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Immediate Effects of High Intensity Training in Children with Cerebral Palsy GMFCS Levels I-III: A Pilot Study

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IMMEDIATE EFFECTS OF HIGH INTENSITY TRAINING IN CHILDREN WITH
CEREBRAL PALSY GMFCS LEVELS I-III: A PILOT STUDY

By

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A doctoral project submitted in partial fulfillment
of the requirements for the

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University of Nevada, Las Vegas

The Graduate College

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THE GRADUATE COLLEGE

We recommend the doctoral project prepared under our supervision by

Andrea Blahovec, Andrea Kuiken, Jillian Mears, and Heather Riggins

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ABSTRACT

Background: Cerebral Palsy is one of the most common causes of motor disability in the U.S., but there is still a lack of consensus for best intervention strategies to improve function and gait efficiency.

Objective: Determine if ambulatory children with CP, exposed to a brief, high intensity training session will: 1) experience changes in temporal-spatial gait characteristics 2) demonstrate increased gait speed and 3) demonstrate improved gait kinematics.

Design: Five participants walked at preferred and fast speeds over an instrumented walkway followed by a 15-minute intervention. After a short rest, post-intervention walking was completed.

Results: Ten dependent variables were extracted at each speed. A single subject statistical technique was used to examine pre-post characteristics. There were no significant differences identified for participant 1 and only minimal significant findings for participant 2. However, there were significant findings for several variables for participants 3-5 in both of the conditions, including greater stride velocity, reduced time in double limb support and greater stride length.

Conclusion: Results suggest that a short bout of large amplitude training may cause immediate positive outcomes in some children with CP. Further investigation of intervention effects and presentation, including dose response and a more rigorous intervention protocol, is warranted.

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- Jill Slaboda, PhD

INTRODUCTION

Cerebral palsy (CP) is the one of the most common causes of motor disability in the United States (King et al, 2006). It affects approximately 3.3 children per 1000 live births annually (King et al., 2006), comprising the largest diagnostic group for which pediatric rehabilitation services are provided (Odding, Roebroek, and Stam, 2006). CP is a group of heterogeneous movement disorders with varying etiologies and levels of severity (Rosenbaum et al, 2006). The most recent definition of CP includes permanent activity limitations of posture and movement as the hallmark features, but recognizes that children with CP may also experience difficulty with sensation, perception, cognition, communication, behavior, epilepsy and numerous other secondary disabling conditions (Rosenbaum et al, 2006). Clinical diagnosis of CP is based on the presence of permanent developmental impairments of motor function that limits activity (Rosenbaum et al, 2006). Of the brain lesions radiographically demonstrated in children with CP, lesions affecting the basal ganglia are some of the more common injuries seen and were associated with sustained atypical muscle contraction (dystonia) (Okerefor et al, 2008) or decreased voluntary, controlled movements and increased involuntary movements (dyskinesia) (Griffiths et al, 2010). These lesions are considered to be nonprogressive. However, individuals with CP often experience progressive changes in postural control and functional mobility throughout their lifespan (Damiano, Alter, and Chambers, 2009).

Given the complexity of this neurodevelopmental disorder, children with CP frequently require resource-intensive intervention services from multiple providers simultaneously (eg, speech pathologists, physical therapists, occupational therapists, etc) for long periods of time throughout their lifespan. While it is not known what percentage of children receiving early intervention (EI) services were later diagnosed with CP, the statistics regarding children in EI who received multiple services may reflect the needs of this population. In 2005, nearly 294,000

US children received EI services, many of whom were diagnosed with CP (Hebbeler et al, 2007). Many of these children received more than one EI service at a time. Approximately 26% received six services concurrently during their first six months of intervention (Hebbeler et al, 2007). In addition to the multiple services that are being utilized concurrently, it is estimated that one to three percent of children below the age of five years have developmental delay (DD) occurring in multiple developmental domains (Fox et al, 2006). The developmental domains commonly addressed in EI include: gross motor, fine motor, communication (speech/language), cognition, personal/social and self-help adaptive skills (Shevell et al, 2003). Incorporating interventions that demonstrate improvements in multiple domains, such as gross motor and social skills, would be more efficient for the healthcare professionals working with the children, to the families who spend time and money on countless appointments and for the children who spend the numerous hours in therapy.

Furthermore, a recent study conducted in China estimated the cost of care over a lifetime for individuals with CP to be in the range of two to four million US dollars (Wang et al, 2008). While there may be cost differences between China and elsewhere, this cost estimate along with the multiple services that are utilized highlights the significance of CP as an important public health problem. Identifying an intervention strategy that could effectively improve outcomes of children with CP in multiple developmental domains at one time would make a significant contribution to addressing the needs of children and families with CP.

Children with CP display a variety of abnormalities of postural control and movement patterns that interfere with development of functional tasks, such as walking and the ability to participate in the roles a child typically assumes at home, at school and in the community (Rosenbaum et al, 2007). With specific regard to gait, children with CP have less efficient, less fluid and less adaptable gait patterns than their peers (Cavagna, Franzetti, and Fuchimoto, 1983).

They have difficulty performing the mechanical work necessary to lift their legs and maintain their center of mass over their base of support (Kurz, Stuberger, and DeJong, 2010). Specific gait parameters that are affected include temporal and spatial gait parameters such as differences in double limb support, stride length, and step length when compared to typically developing peers (Chen et al, 2009; Hoon et al, 2009). Children with CP also demonstrate lower gait velocity, shorter gait cycles and more regular frequency of postural sway than their age-matched peers (Donker et al, 2008).

