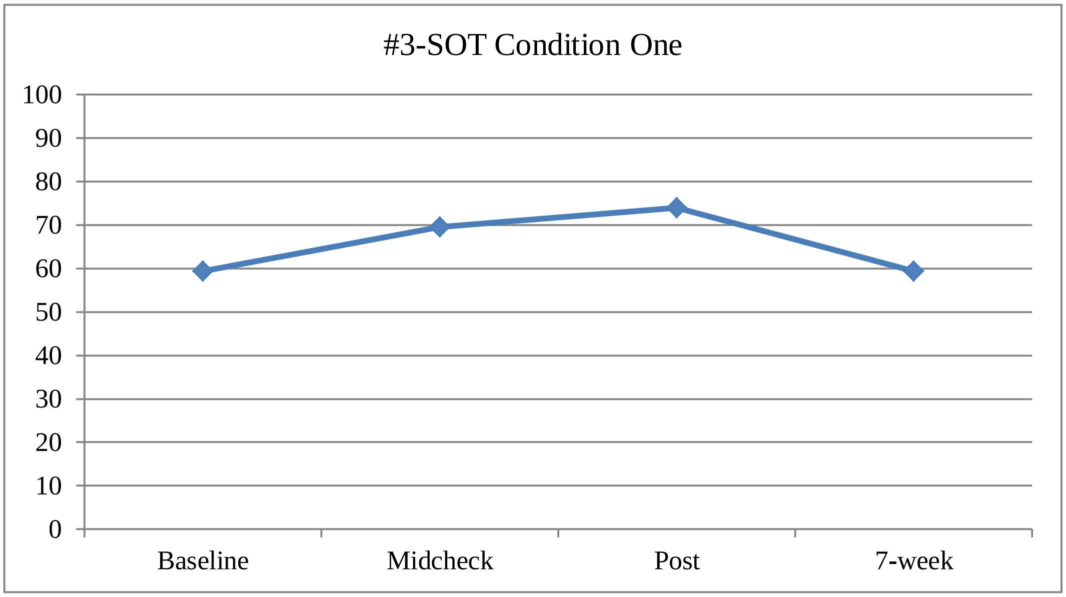

Figure 9a: Participant #3-SOT Condition One

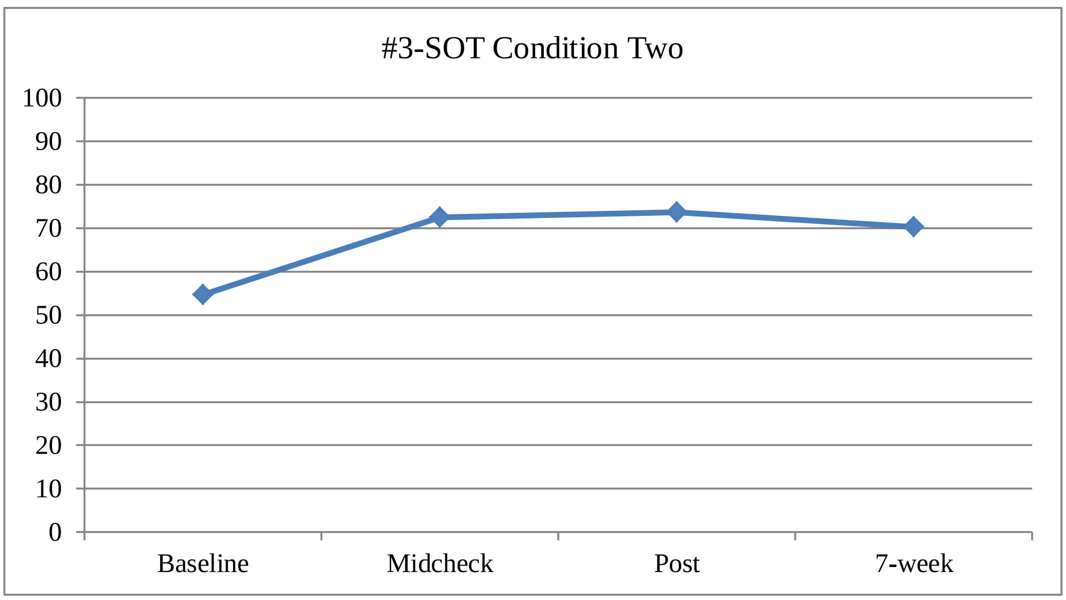

Figure 9b: Participant #3-SOT Condition Two

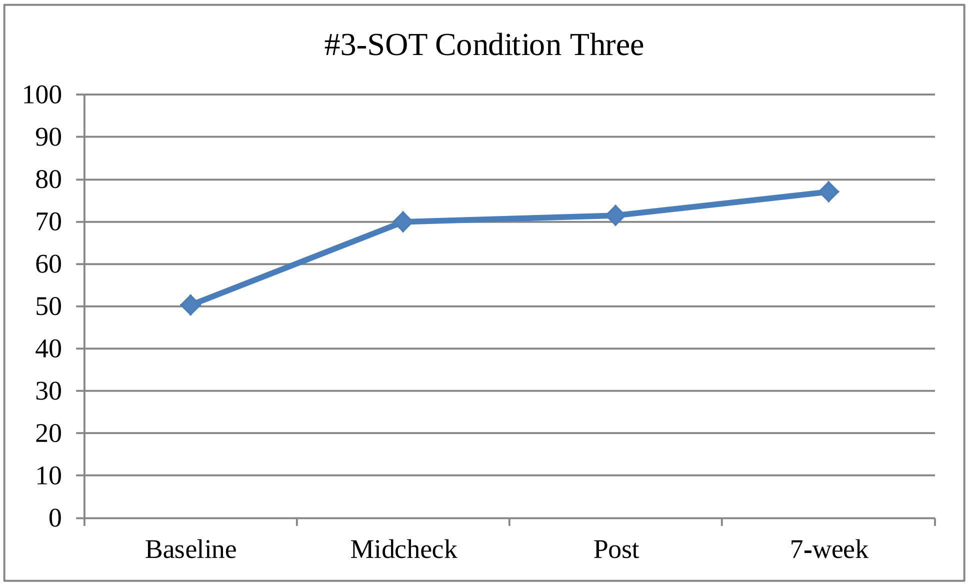

Figure 9c: Participant #3-SOT Condition Three

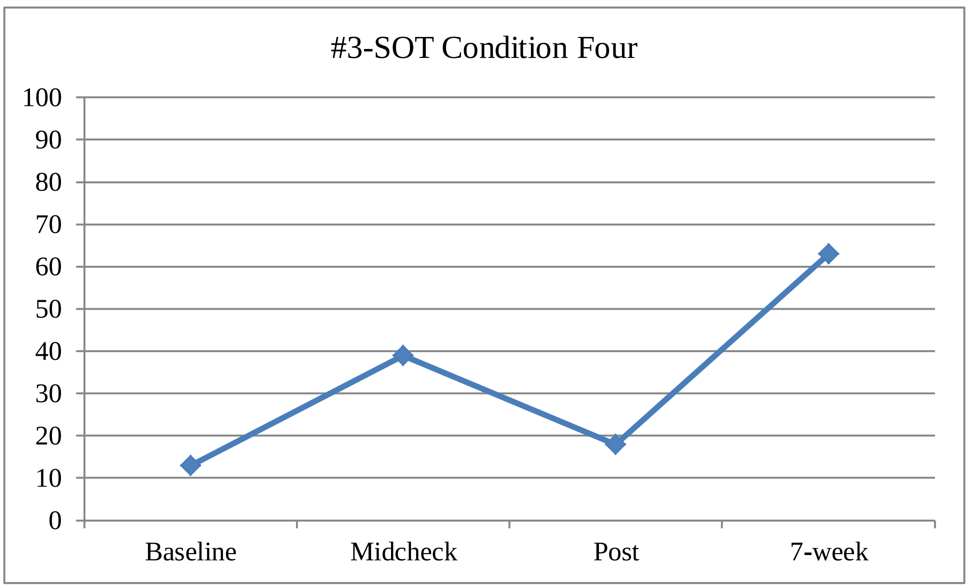

Figure 9d: Participant #3-SOT Condition Four

