Evaluation of the Optimum Duration and Effectiveness of a Plyometric Training Program for Improving the Motor Abilities of Youth with Cerebral Palsy

Barbara A. Johnson

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EVALUATION OF THE OPTIMUM DURATION AND EFFECTIVENESS OF A
PLYOMETRIC TRAINING PROGRAM FOR IMPROVING THE MOTOR
ABILITIES OF YOUTH WITH CEREBRAL PALSY

by

Barbara A. Johnson

A dissertation submitted in partial fulfillment
of the requirements for the degree
of
DOCTOR OF PHILOSOPHY
in
Disability Disciplines

Approved:

__________________________________________
Judith Holt, PhD
Co-Major Professor

__________________________________________
Charles Salzberg, PhD
Co-Major Professor

__________________________________________
Timothy Slocum, PhD
Committee Member

__________________________________________
Sarah Rule, PhD
Committee Member

__________________________________________
Sarah Bloom, PhD
Committee Member

__________________________________________
Mark R. McLellan, PhD
Vice President for Research and
Dean of the School of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2012
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ABSTRACT

Evaluation of the Optimum Duration and Effectiveness of a Plyometric Training Program for Improving the Motor Abilities of Youth with Cerebral Palsy

by

Barbara A. Johnson, Doctor of Philosophy

Utah State University, 2012

Major Professors: Dr. Judith Holt & Dr. Charles Salzberg
Department: Special Education and Rehabilitation

Current research examining the effects of resistive exercise programs in children with cerebral palsy (CP) has not met national guidelines for the duration of training. The lack of improvement in gross motor abilities after resistive training may be attributed to insufficient duration. Additionally, plyometric training has not been used as a treatment, despite evidence suggesting that it can improve running, throwing, and jumping skills. The current study evaluated the optimum duration and effects on gross motor abilities of a plyometric training treatment for three participants with spastic, unilateral CP using a multiple baseline, multiple probe design. Treatment was designed using the National Strength and Conditioning Association’s guidelines for intensity, volume, frequency, and variety of training. Treatment resulted in improvements in GMFM 66 scores, agility, and broad jump distance for all three participants. Consistency preceded improvements in distance or height. The optimum duration was dependent on the individual child and the outcome measure. Ongoing training is necessary to maintain running speed. However,
slight declines or maintenance of performance in the GMFM, agility, and power tests at follow-up may be attributed to inconsistency in performance rather than decline.
PUBLIC ABSTRACT

Evaluation of the Optimum Duration and Effectiveness of a Plyometric Training Program for Improving the Motor Abilities of Youth with Cerebral Palsy

by

Barbara Johnson

The Pediatric Section of the American Physical Therapy Association determined that dosing of treatments for children with cerebral palsy (CP) was a priority topic for research funding in 2013. Pediatric physical therapists currently have very little information about the best duration for treatment. Research that could answer the question “How long should my child’s treatment last?” would be of interest to families of children with CP and their physical therapists.

A type of resistive exercise called plyometric exercise was used as a treatment for three children with cerebral palsy. This study used a design called single subject that allowed the program to continue until improvement plateaued. It also allowed all children who enrolled in the study to receive the treatment. The children in the study had difficulty in performing gross motor skills consistently. For example, one day they would throw a ball 550 centimeters, and the next 650 centimeters. They became more consistent in achieving their best effort, or throwing the ball 650 centimeters every time. If they already had good consistency, then they made changes in the distance they could throw. For example, by the end of treatment they would be able to throw 700 centimeters several days in a row.
However, we found that there was no optimum treatment length. The first child plateaued in 8 weeks, the second in 14 weeks, and the third in 9½ weeks. In summary, the length of treatment needs to be individualized for each child. Duration should be determined by monitoring the child’s progress each session and treatment should be continued until the child reaches a plateau or fails to respond to treatment.
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INTRODUCTION

Cerebral palsy (CP) is defined as a group of permanent disorders of the development of movement and posture, which are often accompanied by disturbances of sensation, perception, cognition, communication, and behavior. The definition and classification of CP described by Rosenbaum, Paneth, Leviton, Goldstein, and Bax, (2007) was intended to represent a common conceptualization of CP in a broad spectrum of international audiences. The anatomical description refers to motor disturbances on either one side of the body (unilateral) or both sides of the body (bilateral). CP is further classified using four components

1. The type of motor disorder. The three groupings of the motor disorder include spastic (resistance to movement), dyskinetic (fluctuating movement), or ataxic (exaggerated movement).