Because the hallmark feature of CP is a permanent disorder of “movement and posture causing activity limitation,” (Rosenbaum et al., 2007) physical therapists play an integral role in the clinical management of CP across the lifespan (Antilla et al, 2008). Many different physical therapy interventions have been used to improve walking and functional mobility skills in children with CP, but few are supported by strong empirical data and are mostly targeted at the level of body structure and function, such as range of motion and strength (O'Neil et al, 2006). This may be one reason why participation rates (Orlin et al, 2010) and activity levels (Bjornson et al, 2007) of children with CP remain significantly lower than those of their peers and the need for physical therapy remains high. In contrast to existing interventions, incorporating evidenced-based, task-specific procedural interventions targeting activity limitations, such as decreased ability to walk, run, and jump, will more directly improve participation levels related to functional mobility among children with CP, not just aiming to address their impairments.

One current physical therapy intervention shown to be effective in addressing the activity limitation of decreased ability to walk in patients with Parkinson's disease (PD) involves the use of high-intensity, large amplitude-specific movement patterns. PD, like CP, results from a pathological process in the basal ganglia causing decreased control of voluntary movements (dyskinesia) (Farley and Koshland, 2005). Farley and Koshland reported significantly increased

gait velocity and stride length during ambulation, and subjects in this study demonstrated significant improvements in function (Farley and Koshland, 2005). This study reflects large improvements in walking skills resulting from task-specific practice of ambulation, and changes in reaching, which provided evidence for transfer of improvements to a novel skill that was not practiced (Farley and Koshland, 2005). When considering the etiology, which results in dyskinesic movements and contributes to an inability to perform functional mobility in patients with PD and CP, this task-specific intervention could be just as effective in addressing similar activity limitations related to disturbances in gait and other movement skills that are fundamental to children (Dietz, 2001; Hackney and Earhart, 2009; Rosenbaum et al, 2007).

To our knowledge, this type of large-amplitude physical therapy intervention has not been investigated in children with CP. While we acknowledge differences between PD and CP, evidence shows similarities related to body structure and function, activity limitations and participation leading us to suspect this type of intervention has high potential to drive improvements in children with CP across all levels of the ICF (WHO, 2001; WHO, 2005). Disturbances of gait, balance and functional movement skills are hallmark activity limitations of both PD (Dietz, 2001; Hackney and Earhart, 2009) and CP (Rosenbaum et al, 2007). Individuals with PD experience participation restrictions reflecting poorer quality of life than their age-matched peers (Dowding, Shenton, and Salek, 2006) just as the participation rates (Orlin et al, 2010) and activity levels (Bjornson et al, 2007) of children and youth with CP are significantly lower than those of their peers.

Adapting the existing protocol that is used for patients with PD for children with CP may be a way for therapists to provide high volume, task-specific practice of gait and functional mobility tasks that may be delivered at different times across the lifespan. Because of their diminished executive functions for understanding complex instructions, (Bottcher, Flachs, and

Uldall, 2010) using an intervention approach that provides them with a singular focus may be very effective in improving functional movement patterns. Further, the incorporation of task-specific practice of activities that are motivating for the child is consistent with current best practice paradigms for children with CP (O'Neil et al, 2006). Testing this intensive protocol in this population with an interdisciplinary team that can quantify characteristics and changes in gait, along with clinically relevant measures of activities and participation, has the potential to make important contributions to the daily practice of pediatric and neurologic physical therapy and biomechanics. Therefore, the purpose of this study was to determine whether adapting this large amplitude intervention for children with CP is an effective therapeutic intervention strategy for improving gait and functional movement outcomes across all levels of the ICF.

We hypothesize that children with CP exposed to a brief training session will experience improved temporal-spatial gait characteristics, demonstrate increased gait speed when cued to walk as fast as possible, and demonstrate improved gait kinematics after a brief training period with high amplitude movement patterns and verbal instruction. We synthesized the hypothesis from evidence that suggests practicing task-specific training of movements that resemble functional mobility activities with emphasis on high amplitude movement and sensory calibration will address these specific deficits commonly present in children with CP (Farley and Koshland, 2005).

METHODS

Participants

A sample of convenience was used to recruit 5 ambulatory children (4 males and 1 female) ages 6 through 17 with a clinical diagnosis of CP (age 7.0 ± 1.0 yrs, mass 26.0 ± 5.1 kg, height 125.7 ± 7.4 cm) (table 1). To be included in the study, participants were required to 1) be functioning at Gross Motor Function Classification System (GMFCS) Levels I-III; 2) be able to walk

with or without an assistive device; 3) have no activity restrictions due to recent surgery or health problem (in the past year); 4) be English-speaking; 5) be able to follow one-step commands and 6) be able to participate in a brief (15 minute) intervention session. Written informed parental consent and child assent were obtained for each subject prior to participation. This study was approved by the Office of Research Integrity, Human Subjects Committee at the affiliated institution.

Insert table 1 about here

Study Design

Children meeting the entry criteria were invited to the Biomechanics Laboratory, along with a parent or legal guardian. Following written consent and assent, the child's ambulatory and functional statuses were determined through direct observation as well as parent interview. For this purpose, the Ambulatory Status Rating Scale x 3, which combines three separate rating scales into one document, was used. Evidence suggests that this document is both reliable and valid for use in determining the walking ability in children with CP (Bodkin, Robinson, and Perales, 2003; Graham et al, 2004; Novacheck, Stout, and Tervo, 2000; Ortin et al, 2009). The GMFCS was specifically used to evaluate each participant's current abilities and limitations in gross motor function (figure 1). There is evidence to suggest the reliability of this tool (Bodkin et al, 2003; Palisano et al, 1997). In the current study, inter-rater reliability among the four raters was good using the GMFCS: ICC (3,1)=0.975 (95% CI:.952-.990).