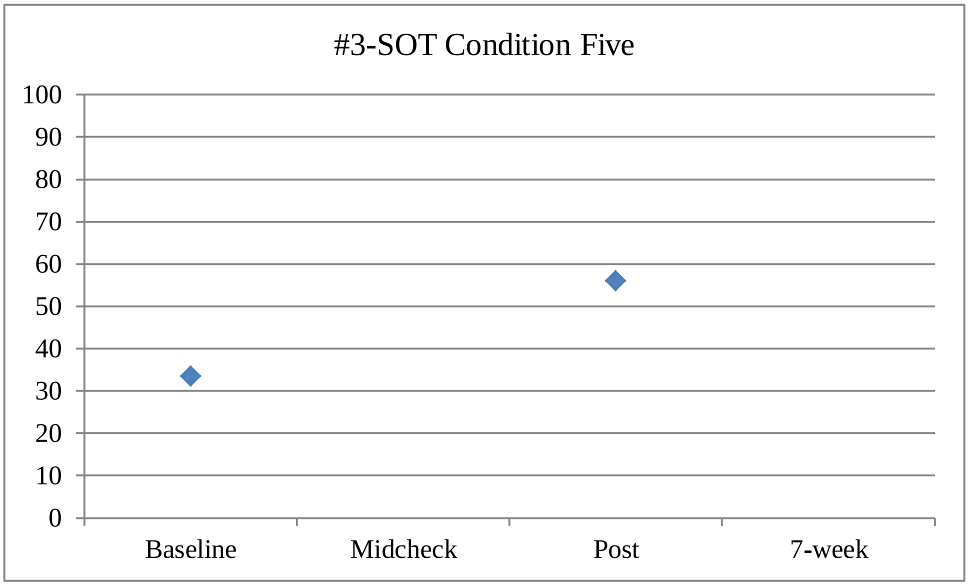

Figure 9e: Participant #3-SOT Condition Five

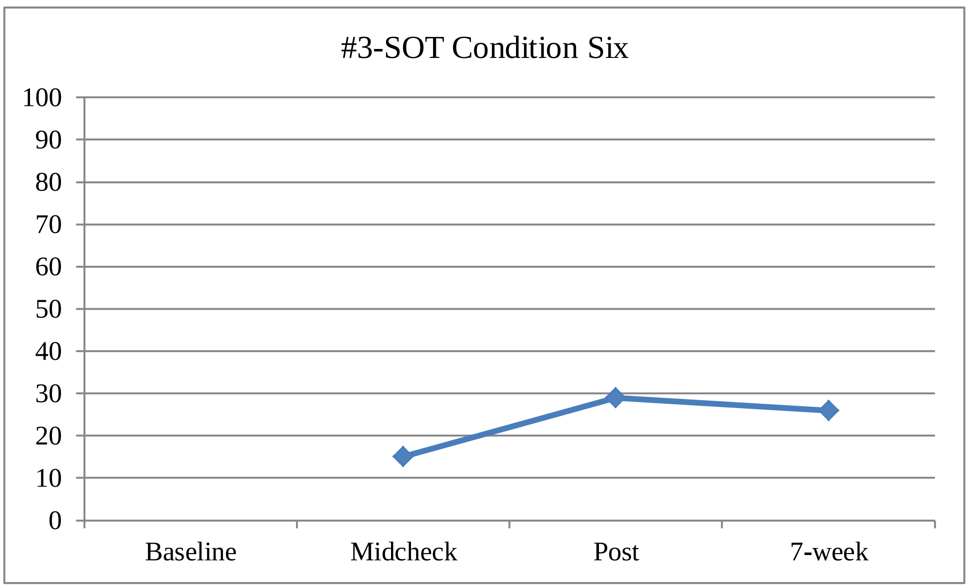

Figure 9f: Participant #3-SOT Condition Six

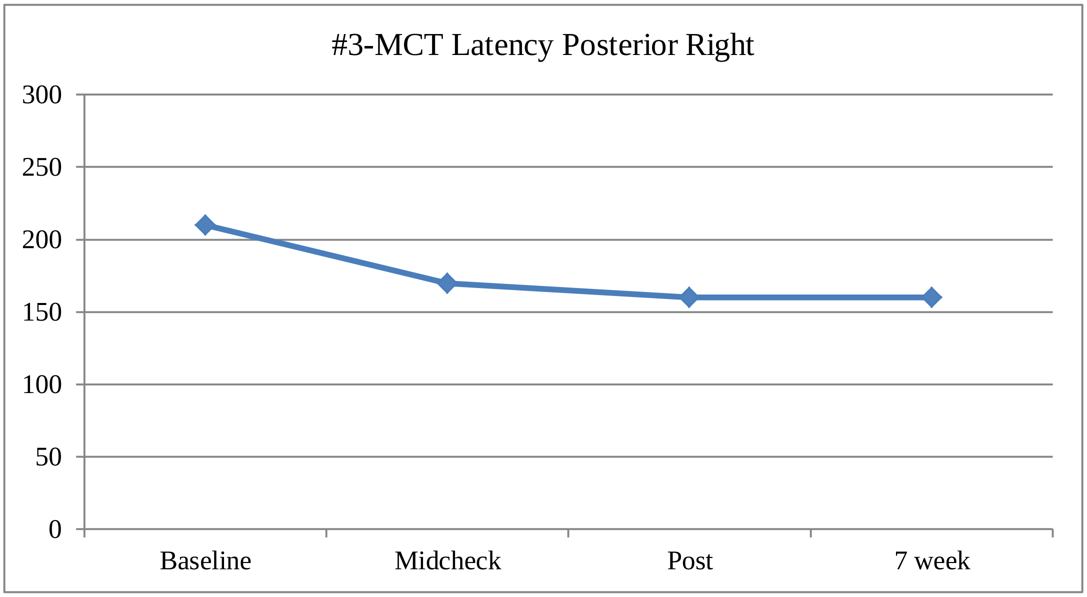

Figure 10a: Participant #3-MCT Latency Posterior Right

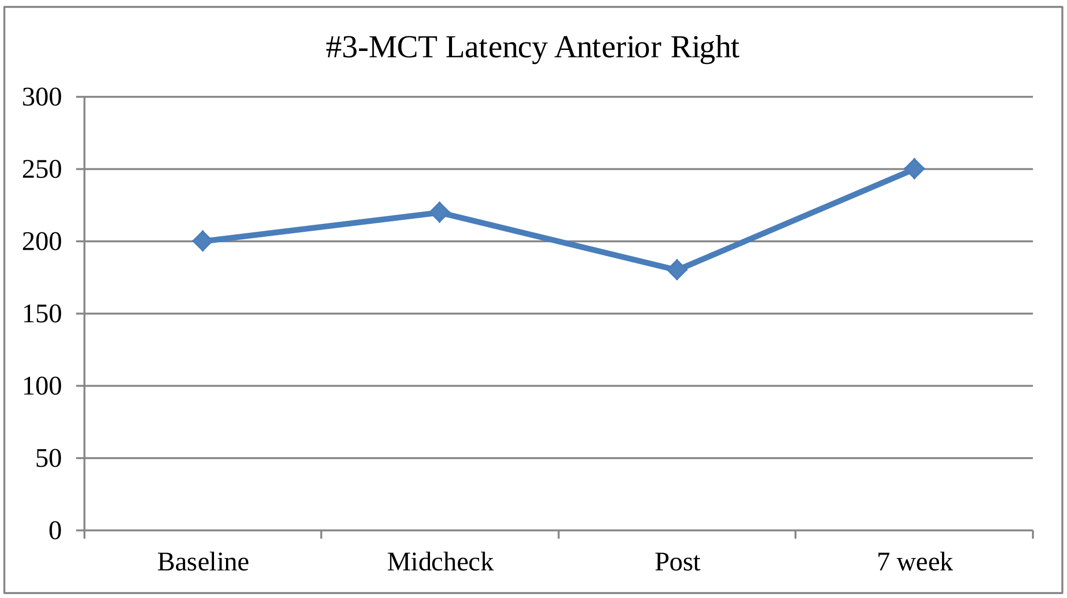

Figure 10b: Participant #3-MCT Latency Anterior Right