2. The functional motor abilities. There are two functional motor classification systems, one for mobility and one for hand use. Both classification systems use five levels to describe children’s function. The highest level describes individuals who do not require assistance (Level I) and the lowest level describes individuals who require the most assistance (Level V). The Gross Motor Function Classification Scale (GMFCS) (Palisano et al., 1997; Palisano, Rosenbaum, Bartlett, & Livingston, 2008) was designed to describe children’s mobility and the Manual Ability Classification System (MACS) (Eliasson et al., 2006) was designed to describe how children use their hands during activities of daily living.
3. Accompanying Impairments. Impairments can accompany the motor disorder and limit an individual’s ability to function in daily life. Rosenbaum et al. 2007 have recommended listing and describing impairments using standardized accepted terminology and rating systems of severity.

4. Age. The age of the individual can be listed or categorized using the following categorizations: Infant/toddler (1-3 year-olds), children (4-7 year-olds), youth (8-12 year-olds), adolescents (13-17 year-olds), and adults (>age 18).

The impairments of CP cause limitations in the task execution. Pediatric physical therapy interventions address limitations in gross motor abilities such as standing, walking, and running. The use of the Gross Motor Function Classification System (GMFCS) with the Gross Motor Function Measure (GMFM) (Russell, Rosenbaum, Avery, & Lane, 1993) allowed clinicians to track gross motor development and to make comparisons to age and severity-matched peers with CP. The publication of motor development curves based on severity classification, and age (Rosenbaum et al., 2002) depict the rate and limits of gross motor development in children with CP. This work represents an important advancement in predicting and measuring gross motor achievement in children with CP and provides a means for researchers to assess the outcomes of physical therapy interventions to improve gross motor abilities.

A systematic review of strengthening interventions for children with CP concluded that strengthening interventions from five randomized controlled trials did not increase strength or improve GMFM scores (Scianni, Butler, Ada, & Teixeira-Salmela, 2009). Verschuren et al. (2011a) compared the intervention durations of the studies
reviewed to the National Strength and Conditioning Association (NSCA) (Faigenbaum et al., 2009b) guidelines for typically developing children. Not one of the five studies met the criteria for adequate duration. Given that the majority of current research has not met the guidelines for resistive exercises in typically developing children, it seems even more likely that the duration of resistive training programs were insufficient for children with CP. Therefore, determining the optimum duration for a training program for children with CP is an important clinical research question.

Resistance training is an accepted intervention in pediatric physical therapy. There is a moderate relationship (.60 to .70) between muscle power, muscle strength, agility and the standing, walking, and running dimensions of the GMFM (Verschuren, Ketelaar, Gorter, Helders, & Takken, 2009). The evidence supporting resistive training interventions is based on the knowledge of this relationship and the goal of improving gross motor abilities. There are a variety of types of resistance training programs.

Training modalities used in children with CP include body weight exercises (Dodd, Taylor, & Graham, 2003; Liao, Liu, Liu, & Lin, 2007; Verschuren et al., 2009), weight machines (Scholtes et al., 2010) free weights (Lee, Sung, & Yoo, 2008) and eccentric exercise (Reid, Hamer, Alderson, & Lloyd, 2010). Training adaptations that occur in youth are specific to the movement pattern and the speed, force and contraction type that are trained. Changes in strength during childhood are attributed to neural factors such as increase in motor unit recruitment, increase in firing rate of muscle fibers, and changes in coordination or the speed and timing of movement. Improvements are generally seen in motor skill performance and coordination. Expected gains in motor performance in
youth with typical development are usually 30% above initial levels for short duration programs i.e., 8 to 10 weeks (Faigenbaum et al., 2009b).

Plyometric exercise is a type of resistance exercise used to improve strength and power. It consists of high impact activities such as hopping, jumping, bounding, and throwing. In contrast to body weight exercises (sit to stand, squats, step-ups, and stair walking) which train everyday tasks, plyometric exercise trains the specific muscle actions needed for running, jumping, hopping, and throwing. Despite the potential benefits of plyometric exercise, there have been no published studies evaluating the use of plyometric training programs in children with CP, or in children with any other disabling health condition. This study proposes to evaluate the optimal duration of a plyometric exercise treatment and to evaluate the efficacy of plyometric exercise for improving gross motor abilities in children with CP.
LITERATURE REVIEW

Several challenges exist in carrying out an intervention for children with CP. Many children with CP have difficulty with motor skill performance, learning, and attention. Learning the exercises, attending to the task, complying with requests, and performing the exercises may be challenging for the child and may impact the success of the intervention. For that reason it is important to assure that the researchers adapt their programs to the capability of the child, use techniques to facilitate motor learning, increase the exercise load appropriately, provide a safe intervention, and facilitate compliance with the exercises. The literature review consists of three topics pertinent to resistive exercise training in children with CP. The three topics are: (a) a review of plyometric exercise; (b) a review of motor learning principles; and (c) a review of exercise science principles. The NSCA guidelines for resistive training in children and adolescents are also summarized below.