Insert figure 1 about here

Each participant's height was measured to the nearest 0.1 cm and mass to the nearest 0.1 kg. Leg length was measured to the nearest 0.1 cm using a 2 part technique measuring first from the greater trochanter of the femur to the mid-point of the lateral joint line of the knee

and second from the mid-point of the lateral joint line of the knee to the apex of the lateral malleolus. The two measures were combined to form a total leg length. This technique accounted for any spasticity or contractures that children with CP may experience (Russell, Bennett, Kerrigan, and Abel, 2007). The four raters of our study had moderate reliability when using this technique to measure leg length: ICC (3,1)=.729 (95% CI:.317-.962)

Each of the five participants performed 4 ambulatory passes across an instrumented walkway system, GAITRite (model 3.9, version 4.0, 59).¹ These walking passes occurred over a 14 ft. (4.27 m) GAITRite walkway and included the following: 2 passes at self-selected velocities and 2 passes at fast ambulatory speeds. The GAITRite computerized electronic walkway was used to measure temporal and spatial parameters associated with locomotion (Sorsdahl, Moe-Nilssen, and Strand, 2008). All walking passes and interventions were performed with shoes on. The children who required AFO's for stability kept them on during walking passes and interventions. No external support (handrails or crutches) were utilized. The reliability of the GAITRite in measuring the cadence, step length, stride length and single stance time of children with CP has been shown to be high to excellent (ICC(1,1)=0.73 to 0.95) (Sorsdahl, Moe-Nilssen, and Strand, 2008). A total of ten dependent variables (five variables measured bilaterally) were extracted for each participant. These variables include 1) stride length; 2) heel-to-heel base of support (stride width); 3) time in single limb support; 4) time in double limb support and 5) stride velocity.

Following these passes on the GAITRite, each child was given a 15-minute training session in high-amplitude movement, which included sit-to-stand and walking movements followed by a preferred activity chosen by the participant. Chosen activities included jumping, skipping, kicking and throwing. Movements were performed in a blocked sequence and student physical therapists provided constant feedback and standby assistance. Typical narrative to

induce the large amplitude movements included “move as big as you can”, “reach for the sky”, “bigger steps”, in addition to asking the children if they feel they could move larger.

After a brief rest period, the ambulatory passes over the GAITRite that were described above were then repeated to compare pre and post temporal and spatial gait measurements. All measurements were performed in one visit, with each child participating in the study for up to 2 hours with rest breaks if needed.

A single subject statistical technique (Model Statistic, $\alpha = 0.05$) was used to examine pre-post walking characteristics at each walking speed for each participant. The Model Statistic was developed for use in studies with small sample sizes or single subject research designs to facilitate testing of within-subject differences while accounting for within-subject variability. The Model Statistic procedure allows analyses of within-subject differences by using each footstep recorded on the GAITRite as an “observation” in that child’s study. In this way, the analytic procedure incorporates variability of each participant’s performance to compare pretest/posttest mean values.

RESULTS

The results of the pre and post intervention GAITRite data from the 5 participants were analyzed using the Model Statistic (Dufek, Bates, Stergiou, and James, 1995). Significant findings were determined through analysis of the critical difference versus the observed difference. Similar to a t-test, the critical difference is determined as a function of sample size (number of walking strides) and level of significance. The number of walking strides available for analysis varied by participant and ranged from 4 to 9 for each condition. Results of the walking analysis identified differential responses to the intervention for each participant (P).

There were no significant differences identified at either speed (preferred vs fast) for any of the dependent variables for P1. While P2 did demonstrate some significant changes

($p < 0.05$) from pre- to post-intervention in the fast condition (left stride length 126.1 ± 1.9 to 94.6 ± 7.3 , right stride length 126.5 ± 8.4 to 88.2 ± 4.8 , time spent in single limb stance on the left 27.9 ± 0.6 to 22.3 ± 3.5 , time spent in single limb stance on the right 31.1 ± 1.9 to 26.1 ± 2.8 , time spent in double limb stance on the left 12.6 ± 12.0 to 7.7 ± 2.8 , and time spent in double limb stance on the right 11.1 ± 1.7 to 6.7 ± 3.4), P2 did not display any significant changes in the preferred condition following the intervention.

The final 3 participants (P3, P4 and P5) displayed a much more visible response to the brief intervention. The statistical findings based on critical vs observed difference are listed in table 2 for the preferred walking condition and table 3 for the fast walking condition.

Insert table 2 and table 3 around here

During the preferred walking condition, P3 demonstrated increased stride length bilaterally, greater bilateral base of support, reduced double limb stance time on the left, and increased bilateral stride velocity (figure 2). During the fast walking condition, P3 demonstrated a reduced base of support on the right and increased bilateral stride velocity (figure 3).

Insert figure 2 and 3 about here

During the preferred walking condition, P4 demonstrated reduced time in single limb stance on the left, reduced time in double limb stance bilaterally, and greater bilateral stride velocity (figure 4). During the fast walking condition, P4 demonstrated reduced double limb stance time on the left and greater stride velocity on the left (figure 5).

Insert figure 4 and 5 about here

During both the preferred walking condition and the fast walking condition, P5 demonstrated greater stride length bilaterally, reduced time spent in double limb stance bilaterally, and increased bilateral stride velocity (figure 6 and figure 7).

Insert figure 6 and 7 about here

DISCUSSION

The primary purpose of this study was to test the effects of a short bout of high intensity training protocol on specific gait parameters in children with cerebral palsy, aged 6 to 17. The preliminary results of this study support our hypothesis and suggest that there is promise for this high intensity, large amplitude intervention, in which subjects demonstrated significant improvements in temporal-spatial characteristics of gait during walking trials.

The different gait parameters that significantly changed after the intervention among all of the final 3 participants (P3, P4 and P5) included greater stride velocity, reduced time in double limb support and greater stride length. Each of the three participants also exhibited additional significant findings that are unique to each individual and suggest positive effects of the intervention protocol. These variable findings among the subjects suggest that clinicians should perform a thorough, individualized gait analysis prior to intervention, but also personalize intervention protocols to correspond with the specific impairments of the child.