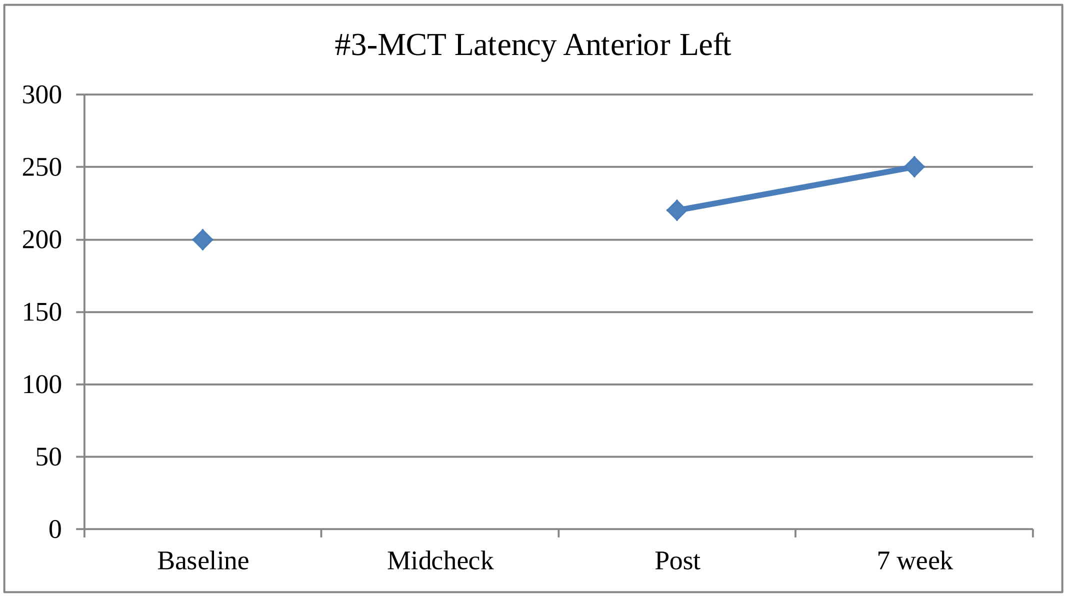

Figure 10c: Participant #3-MCT Latency Anterior Left

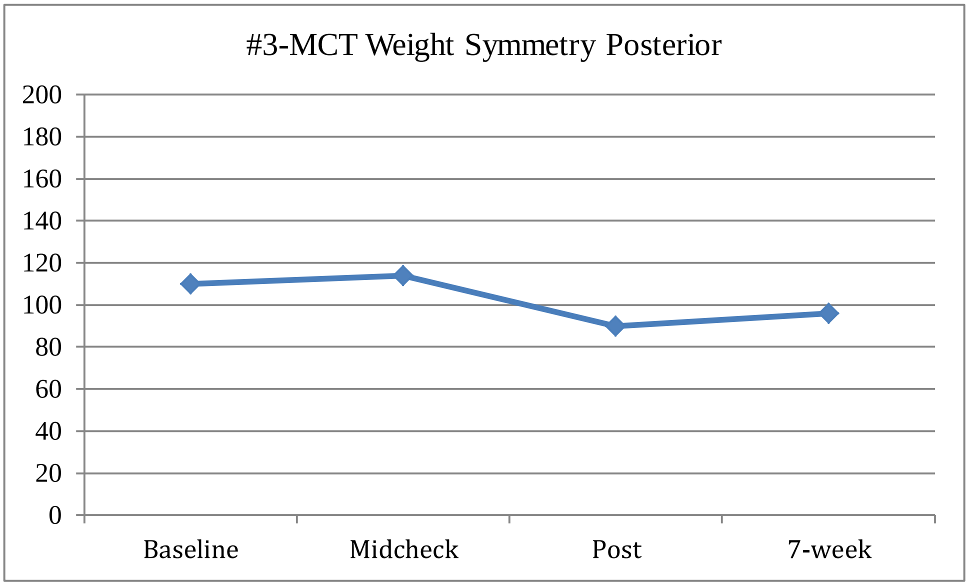

Figure 11a: Participant #3-MCT Weight Symmetry Posterior

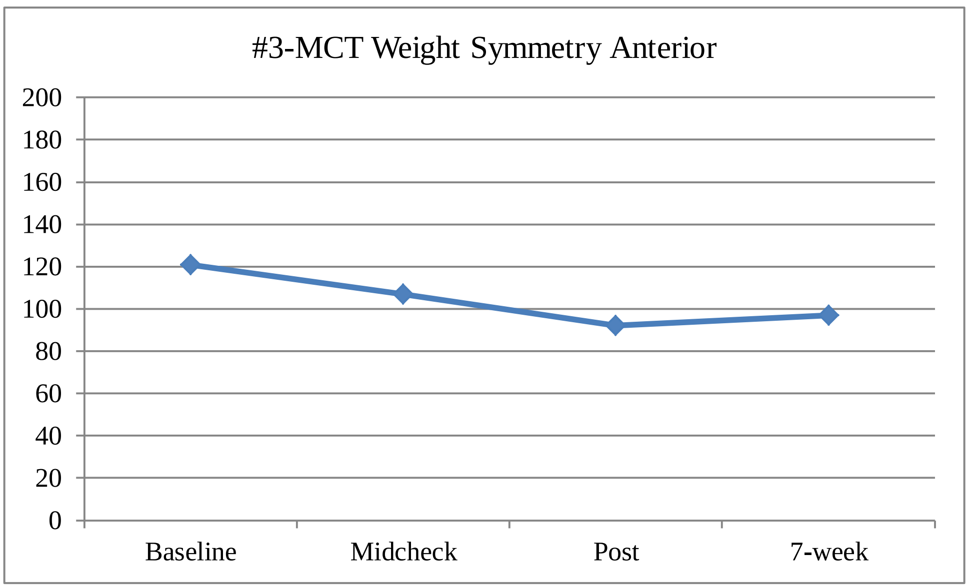

Figure 11b: Participant #3-MCT Weight Symmetry Anterior

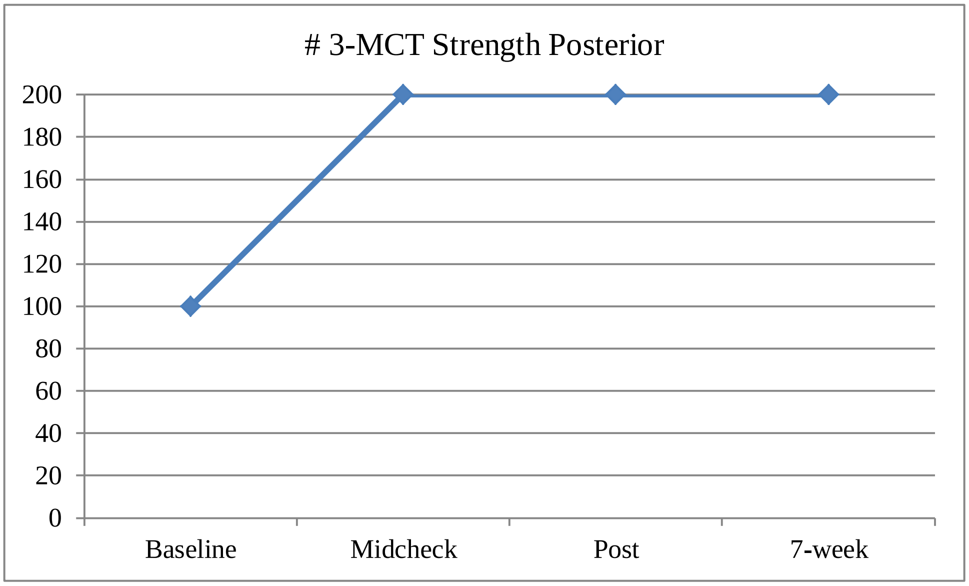