Review of Literature on Plyometric Exercise

Plyometric exercise starts with a rapid stretch of a muscle followed by a rapid shortening. The nervous system is conditioned to react more quickly to the stretch-shortening cycle. This type of exercise can enhance a child’s speed of movement, increase power production (Diallo, Dore, Duche, & Van Praagh, 2001; Kotzamanidis, 2006; Meylan & Malatesta, 2009; Rubley, Haase, Holcomb, Girouard, & Tandy, 2011), and strengthen bone (Greene & Naughton, 2006). Plyometric training programs have been shown to be effective in adults and pubertal children for improving running speed and jumping ability (Markovic, 2007) and for increasing strength (Saez-Saez, De
Villarreal, Requena, & Newton, 2010). Strength training can improve muscle performance and coordination of muscle groups. However to improve sport performance, children benefit more from practicing and perfecting the specific skills used in the sport (Bernhardt et al., 2001). Therefore, plyometric training may be an appropriate intervention for improving the ability to run, hop, jump, and throw since it provides both a means of practicing motor skills and enhancing strength.

Recent research on pre-pubertal youth with typical development and athletes suggests that plyometric training had a large effect on improving the ability to jump (Kotzamanidis, 2006; Meylan & Malatesta, 2009; Rubley et al., 2011) and run (Kotzamanidis, 2006; Meylan & Malatesta, 2009), but only a small effect on improving strength (Faigenbaum et al., 2009a; Ingle, Sleap, & Tolfrey, 2006). The small effect on improving strength may be explained by the differences in the mechanisms for strength gain in pre-pubertal children. Strength gains in youth have been attributed to intrinsic muscle adaptation and neural adaptation since pre-pubertal children lack circulating androgens responsible for muscle hypertrophy (Guy & Micheli, 2001). The evidence suggests that plyometric training also had a large effect on improving kicking distance (Rubley et al., 2011), and agility (Meylan & Malatesta, 2009).

**Review of Literature on Principles of Motor Learning**

It is important to consider principles of motor learning theory when working on improving children’s motor abilities. Principles of motor learning theory include the use of verbal instructions; amount, structure and schedule of practice; and frequency of feedback to enhance the intervention and enhance the generalization or transfer of
learning to new situations (Levac, Wishart, Missiuna, & Wright, 2009). Children require more feedback to initially learn a motor skill than do adults and benefit from longer periods of practice with feedback that is gradually reduced to optimize motor performance (Sullivan, Kantak, & Burtner, 2008). Pless, Carlsson, Sundelin, and Persson (2000) concluded that children who had definite motor difficulties did not change their motor abilities with a group motor skill intervention provided by a physical therapist. Thus, they suggested that an individual program may be more effective for children with low motor competence. An individualized program may offer more opportunity for practice and feedback from the therapist than a group program. Additionally, individual programs can be tailored to the specific needs and capabilities of the child.

The type of instruction provided to children also appears to be important to optimize motor learning. Providing short, precise verbal cues on how to perform a task, asking children about a task, and explaining why a movement should be executed was related to better movement performance than giving lengthy instructions and commands, demonstrating motor tasks, or adjusting a child’s body position (Niemeijer, Schoemaker, & Smits-Engelsman, 2006). Children also showed greater improvement in motor skills when given cues that describe the specific motor behavior versus cues that describe the goal or outcome. An example of a specific motor behavior cue would be “land on your toes with your knees slightly bent” or “start by holding the ball at shoulder level with your thumb pointed to your ear” versus a goal or outcome oriented cue such as “throw the ball to the catcher’s glove” or “jump farther this time.”

A plyometric training program in a study by (Meylan & Malatesta, 2009) resulted in a large ES on running and jumping of young soccer players. The authors provided
detailed participant instructions and emphasized technique including an upright posture, body alignment, avoiding excessive side to side movement in vertical jumps, soft landings, and instant recoil to prepare for the next jump. The use of specific verbal cues explaining how a movement should be executed and providing greater verbal feedback may have resulted in the larger effects on performance.