Interesting findings for subject 3 included an increased base of support (BOS) during the preferred speed condition, greater bilateral stride length during the preferred condition, and greater bilateral stride velocity during the preferred and fast speeds. Although an increase in base of support in normal developing children may indicate gait instability, this may not be the case in this study. Due to the high prevalence of equinus, also known as toe walking, in children with CP, we find that this increase in BOS may actually show a trend toward a BOS that is more normal to typically developing peers. Durham et al (Durham, Eve, Stevens, and Ewins, 2004) found that this equinus negatively affects the balance of children with CP, as well as adversely affecting their base of support, depending on their type of CP. A wider BOS may also lend itself to a decrease in scissoring gait, which is another common gait deviation that is seen in children with cerebral palsy (Wren, Rethlesfsen, and Kay, 2005). Scissoring gait is described as a person's

leg crossing in swing causing problems with foot clearance and subsequently may lead to falls (Wren, Rethlesfsen, and Kay, 2005). By widening a subject's BOS, their feet are shifted more laterally, towards normal, thus decreasing their chance of tripping or falling over their own feet while walking.

Along with subject 3, subject 4 also exhibited an increase in bilateral stride velocity during the preferred speed as well as a decrease in double limb support. Chen et al found that children with CP had a significant increase in the double limb stance phase compared to their normal aged peers (Chen et al, 2009). This decrease in the double limb stance phase and increase in stride velocity is consistent with a faster walking child, as well as feeling more confident and stable during gait.

Subject 5 exhibited an increase in stride length in both conditions, as well as reduced time in double limb support and greater stride velocity. As stated above, these findings suggest that this child, as well as the 2 other children, felt more stable, coordinated and demonstrated improvement in gait efficiency after a short bout of intervention.

In addition to the biomechanical improvements and more efficient gait pattern demonstrated in these subjects, this has some positive implications for the children's function, particularly in play, which is a very important component in a child's life. With a more efficient gait pattern, particularly with the increase BOS demonstrated, these children would have better balance, decreasing their risk for falls. This is important on the playground, interacting with peers and for their own self-confidence. If children are faster and more coordinated, they may be more willing to play a school sport or feel inspired to play in gym class, increasing their overall activity and participation levels. The age group that we targeted in this study are thought to view social activity and sports as priorities in their daily lives (McGavin, 1998), therefore promoting an improvement in gait towards functional and motivational goals can be viewed as

an important objective for these children.

It has been suggested that one of the key reasons that so many of the physical therapy interventions used with children with CP may not be able to demonstrate effectiveness is that they involve the physical therapist giving numerous instructions and ongoing verbal feedback that may be difficult for children to process. Children with cerebral palsy have difficulty with focused attention and motor executive functions (Bottcher, Flachs, and Uldall 2010). Executive functions include those regulated in the prefrontal cortex of the brain such as controlling impulses, anticipating consequences, monitoring results of one's own actions, and processing feedback. Therefore, the use of a singular focus in intervention strategies becomes a relevant factor that may have contributed to successful outcomes in this study. Farley et al. (Farley, Fox, Ramig, and McFarland, 2008) described that for patients with Parkinson's disease, focusing singularly on making movements big, versus making movements look good, reduces the cognitive load on the patient and allows for repeated practice on the specific task. This may also affect the patient on an internal level in regards to scaling of motor output, and could carryover to everyday living (Farley, Fox, Ramig, and McFarland, 2008; Farley, 2010). This sensorimotor carryover may have been one of the reasons that some participants improved after the high intensity intervention. It is possible that intervention strategies that provide children with a singular focus and teach them to monitor their own movement patterns can be more effective than traditional strategies in which attention is divided among many components or qualities of movement.

We also propose that, along with possible experimental and learning effects, a type of sensory calibration may have caused some of the positive effects seen in the children's gait. It is known that children with CP present with sensory impairments, specifically because most of the brain lesions that cause CP are located near the posterior thalamic region, which have an

important influence on the motor system (Hoon et al, 2009). By giving verbal cues and allowing the children to process their own internal cues of what is large and what isn't, the children were able to independently shift into the larger movement patterns that they were taught without any cues from the researchers. With these large, yet complex repetitive movements, the children were able to focus directly on one movement pattern. These activities not only challenged them to complete larger movements, but also feel that these larger movement patterns that were abnormal prior to the intervention, were not so abnormal after.

Although there was significant variability among the participants' results in both the preferred and fast conditions, our results imply that children with CP have the potential to benefit from short bouts of intensive rehabilitation. This finding is consistent with a study done by Trahan et al, (Trahan and Malouine, 2002) whose results suggested that shorter bouts of intensive therapy sessions with longer rest periods rather than interventions delivered at lower doses over a long period of time may be optimal for motor training in children with CP. High intensity therapeutic approaches, such as constraint induced movement and body weight support gait training (Antilla et al, 2008), that have thus far demonstrated efficacy in improving multiple outcomes for children with CP, share common characteristics with the protocol that was utilized in this pilot study, including high intensity training in short bouts of time, goal oriented activities, and a singular over arching task. This combination of characteristics is believed to drive experience-dependent plasticity. That is, even though the brains of children with CP show evidence of damage, the neurons still demonstrate capacity to work together to produce a coordinated movement, particularly when that movement has been practiced with sufficient frequency and intensity. Although this pilot study only reveals the immediate effects of a large intensity training protocol, we believe that this combination of high intensity functional tasks while focusing only on making the movement big, in addition to the repetition,

indicates that plasticity and new motor patterns may begin to develop and is a possible mechanism behind the improvement that was seen in several of the participants.

Although 3 of the 5 subjects in our study demonstrated positive effects after the short bout of intervention, 2 of the subjects yielded none to minimal changes. We propose this could be from a few reasons. First, as a pilot study, the researchers were constantly evaluating their performance, in particular their cueing and instruction during the intervention, becoming more familiarized with what works and doesn't work with children in this age group. As our results show, the first 2 children in the study did not show significant differences, and it very well may be from a protocol standpoint and not a motor determinate of the children. Another reason could quite possibly be because of the very short intervention that was utilized in this pilot study. Although all children were either level I or II on the GMFCS, the first 2 children may have needed more time to grasp the motor activity in the protocol, needed increased manual or verbal cueing, and/or did not process the singular focus to move larger, therefore not demonstrating carry over during the post test. As with most research with children, variability in behavior, mood, and focus is always a factor to consider as well.