Figure 12a: Participant #3-MCT Strength Posterior

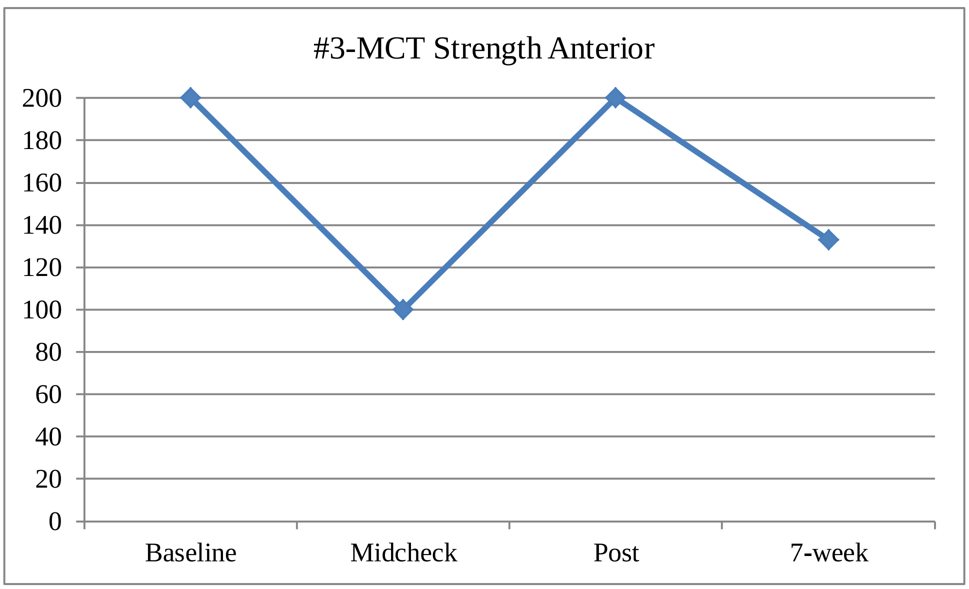

Figure 12b: Participant #3-MCT Strength Anterior

Appendix B

California State University, Northridge
CHILD ASSENT TO BE IN A HUMAN RESEARCH PROJECT

Effects of Aquatic Exercise on Gait and Balance in Children with Cerebral Palsy

This paper explains a research project. The people doing the research would like your help, but they want you to know exactly what this means. Participating in this project is your choice. Please read about the project below. Feel free to ask questions about anything that you do not understand before deciding if you want to participate. A person connected to the research will be around to answer your questions.