**Review of Literature on Principles of Exercise Science**

An American College of Sports Medicine (ACSM) report (Faigenbaum, 2000) states that plyometric training can be a safe, effective and fun conditioning method for children. The ACSM report recommends beginning with low intensity skills, progressing slowly, providing one minute of rest between sets, wearing supportive athletic footwear and exercising on a resilient surface. These principles were incorporated into plyometric training programs for young children with typical development in recent research studies. Programs were carried out for 8 to 10 weeks (Faigenbaum et al., 2009a; Ingle et al., 2006; Kotzamanidis, 2006; Meylan & Malatesta, 2009) and consisted of a low to moderate intensity exercise load. The exercise load was progressively increased over the duration of the 8 to 10 week session. Exercising children performed 50 to 60 jumps per session at the beginning of the training program and increased repetitions by 12 to 18 repetitions weekly to a maximum of 90 to 190 jumps per session. Rubley et al. (2011) described a low intensity program and trained children once a week with a low exercise load for a longer period of time -- 14 weeks. This study demonstrated improvement in motor performance. However, the magnitude of change was not as large as programs that provided exercises twice a week with a moderate exercise load. A low intensity program
over a longer period of time may be advantageous for children who do not have the capability or tolerance for a twice a week program.

The study by Meylan and Malatesta (2009) described the intervention in detail. These authors adapted the plyometric exercises to the coordination capacity of the children and encouraged children to perform at full speed. The drills lasted only 10 s with a 90 s rest period between drills. Sessions were separated by 48 hours. The focus of one session was on vertical power (jumping up); the second session on horizontal power (jumping forward). The intensity and progression were determined by considering both the difficulty of the exercise and number of ground contact times. The load was varied and the researchers used a blocked periodization concept (BP). BP is a training method which incorporates periods of increasing the exercise load with rest, and concentrates training on a minimal number of motor abilities (Issurin, 2008). Meylan and Malatesta (2009) and Kotzamanidis (2006) used BP training methods in young children. This method resulted in a large ES for improving running and jumping ability in soccer players.

The attention to principles of exercise and sport science, motor learning theory, and NSCA guidelines for optimizing the benefits of plyometric exercise may have been responsible for the large ES in the results of the studies by Meylan and Malatesta (2009) and Kotzamanidis (2006). The addition of weight training exercises, in combination with plyometric exercise in a study by Ingle et al. (2006) may have been responsible for the lack of change seen in running and jumping, since the program attempted to train more than one type of exercise simultaneously and did not provide adequate duration of training for either type of exercise. It is well known that exercise must be maintained or
the benefits of the training program will be lost. Ingle et al. (2006) performed a follow-up evaluation 12 weeks after the intervention. A decline of strength occurred at the follow-up evaluation, indicating a need to continue exercise training to maintain strength gains. Gains in performance can be made with traditional training routines. However, concepts used in training athletes may maximize the use of time and resources and produce the largest effects. It will be important to perform a follow-up assessment to determine if the skills learned in the exercise training program can be maintained and if children choose to continue the exercises or activities on their own.

**Purpose Statement and Research Questions**

A specific and individualized plyometric training program has not been used as a physical therapy intervention to improve motor skills for children with CP. This study extended the use of plyometric training to children with CP.

The purpose of the study was (a) to evaluate the efficacy of a specific and individualized plyometric exercise program for improving gross motor abilities, (b) to determine the optimal duration of plyometric training programs by monitoring changes in gross motor ability weekly and (c) to extend the program until gross motor ability plateaus. This research attempted to answer the following research questions.

1. Does the use of a specific and individualized plyometric training program result in improvements in gross motor abilities in three youth with CP as measured with the GMFM 66 scores and percentile rank scores, agility, running speed, and power tests?
2. Given that gross motor ability improves with plyometric training, how long does it take for gross motor ability to plateau in three youth with CP as measured by session to session performance on the three power tests (throw basketball, broad jump, and vertical jump)?