CONCLUSION

Results of this pilot study suggested encouraging, immediate positive outcomes following a short bout of large amplitude training for some children with CP. Further investigation of the intervention effects and intervention presentation, including dose response, is warranted. Given the lack of demonstrated effectiveness of traditional interventions and sound theoretical framework, our promising pilot study findings lead us to believe that episodic, large amplitude training can effectively improve gait and functional mobility in children with CP. The goal of further research that is currently being investigated is to test whether ambulatory, school-aged children with cerebral palsy demonstrate improved gait and functional mobility

skills following of a full episode of large amplitude training adapted for this population and delivered in a summer day camp type setting.

Table 1: Participant characteristics (N=5)

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Age	6	8	8	6	7
Gender	Female	Male	Male	Male	Male
Race	Other	White	Other	White	White
Ethnicity	Hispanic	Non-Hispanic	Hispanic	Non-Hispanic	Non-Hispanic
Height (cm)	121	131	135	116.8	124.5
Mass (kg)	24.4	34.2	26.5	20.5	24.5
GMFCS Level	2	1	1	2	1
Orthotics	Bilateral AFO	Left AFO	None	Bilateral AFO	Right AFO
AD	None	None	None	None	None

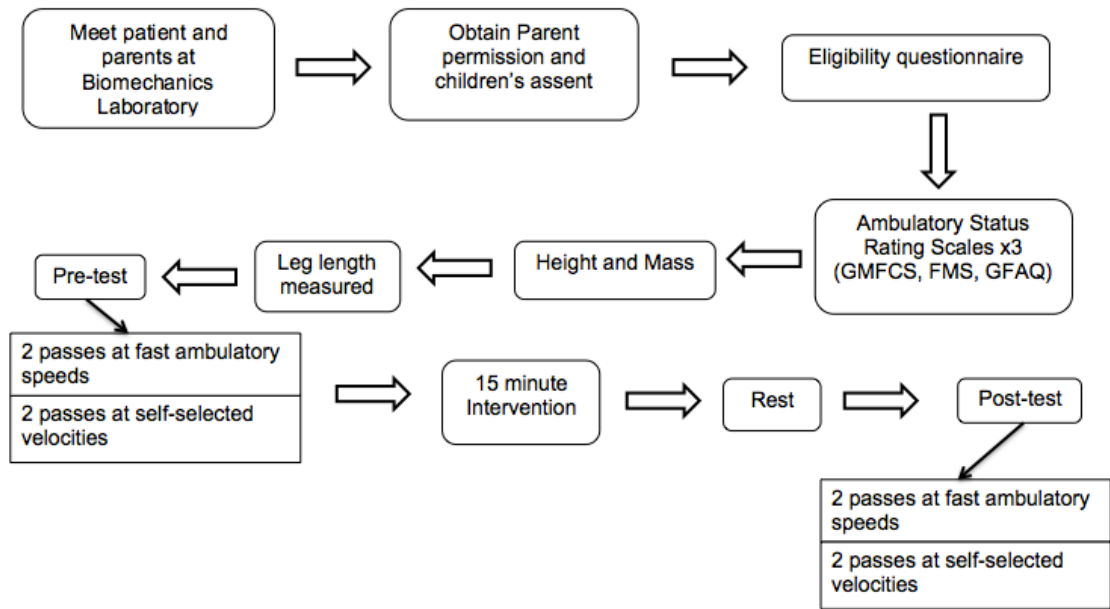


Figure 1: Study Design

Table 2: Critical versus observed differences for participants 3-5 for the preferred speed

	SL-L	SL-R	BOS-L	BOS-R	SS-L	SS-R	DS-L	DS-R	SV-L	SV-R
Obs Diff	9.2590*	17.2835*	3.1205*	3.3545*	0.0123	0.0033	0.0330*	0.0065	9.9213*	18.9160*
Crit Diff	6.6570	6.5405	1.8975	1.8975	0.0259	0.0268	0.0218	0.0332	9.2366	9.3589
Obs Diff	2.2365	2.7490	3.9292*	2.8183*	0.0492*	0.0057	0.0362*	0.0287*	6.1533*	6.8648*
Crit Diff	4.4884	3.2156	3.0357	1.7054	0.0232	0.0149	0.0201	0.0200	5.3129	5.6357
Obs Diff	12.5765*	8.3981*	0.7309	0.4040	0.0135	0.0063	0.0540*	0.0564*	35.8717*	37.4058*
Crit Diff	4.6675	4.7356	2.1423	2.2214	0.0387	0.0252	0.0285	0.0222	15.0333	14.8956

If the observed difference is greater than the critical difference, then it is statistically significant.

Obs Diff = observation difference; Crit Diff = critical difference; SL = stride length (cm); BOS = heel to heel base of support (cm); SS = time in single limb support (ms); DS = time in double limb support (ms); SV = stride velocity (cm/s); L = left lower extremity; R = right lower extremity.

*Significant at $p < .05$

Table 3: Critical versus observed differences for participants 3-5 for the fast speed

	SL-L	SL-R	BOS-L	BOS-R	SS-L	SS-R	DS-L	DS-R	SV-L	SV-R
Obs Diff	2.0870	1.6768	1.9270	2.5346*	0.0017	0.0114	0.0060	0.0019	8.0604*	7.1626*
Crit Diff	4.2178	3.7518	1.9743	2.4585	0.0170	0.0209	0.0165	0.0240	5.3551	7.1411
Obs Diff	0.8550	1.3570	0.4770	1.4165	0.0095	0.0100	0.0365*	0.0317	10.8376*	8.4561
Crit Diff	6.0281	3.9324	1.1990	2.2638	0.0310	0.0217	0.0324	0.0360	10.4941	8.9987
Obs Diff	5.9132*	8.0354*	0.2640	1.2442	0.0022	0.0070	0.0332*	0.0299*	27.8975*	28.2288*
Crit Diff	4.4766	5.2771	1.6840	2.0463	0.0145	0.0298	0.0164	0.0169	16.4744	16.4871

If the observed difference is greater than the critical difference, then it is statistically significant.