Informal Title of the study – How water exercise can help you walk and stand better
Formal Title: Effects of Aquatic Exercise on Gait and Balance in Children with Cerebral Palsy

RESEARCH TEAM
Name and Title of Researcher: Robert De La Cruz, Graduate Teaching Assistant
Department: Kinesiology
Telephone Number: (818) 677-2182

Name and Title of Faculty Advisor: Dr. Taeyou Jung
Department: Kinesiology
Telephone Number: (818) 677-2182

Study Location(s): Center of Achievement through Adapted Physical Activity, California State University, Northridge

YOU ARE HERE BECAUSE….

We want to study how water exercise can help you walk and stand better. We want to see if you would like to be in our study.

WHY ARE THEY DOING THIS PROJECT?

Dr. Jung, Mr. De La Cruz, and some other researchers are doing this research project to learn more about how the pool exercises might help you stand and walk better.

WHAT WILL HAPPEN IN THE PROJECT?

These things will happen if you want to be in the study:

1.) When you say yes to help us, you will be asked to do exercises at home or in the pool 3 times a week for 12 weeks. Before and after the 12 weeks of exercise, you will be tested for standing and walking.

2.) When you come to our center for our study, you will be asked to stand still on a square metal plate for the standing test and walk on a path a few times for the walking test. We will tell you more about what to do when you get to the center.

3.) When you are doing the standing test, you will wear a safety vest to make sure you do not fall. You will be asked to stand still on the metal plate while you are given directions such as closing your eyes or moving your body from side-to-side. During some of the tests, the plate that you are standing on might wobble. The computer will trace how your body moves while you are trying to stand still. You will be able to sit down and rest after each test.

4.) When you are tested for walking, you will be asked to change into tight fitting bike shorts. We will measure how tall you are, how much you weigh, and how you’re your legs are. Shiny stickers will be put on your skin. You will be asked to walk on a path a few times while the cameras record your walking. You will be able to sit down to rest after each time you walk.

5.) If you are told to exercise in the pool, you will workout for 40-minutes in the water 3 times a week for 12 weeks. You will do some stretching, walking, standing exercises, and fun games. A teacher and a lifeguard will be there to help you.

6.) If you are told to exercise at home, you will workout for 40-minutes at home with your parent/guardian 3 times a week for 12 weeks. You will do some stretching, walking, standing exercises, and fun games with your parent/guardian.

You might feel bored, tired, thirsty, and pain in your legs and/or chest. Before you do any of the exercise, your doctor will need to say that it is okay for you to exercise. You will have breaks to rest will be asked to drink plenty of water to keep you from being thirsty.

IF YOU HAVE ANY QUESTIONS

You can ask questions any time. You can ask now or you can ask later. You can talk to the researchers, your family or someone else in charge. It is important that you know what is going on.

DO YOU WANT TO BE IN THE PROJECT?

No

You do not have to be in the study. No one will be upset with you if you don't want to do this. If you don't want to be in this study, or if you want to skip a question that is hard or confusing, that’s fine. Just tell the researchers and they won’t get upset.

Yes

If you want to be in the study sign your name below. You can say yes now and say no later. It is up to you to decide.

______________________________	__________________	______
Signature of Child	Age	Date

______________________________ ______
Signature of Researcher Date

______________________________ ____________
Signature of Individual Obtaining Assent Date
If different from researcher

Appendix C

California State University, Northridge
ADOLESCENT ASSENT TO BE IN A HUMAN RESEARCH PROJECT

Effects of Aquatic Exercise on Gait and Balance in Children with Cerebral Palsy

We would like to invite you to participate in a research project. Participating in this project is your choice. Please read about the project below. Feel free to ask questions about anything that you do not understand before deciding if you want to participate. A person connected to the research will be around to answer your questions.

Informal Title of the study – What are the benefits of water exercise for children with Cerebral Palsy
Formal Title: Effects of Aquatic Exercise on Gait and Balance in Children with Cerebral Palsy

RESEARCH TEAM
Name and Title of Researcher: Robert De La Cruz, Graduate Teaching Assistant
Department: Kinesiology
Telephone Number: (818) 677-2182

Name and Title of Faculty Advisor: Dr. Taeyou Jung
Department: Kinesiology
Telephone Number: (818) 677-2182

Study Location(s): Center of Achievement through Adapted Physical Activity, California State University Northridge

WHAT IS THIS PROJECT ABOUT?

This project studies why children with cerebral palsy sometimes fall and need help when they walk. They want to see if you would like to be in this project.

WHAT WILL HAPPEN IN THE PROJECT?
These things will happen if you want to be in the study:

1.) When you agree to participate in this study, you will be asked to do exercises at home or in the water 3 times a week for 12 weeks. Before and after the 12 weeks of exercise, you will be tested for balance and walking.

2.) When you come to the laboratory for our test session, you will be asked to stand still on a square metal plate for the balance test and walk on a path a few times for the walking test. The detail steps of each test will be explained to you.

3.) When you are tested for balance, you will wear a safety vest to make sure you do not fall. You will be asked to stand still on the metal plate while you are given specific instructions such as closing your eyes or moving your body from side-to-side. During some of the tests, the plate that you are standing on might wobble. The computer will record your body's movements while you are trying to keep your balance. You will be able to sit down and rest after each test.

4.) When you are tested for walking, you will be asked to change into tight fitting bike shorts. Your height, weight, and leg length will be measured. Shiny stickers will be attached on your skin. You will be asked to walk on a path at your comfortable and fastest speed a few times while the high-speed cameras will record your walking. You will be able to sit down to rest after each time you walk.