3. Given that changes in gross motor abilities are seen following plyometric training, will the participants maintain the benefits gained after the training is discontinued as measured with a 6 week follow up assessment using the GMFM 66 scores and percentile rank scores, agility, running speed, and power tests?
METHODS

Participants and Setting

A search of the electronic medical record at Shriners Hospital for Children was conducted to identify children with the diagnosis of unilateral spastic cerebral palsy. Fifty-two children were identified. The inclusion criteria were (a) a diagnosis of spastic, unilateral type CP, (b) GMFCS Level I and a MACS Level I or II classification by their therapist or physician; (c) 7 to 11 years of age and (d) child and parent agreement to participate after being fully informed. Exclusion criteria were (a) an orthopedic or neurosurgery within the past year, (b) a botox injection in the past 6 months, and (c) inability to attend or participate in the twice a week, 10 to 15 week intervention. The medical record was reviewed and 41 children had received excluded treatments or had moved from the Salt Lake City area. Eleven children met the inclusion criteria. Participants were recruited from the orthopedic, physical therapy, and motion analysis clinics. The researcher met with the child and family during their clinic visit to give them information on the study. Five of the 11 children and their parents expressed interest in participating and were given the functional classification scales (GMFCS and MACS level) by the researcher or the physician. One child decided she was not interested after talking with her parents at home. Four children agreed to participate in the study and signed assent and consent forms. One participant decided she could not attend twice a week for 10 to 15 weeks and withdrew. Table 1 describes the characteristics of the remaining three participants.
Table 1

Research Questions, Measures, and Assessment Timetable

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<th>Research question</th>
<th>Measure</th>
<th>Assessment timetable</th>
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<td>Does the use of a specific and individualized plyometric training program result in improvements in gross motor abilities, agility, running speed, and power?</td>
<td>Gross motor ability (GMFM D, E, 66 &amp; percentile rank) Agility (10X 5 m sprint) Running speed (20 m running start sprint) Power (throw basketball, broad jump, vertical jump)</td>
<td>Pre-treatment, post-treatment, and 6-week follow-up</td>
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<tr>
<td>Given that gross motor ability improves with plyometric training, how long does it take for gross motor ability to plateau?</td>
<td>Power (throw basketball, broad jump, vertical jump)</td>
<td>Pre-treatment, post-treatment, 6-week follow-up, and at the beginning of each treatment session</td>
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<tr>
<td>Given that changes in gross motor abilities are seen following plyometric training, will children maintain the benefits gained after the training is discontinued?</td>
<td>Gross motor ability (GMFM D, E, 66 &amp; percentile rank) Agility (10X 5 m sprint) Running speed (20 m running start sprint) Power (throw basketball, broad jump, vertical jump)</td>
<td>Pre-treatment, post treatment, and 6-week follow-up</td>
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The assessments were conducted in the motion analysis laboratory at Shriners Hospital for Children by the researcher. The treatment sessions were delivered to each participant individually by the researcher in the gym at Shriners Hospitals for Children, Salt Lake City or at the playground. The exercises were performed on grass, on a mat, or on the gym floor in an area that had sufficient room for jumping and throwing. The participants were encouraged to exercise in appropriate exercise apparel. Water and sunscreen were provided for the participants by the therapist.
Dependent Variables

The assessments were chosen to measure the anticipated effects of plyometric training using measures of (a) gross motor ability, (b) running speed, (c) agility, and (d) muscle power. The muscle power measures were also used in the baseline and treatment conditions to evaluate the response to treatment (plyometric exercise) and to determine the optimal duration of the training.

All of the assessments have standardized procedures, are valid and reliable standardized tests, and are routinely used by the researcher. The results were recorded on the appropriate data sheet (Appendix A). All data was collected and stored in compliance with IRB protections for confidentiality. A description of the measures performed, an assessment timetable, and the relationship to the research question is depicted in Table 1.

The three participants received the pre-treatment assessment between January 24, 2012 and February 6, 2012, the post-treatment assessment one week after the last training session, and the follow-up assessment 6 weeks after the last exercise session. The measures were performed after a five min warm up.

Gross Motor Ability Measure - GMFM 66

The GMFM 66 is a standardized test of gross motor ability for children with CP (Russell et al., 1993). The inter-rater reliability (ICC .76 to 1.00) is high (Palisano et al., 1997) and longitudinal responsiveness to change (ES values of 0.3 to 0.4) is fair (Lundkvist, Jarnlo, Gummesson, & Nordmark, 2009). Reference curves are available to provide normative comparisons to function and age-matched peers with CP. Individual sections of the GMFM can be used to monitor change depending on the functional
classification of the child. Sections D (standing) and E (walk, run, jump) were used since those sections were the most appropriate for testing the motor skills of children in GMFCS Level I classification.