Obs Diff = observation difference; Crit Diff = critical difference; SL = stride length (cm); BOS = heel to heel base of support (cm); SS = time in single limb support (ms); DS = time in double limb support (ms); SV = stride velocity (cm/s); L = left lower extremity; R = right lower extremity.

*Significant at $p < .05$

Participant 3 Preferred Speed

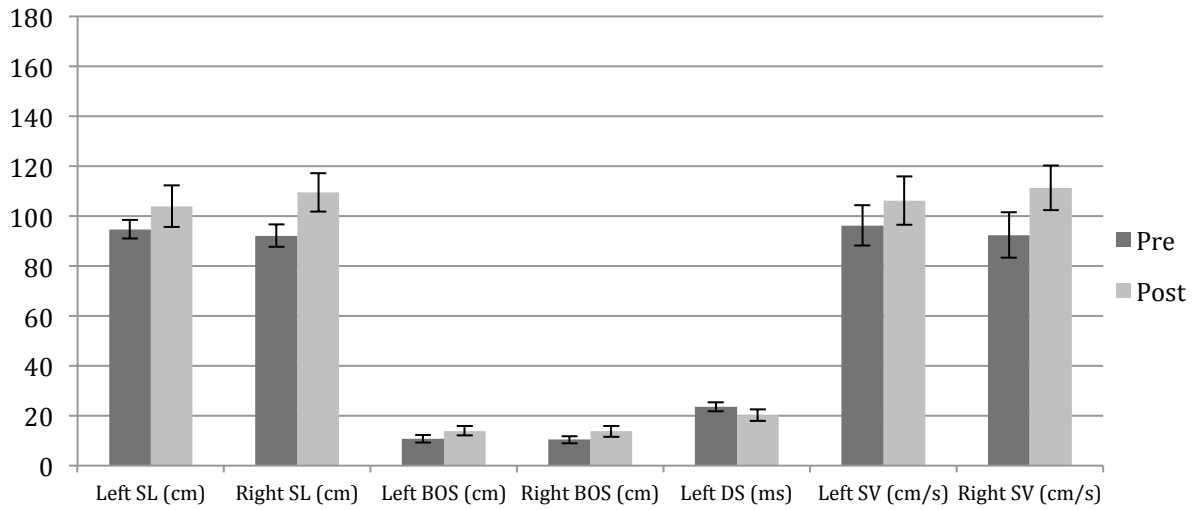


Figure 2: Significant findings ($p < 0.05$) with mean values and SD bars from pre- to post-intervention testing for the preferred walking condition for P3

Participant 3 Fast Speed

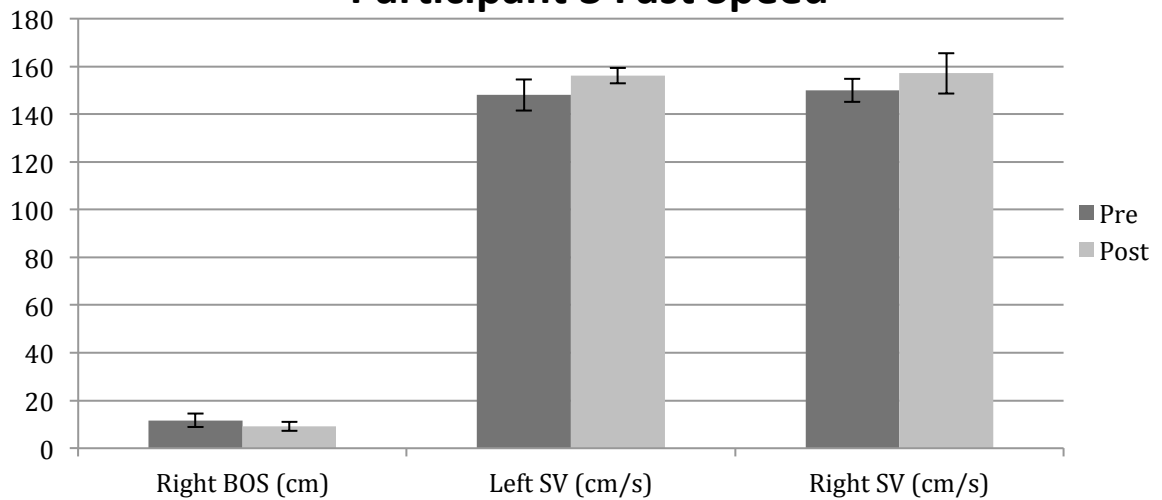


Figure 3: Significant findings ($p < 0.05$) with mean values and SD bars from pre- to post-intervention testing for the fast walking condition for P3