5.) If you are chosen to be in the water exercise program, you will be asked to do 40-minutes of exercise in the water 3 times a week for 12 weeks. The water exercises will include some stretching, walking, balance exercises, and fun games. A water exercise teacher will teach your exercises and a lifeguard will be there for your safety too.

6.) If you are chosen to be in the home exercise program, you will be asked to do 40-minutes of exercise at home with your parent/guardian 3 times a week for 12 weeks. You will be asked to do some stretching, walking, balance exercises, and fun games with your parent/guardian.

You might feel bored, tired, thirsty, and pain in your legs and/or chest. Before you do any of the exercise, your doctor will need to say that it is okay for you to exercise. You will have breaks to rest will be asked to drink plenty of water to keep you from being thirsty.

BENEFITS OF THE PROJECT TO YOU AND OTHERS

You will not receive any money or gifts for participating in this study. However, your participation can help doctors and researchers understand the benefits of water exercise for children with cerebral palsy.

DO YOU HAVE ANY QUESTIONS ABOUT THE PROJECT?

You can ask questions any time. You can talk to the researchers, your family or someone else in charge, before you decide if you want to participate. If you do agree to participate, you can change your mind and withdraw from the study at any time without any penalty.

If you are unable to reach a member of the research team listed on the first page of the form and have general questions, or you have concerns or complaints about the research study, research team, or questions about your rights as a research subject, please contact Research and Sponsored Projects, 18111 Nordhoff Street, California State University, Northridge, Northridge, CA 91330-8232, or phone 818-677-2901.

If you want to be in the study sign your name below.

Signature of Child	Age	Date

Signature of Researcher	Date
Signature of Individual Obtaining Assent If different from researcher	Date

Appendix D

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE
PARENTAL INFORMED CONSENT FORM

Graduate Thesis title:
"Effects of aquatic exercise on gait and balance in children with cerebral palsy"

You and your child are invited to participate in a study titled "Effects of aquatic exercise on gait and balance in children with cerebral palsy" conducted by Robert De La Cruz, a graduate student in the Department of Kinesiology. The study will take place at the Center of Achievement, California State University, Northridge (CSUN) under the supervision of Dr. Taeyou Jung.

Introduction:

Improvement of gait and balance is one of the major goals in the rehabilitation programs for children with cerebral palsy (CP). Many studies have shown the benefits of aquatic and land-based exercise on various aspects of health in children with CP; however, few studies have examined the influence on aquatic exercise on gait and balance in children with CP. The purpose of this study is to investigate the effects of aquatic gait and balance outcomes in children with CP.

You and your child are invited to participate in this study if your child is a) diagnosed with CP, b) 7-17 years old, c) able to walk with or without walking aide, d) able to follow instructions in English, e) able to obtain a medical clearance for adapted exercise or/and aquatic exercise, f) not afraid of water, and g) not suffering from additional illness (for example: an ear infection, open wound, and/or flu).

Description of Research Interventions:

In this study, you and your child will participate in a 12-week exercise program. Your child will be randomly assigned to either the aquatic exercise program or home-based exercise program. Aquatic exercise will be about 40 minutes, 3 times a week for 12 weeks. The aquatic exercise will consist of warm-up, walking, balance exercises, and fun games. The aquatic program will be supervised by a main instructor with several assistants in the pool and there will be a lifeguard in each session to assure water safety. Home-based exercise program will consist of similar components: warm-up walking, balance exercises, and cool-down. You will implement the home-based exercise program. Initially, orientation will be provided with specific instructions for each exercise component. You will be trained in the home-based exercise program prior to the 12-week intervention. You will conduct the 40-minute exercise session 3 times a week for 12 weeks with your child. You will be asked document your child's participation using a weekly journal. The researcher will call you once a week to help you and answer any questions.

Study Procedures:

There will be a gait and balance evaluation before and after the 12-week training period. When you and your child come to the evaluation session, you will be informed about the testing procedures. First, your child will be tested for balance on a computerized balance assessment equipment. A safety harness will be attached to your child to prevent unexpected falls. Your child will be asked to maintain standing balance on a force plate (force measuring device) under various circumstances (e.g., eyes closed, unstable standing surface, or moving surroundings). The computerized balance system will record body sway and reaction times while your child is trying to stand still. Then your child will be tested for walking. Your child will be asked to change into tight fitting bike shorts. Your child's height, weight, and leg lengths will be measured. Small reflector markers will be attached on your child's skin with nontoxic tape. High speed cameras will be capturing the reflective markers while your child is walking at comfortable and maximum speeds on a 10-meter walkway. Scheduled rest time and water breaks will be provided. Total time for testing procedures will take approximately one hour.
Home Exercise Intervention:
Risks:

The study may have potential for risks including cardiovascular complications, dehydration, drowning, falling, physical fatigue, muscle cramps, skin irritation and other water safety issues. Physician clearance will be obtained to ensure that your child does not have any contraindications for any of the two exercise protocols. Your child will be asked to drink plenty of water in order to keep themselves hydrated during the exercise intervention. To minimize the risk of falling, active spotting by a research assistant will be provided. For balance assessment, a safety harness will be used in addition to having an active spotter. There will be scheduled rest periods between testing trials to prevent physical fatigue. A certified lifeguard will ensure your child's safety in the water. In case of emergency, emergency services (911) will be contacted and your child will be referred to their primary care physician at your own cost. The temperature of the pool water will be maintained at approximately 35 degrees in Celsius (95°F).