There are 13 items in section D and 24 items in section E of the GMFM (Appendix B). Each item was scored using the criteria in the test manual from 0 to 3 points. A computer program accompanies the test manual for entering test data. The program generated a total score (GMFM 66), a percentile score for each section (number correct/number possible), and a percentile rank (similar to a growth curve percentile rank).

**Agility Measure - The 10 X 5 m Sprint**

This test was used to assess changes in agility. Inter-observer reliability and test-retest reliability were high (ICC 1.0, and .97 respectively) in children with CP (Verschuren, Bloemen, Kruitwagen, & Takken, 2010). Construct validity was determined by evaluating the ability of the test to distinguish between GMFCS Levels I and II ($p = .006$).

The participant first performed the test at walking speed to assure understanding of test performance. The participant started at the cue “three, two, one, go” and ran as fast as possible between two tapelines a distance of 5 m apart. The participant had to place one foot on each line, turn and continue running back and forth between the lines for 10 repetitions. The timer was started at the cue “go” and stopped when the participant crossed the line after the 10th run. The time was recorded.
Running Speed Measure - The 20m Running Start Timed Sprint

This test was used to assess changes in running speed. This test involves running a single maximum sprint over 20 m. Participants stood 10 m behind the starting line. Runners start when they are ready. The timer was started when the participant crosses the starting line and stopped when the runner crosses the finish line. The time was recorded. Age and sex specific percentile values are provided and can be used to characterize performance relative to the normative population (Castro-Pinero et al., 2010).

Power Measures - Throw Basketball, Broad Jump, and Vertical Jump

These tests were chosen since they are specific to the type and speed of contraction, and the movements being trained. Validity (intra-class correlation coefficients of .82 to .99) and intra-rater reliability (.99) of the tests are high. Age and sex specific percentile values are provided and can be used to characterize performance relative to the normative population (Castro-Pinero et al., 2009). The throw basketball test was chosen a priori as the primary measure for indicating stability in baseline and for evaluating change during the treatment condition since it had been found to have a high effect size (.99) and was most responsive to change in children with typical development (Behringer, Vom Heede, Matthews, & Mester 2011). The three power measures take five to 10 min to administer, have standardized instructions, can be carried out in the clinic, have normative references based on age and sex, and require a minimal amount of equipment.

Throw Basketball

This test measures upper extremity explosive power. The participant stood at a
line with the feet slightly apart, holding the ball with the hands and facing the direction in which the ball was to be thrown. The ball was brought back behind the head and then thrown vigorously forward as far as possible. The throwing action is similar to that used for a soccer sideline throw-in. The subject was encouraged to use the legs, back, and arms to assist in maximizing the distance thrown. Two attempts were allowed, and the best effort was recorded. An additional attempt was allowed if the participant fell forward over the line or detached his feet from the floor before, during, or after the throw. The distance in cm was recorded from the starting position to where the ball landed (a midpoint within 10 cm since the ball is 24 cm in diameter).

**Vertical Jump**

This test measures vertical lower-body explosive power. The participant stood side-on to a wall and reached up with the hand close to the wall. With the feet flat on the ground, the point of the fingertips was marked. The participant jumped vertically as high as possible using both arms and legs to assist in projecting the body upward. The participant touched the wall at the highest point of the jump. The score was the difference in cm between the reach height and the jump height. The test was repeated twice and the best score was recorded.

**Standing Broad Jump**

This test assesses horizontal lower-body explosive power. The participant stood behind the starting line and was instructed to push off vigorously and jump as far as possible. The participant must land with his feet together and stay upright. The test was repeated twice, and the best score was recorded. The distance was measured in cm from
the takeoff line to the point where the back of the heel nearest to the takeoff line landed. An additional attempt was allowed if the participant fell backward or touched the ground with another part of the body.

**Self-selected Motor Goal**

The purpose of the self-selected gross motor skill was to motivate the child to attend and participate in the treatment sessions. Progress was monitored. However, the results were not attributed to the plyometric training since achievement of the goal may have been the result of practicing the task rather than a result of the intervention. Each participant selected a motor goal to work on during the cool down activity of the plyometric training session. The goal was determined by asking the participant what gross motor skill they would like to work on, or what they would like to improve. The motor task was defined and a measurement system was developed to track progress on the self-selected goal. At the end of the 5 min cool down the child was given two opportunities to perform the motor task and his/her performance from the best trial was recorded on the data sheet.