Participant 4 Preferred Speed

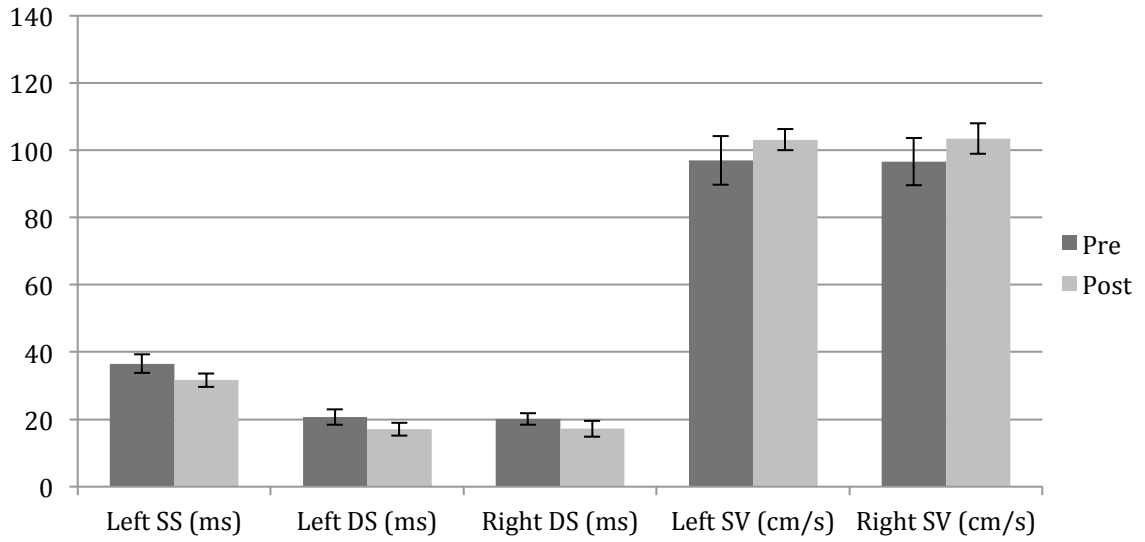


Figure 4: Significant findings ($p < 0.05$) with mean values and SD bars from pre- to post-intervention testing for the preferred walking condition for P4

Participant 4 Fast Speed

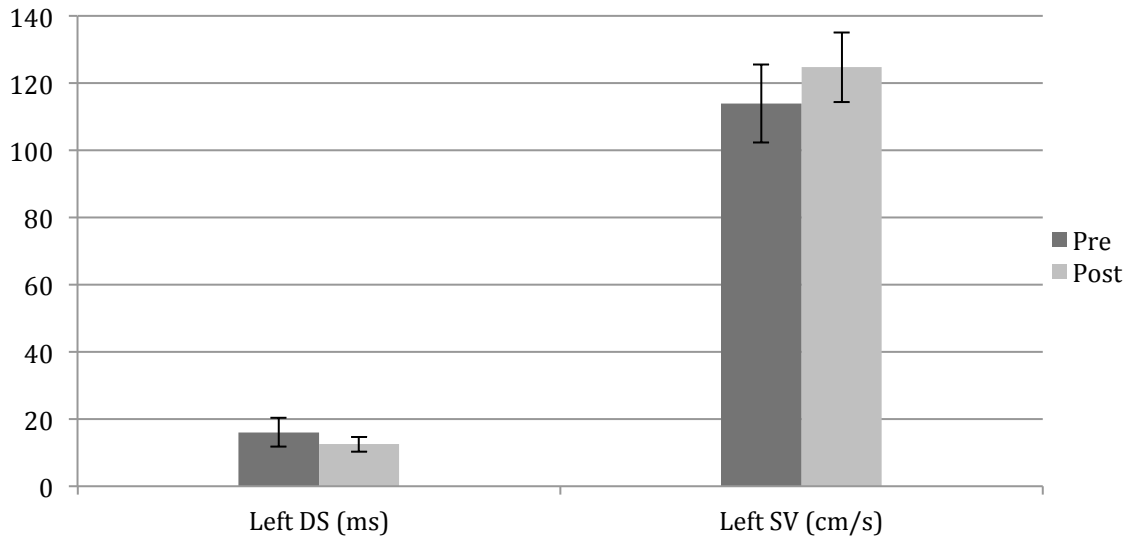


Figure 5: Significant findings ($p < 0.05$) with mean values and SD bars from pre- to post-intervention testing for the fast walking condition for P4

Participant 5 Preferred Speed

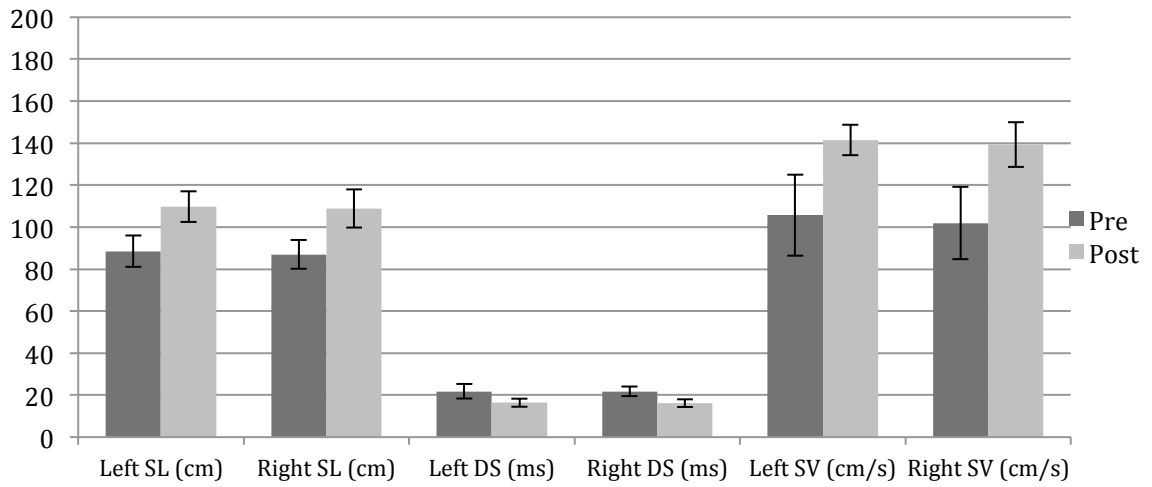


Figure 6: Significant findings ($p < 0.05$) with mean values and SD bars from pre- to post-intervention testing for the preferred walking condition for P5