Benefits:

Your child will not receive any monetary benefits. However, there may be benefits in which your child can expect as a result of participation in this study, including increase in your child's health related physical fitness. Your child will receive complimentary 3D gait assessment, a computerized postural-graphic balance assessment, and a 12-week aquatic exercise or customized home-based exercise program. Other benefits may include helping clinicians and researchers in CP rehabilitation with documenting evidence and understanding clinical significance of aquatic exercise.

Confidentiality:

Any information and digital photographs collected in this study will remain confidential and will be disclosed only with your written permission or if required by law. The cumulative results of this study will be published, but your child's name will be replaced by numeric code for confidentiality. All documentation/data/digital photographs will be secured in a locked file cabinet located in the center's main office up to three years and after three years they will be destroyed. Only Robert De La Cruz, the primary researcher, and Dr. Taeyou Jung, research advisor, will be allowed to access the data and the digital photographs.

Concerns:

If you wish to express a concern about the research, you may direct your question(s) to Research and Sponsored projects, 18111 Nordhoff Street, California State University, Northridge, CA 91330-8232, or phone no. 818-677-2901. With specific questions and concerns about this study, you may contact Dr. Taeyou Jung, research advisor, at the Center of Achievement, 18111 Nordhoff Street, Northridge, CA 91330-8287, or call (818) 677-2182. Your child will also receive a copy of the consent form once signed by parent(s) or guardian(s) for personal records.

Voluntary Participation & Rights:

You and your child should understand that participation in this study is completely voluntary and you and your child may withdraw from the study at anytime, for any reason without jeopardy including but not limited to any of the following reasons: If your child develops any serious side effects, your child fails to meet the inclusion criteria for participation in the study, or your child's physical condition gets worse.

Digital Photographs & Audio Digital Videotaping:

During the course of the data collection, digital photographs will capture walking trials, as well as, exercise interventions in the aquatic setting. Your child's face may or may not be captured. Your initials here_________________ signify your consent for your child to be photographed. Photographs will be used to show experimental set up and visual feedback needed for the study. All photographs collected as part of this study will be kept in a locked cabinet, located in the center's main office up to three years and after three years they will be destroyed.

During the course of the intervention your child may be audio videotaped. Your initials here________________ signify your consent to allow your child to be audio videotaped. Audio digital videotaping will be used as visual and audio feedback to record your child's interaction during intervention. All recorded audio/video taping that have been collected as part of this study will be kept in a locked cabinet, located in the center's main office up to three years and after three years they will be destroyed.

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

EXPERIMENTAL SUBJECTS

BILL OF RIGHTS

The rights below are the rights of every person who is asked to be in a research study. As an experimental subject I have the following rights:

To be told what the study is trying to find out,

To be told what will happen to me and whether any of the procedures, drugs, or devices is different from what would be used in standard practice,

To be told about the frequent and/or important risks, side effects or discomforts of the things that will happen to me for research purposes,

To be told if I can expect any benefit from participating, and, if so, what the benefit might be,

To be told the other choices I have and how they may be better or worse than being in the study,

To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study,

To be told what sort of medical treatment (if needed) is available if any complications arise,

To refuse to participate at all or to change my mind about participation after the study is started. This decision will not affect my right to receive the care I would receive if I were not in the study.

To receive a copy of the signed and dated consent form.

To be free of pressure when considering whether I wish to agree to be in the study.

If I have other questions I should ask the researcher or the research assistant, or contact Research and Sponsored Projects, California State University, Northridge, 18111 Nordhoff Street, Northridge, CA 91330-8232, or phone (818) 677-2901.

X____

Signature of Subject Date

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE
(Universidad Estatal de California, Northridge)

Sujetos Experimentales

Declaración de Derechos

Los derechos que a continuación se mencionan, son los derechos de cada persona que participa en esta investigación. Toda persona al participar en estos estudios, tiene derecho:

A saber que es lo que el estudio esta tratando de investigar,

A estar informado de lo que sucederá, los procedimientos, los medicamentos, y los dispositivos, sean ó no diferentes a los utilizados en un precedimiento normal,

A saber la frecuencia y/ó el grado de riesgo, efectos secundarios, ó incomodidades que sucederan en el transcurso de la investigación,

A saber si hay algún beneficio al participar en el estudio, y cual sería ese beneficio,

A saber si existen otras alternativas que puedan ser mejores ó peores que, participar en esta investigación,

A que se le permita hacer preguntas antes de participar en el estudio, al igual que en el transcurso del mismo,

A saber que tipo de tratamiento médico (si es necesario) está disponible en caso de que ocurran complicaciones,

A renunciar a la participación en el estudio, aún cuando ya haya comenzado. Cualquier cambio de decisión no afectará el derecho a recibir la atención que se provería al no ser parte de esta investigación,

A recibir una copia firmada y fechada de la hoja donde se autorizó la participación,

A estar libre de cualquier presión al decidir si quiere ó no participar en el estudio.

En caso de tener preguntas, puede comunicarse con el investigador, el asistente de investigación, ó a la oficina de Research & Sponsored Projects, California State University, Northridge, 18111 Nordhoff Street, Northridge, CA 91330-8232 ó al teléfono (818) 677-2901.

X____

Firma del participante Fecha