**Safety**

Ground contact times during jumping were counted and repetitions and weight during throwing were recorded each treatment session to prevent overtraining. The children wore heart rate monitors each treatment session and rested if their heart rate exceeded the maximum training zone set on the heart rate monitor. Participants and their parents were asked if the child had experienced any muscle soreness, unusual fatigue, or if they had any concerns after each session.
Interobserver Agreement

Reliability of the agility, running speed, and power measurements was assessed. The researcher and a pre-physical therapy student independently recorded the best effort of each measure. Inter-observer agreement was determined by comparing the measurements recorded by the researcher to that of the independent data collector. Interobserver agreement was calculated using the formula Agreements = (smallest number ÷ largest number) x 100.

Independent Variables

Equipment

The equipment necessary for the plyometric intervention included a yoga mat, a set of weighted balls, a step bench with two risers, and a set of cones. The therapist had a notebook with a description of the exercises (Appendix C), and an exercise log (Appendix D). The data collector had a checklist (Appendix E), a stop watch, and a counter.

Plyometric Exercise Training

The plyometric training treatment was developed using the National Strength and Conditioning Association (NSCA) guidelines. The guidelines of the NSCA are the result of a comprehensive literature review describing the risks, benefits, reported injuries, and recommendations for strength training in children and youth (Faigenbaum, et al., 2009b). The ACSM recommendations and the American Academy of Pediatrics (Behringer et al., 2011) recommendations for resistive training were also considered in the treatment design. Blocked periodization was used to vary the exercises and progress the exercise
load (Bingisser, 2005). The treatment sessions were carried out twice a week on non-consecutive days for up to 15 weeks. The plyometric training program consisted of 1 week to teach eight low intensity plyometric exercises, a 4-week block in which exercise load was gradually increased, 1 week in which 50% of the exercises were changed and four new moderate intensity plyometric exercises were taught, and a second 4-week block of training in which exercise load was increased. A third 4-week block of training was added if motor performance in the throw distance had not reached stability (zero trend and low variability over a minimum of three consecutive data points). Treatment ended when stability in the throw basketball power test was observed or at 15 weeks.

Each treatment session included a 5 min warm-up consisting of dynamic stretching exercises, administration of the power measures (throw basketball, broad jump, and vertical jump), eight plyometric exercises, and a 5 min cool down activity chosen by the child. The first exercise session of the week focused on developing horizontal power, and the second session of the week focused on developing vertical power. The plyometric training program consisted of one to three sets of five repetitions of four upper extremity and four lower extremity plyometric exercises. Lower extremity and upper extremity exercises were alternated and the child was given a 30 s to 2 min rest between each exercise set. The plyometric exercises were chosen dependent on the child’s goal, the impairments identified at the pre-treatment assessment, and the ability to perform the exercise with correct technique. The baseline number of repetitions was noted and the number of repetitions was gradually increased per patient capability to prevent post exercise soreness or injury. Exercise load was increased by asking the children to jump to cones that were placed farther apart or by adding an additional riser to the bench to
encourage the child to jump higher. Upper extremity exercise load was increased using graduated weighted balls or by asking the child to throw a longer distance.

The treatment sessions lasted between 30 and 50 min. The child had the opportunity to earn a small reward at the end of the week for completing the prescribed number of repetitions and following safety rules. The therapist recorded the warm-up activities, the eight plyometric exercises, the number of ground contact times or repetitions performed, the weights of the ball, the distance or height of jumps and throws, and the self-selected cool down activity on an exercise log. Training heart rate was determined by using the formula suggested by (Verschuren, Maltais, & Takken, 2011b) for children (194 - age x 0.65). The participants wore a Polar heart rate monitor each session. The training range was set at 110 to 156 beats per min and the participants were allowed to rest if the heart rate monitor beeped, indicating heart rate was above the training zone. The average heart rate, time in the training zone, above the training zone, and below the training zone was downloaded from the Polar heart rate monitor and recorded on the data sheet. Parents or grandparents were present for every exercise session.

**Assessing Treatment Integrity**

The data collector was a pre-physical therapy student trained by the researcher on operational definitions describing the intervention and data collection procedures. Training included watching a video of an exercise session and filling out an intervention checklist (Appendix E). The data collector and researcher compared responses after watching the video. Discussion between the researcher and data collector continued until the data collector achieved consensus with the researcher over three videotaped treatment
sessions. The data collector watched the intervention from the sideline and recorded information for the 14 items on the treatment integrity check list (Appendix E). Treatment integrity was calculated by dividing the number of items the independent observer recorded the researcher completing during the intervention by the total number possible on the checklist.