Participant 5 Fast Speed

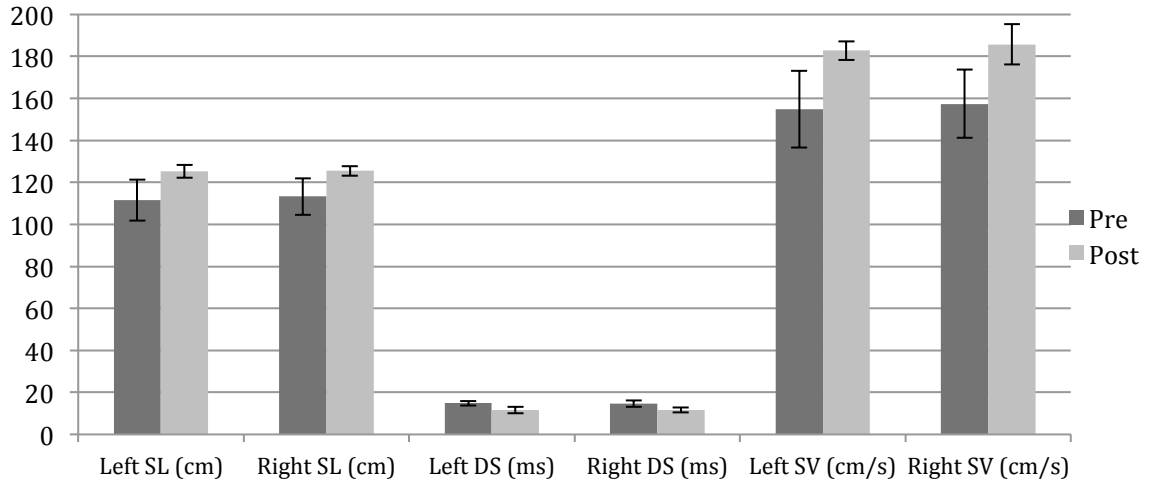


Figure 7: Significant findings ($p < 0.05$) with mean values and SD bars from pre- to post-intervention testing for the fast walking condition for P5

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FOOTNOTES

1. CIR Systems Inc, 60 Galor Dr, Havertown PA, 19083, telephone number: 610-449-4879

DECLARATION OF INTEREST

The authors report no declarations of interest

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PROFESSIONAL WORK EXPERIENCE

- University of Nevada, Las Vegas Department of Physical Therapy Graduate Assistant
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CLINICAL INTERNSHIPS

- HealthSouth Desert Canyon Rehabilitation Hospital-Las Vegas, NV-Inpatient
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- Southern Hills Hospital-Las Vegas, NV- ICU, Medical Surgical, Orthopedic rehabilitation
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- Physiotherapy Associates-Children's Therapy Center- Henderson, NV- Outpatient
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- Physiotherapy Associates-Las Vegas, NV- Outpatient Physical Therapy (July-August 2011)
- Universal Therapy Dynamics-Willoughby, Ohio-Outpatient Physical Therapy (June-July
2010)

RESEARCH

- Thesis: Immediate effects of high intensity training in children with cerebral palsy GMFC
Levels I-III: a pilot study
 - Advisor: Robbin Hickman, PT, DSc, PCS
 - Abstract accepted for presentation at the APTA Annual Conference (June 2012)

PROFFESIONAL MEMBERSHIP

- Member - American Physical Therapy Association (2009-present)

PROFFESIONAL ACTIVITIES

- APTA Combined Sections Meeting – Chicago, IL – February 2012
- APTA Combined Sections Meeting -San Diego, CA - February 2010

AWARDS

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EDUCATION

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- University of Nevada, Las Vegas – Las Vegas, Nevada
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- Reno Sport and Spine – Outpatient Orthopedic Physical Therapy (June-July 2010)

RESEARCH

- Thesis: Immediate effects of high intensity training in children with cerebral palsy GMFCS Levels I-III: a pilot study
 - Advisor: Robbin Hickman, PT, DSc, PCS
 - Abstract accepted for presentation at the APTA Annual Conference (June 2012)
- Balance confidence and fear of falling avoidance behavior are most predictive of falling in older adults: a prospective analysis
 - Student author
 - First author: Merrill Landers, PT,DPT, OCS, PhD(c)
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AWARDS

- 2011 Spring: UNLV Graduate Access Grant \$2,000
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 - Bachelor of Science in Exercise Science – 2008
- University of Nevada, Las Vegas – Las Vegas, Nevada
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CLINICAL INTERNSHIPS

- Kindred Transitional Care & Rehabilitation-Queen Anne – Inpatient Neurologic Rehabilitation (January-March 2012)
- San Diego Navy Medical Center – Outpatient Orthopedic Physical Therapy and Acute Care (September-December 2011)
- Scripps Mercy Hospital – NICU, ICU, General Acute, and Sub-acute Physical Therapy Services (July-September 2011)
- Oasis Physical Therapy – Outpatient Orthopedic Physical Therapy (June-July 2010)

RESEARCH

- Thesis: Immediate effects of high intensity training in children with cerebral palsy GMFCS Levels I-III: a pilot study
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- Member - American Physical Therapy Association (2009-present)
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- APTA Combined Sections Meeting – Chicago, IL – February 2012
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EDUCATION

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CLINICAL INTERNSHIPS

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 - Clinical internship in pediatric outpatient setting
- Hill Crest Health and Rehab – Omaha, NE - October 3 - December 14 2011 (10.5 weeks)
 - Clinical internship in Skilled Nursing Facility
- St. Rose De Lima – Las Vegas, NV - July 11- September 23 2011 (11 weeks)
 - Clinical internship in inpatient acute care setting
- Family and Sports PT- Las Vegas, NV - June 21-July 30 2010 (6 weeks)
 - Clinical internship in orthopedic outpatient setting

RESEARCH

- Thesis: Immediate effects of high intensity training in children with cerebral palsy GMFCS Levels I-III: a pilot study
 - Advisor: Robbin Hickman, PT, DSc, PCS
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PROFFESIONAL MEMBERSHIP

- Member American Physical Therapy Association (2009-present)
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- Member Aquatic Section of the American Physical Therapy Association (2010-present)

PROFFESIONAL ACTIVITIES

- APTA Combined Sections Meeting -San Diego, CA - February 2010
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