**Experimental Conditions**

**Experimental Design**

A multiple-baseline, multiple probe across participants design (Cooper, Heron, & Heward, 2007) was used to examine the effects of the plyometric training treatment on the gross motor abilities of children with unilateral spastic CP. This design is a variation of a multiple baseline design that is often used when participants are likely to be in baseline for extended periods of time creating problems of reactivity to measurement or issues related to practicality (Horner & Baer, 1978). In this study, conducting probes rather than continuous daily assessments in baseline provided a series of performance measurements prior to the introduction of the treatment while decreasing the likelihood that learning from repeated assessments would strengthen performance. The use of intermittent probe measures also eased the burden on families from having to bring children into the clinic for the daily measurements that would have been required in a traditional multiple baseline design.

**Pre-treatment Assessment**

Participants were recruited during the first three weeks of January 2012. All three participants received their pre-treatment assessment within a 2-week period. The
researcher performed the testing. Gross motor ability, agility, running speed, and power measurements were conducted prior to beginning the intervention in order to document baseline function and to account for any improvements that might occur from maturation (see description of assessments).

**Baseline Condition**

A baseline condition preceded plyometric training. The researcher conducted the baseline probes for participant one (P1) at the pre-assessment visit and twice a week until baseline data for throw distance was stable (no ascending trend) after a minimum of three consecutive data points. The probes were performed for participant two (P2) at the pre-assessment visit, when P1 began treatment, and twice a week after the effects of the intervention were observable for P1 until baseline data for throw distance was stable. The probes were performed for participant three (P3) at the pre-assessment, when P1 and P2 began treatment, when the effects of the intervention were evident for P2, and twice a week prior to beginning treatment until baseline data for throw distance was stable. The probe consisted of a 5 min warm up and administration of the power tests (throw basketball, vertical jump, and broad jump).

**Treatment Condition (Plyometric Training)**

Each participant began treatment according to the schedule outlined above. The power tests were conducted at the beginning of each session. Treatment was discontinued after there was stability (zero trend and low variability over a minimum of three consecutive data points) in throwing distance. Treatment ended at the end of 15 weeks, if stability was not achieved.
Post-treatment Assessments

Gross motor ability, agility, running speed, and power measurements were performed within 1 week of ending treatment and again 6 weeks after the end of treatment by the researcher (see description of assessments).
RESULTS

Participant characteristics are listed in Table 2. Descriptive statistics were used to describe changes in body structure due to maturation (Table 3), safety (Table 4), the pre-treatment, post-treatment, and follow up scores of gross motor ability (Table 5), agility, running speed and power tests (Table 6). Data from the best performance of two trials of the power tests and self-selected goal were used for data analysis (see Figures 1-4). The primary measure for determining stability in relation to the multiple probe, multiple baseline design was the throw basketball test. The broad jump, and vertical jump, tests were secondary measures. Visual analysis was used to analyze these data, given the weaknesses in the overlap methods (Wolery, Reichow, & Barton., 2010).

Table 2

*Participant Characteristics*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Sex</th>
<th>GMFCS level</th>
<th>MACS Level</th>
<th>Impairments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9+11 years</td>
<td>Male</td>
<td>I</td>
<td>I</td>
<td>R Unilateral CP, expressive language delay</td>
</tr>
<tr>
<td>2</td>
<td>10+0 years</td>
<td>Male</td>
<td>I</td>
<td>I</td>
<td>R Unilateral CP, expressive language Delay</td>
</tr>
<tr>
<td>3</td>
<td>8+9 years</td>
<td>Male</td>
<td>I</td>
<td>II</td>
<td>R Unilateral CP</td>
</tr>
</tbody>
</table>
Table 3

*Body Structure Characteristics*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Height in centimeters</th>
<th>Weight in kilograms</th>
<th>BMI%</th>
<th>CDC category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pretest</td>
<td>140</td>
<td>27</td>
<td>2</td>
<td>Underweight</td>
</tr>
<tr>
<td>Posttest</td>
<td>141.5</td>
<td>28</td>
<td>3</td>
<td>Underweight</td>
</tr>
<tr>
<td>Follow-up</td>
<td>141.5</td>
<td>29</td>
<td>8</td>
<td>Underweight</td>
</tr>
<tr>
<td>2 Pretest</td>
<td>152</td>
<td>54</td>
<td>96</td>
<td>Obese</td>
</tr>
<tr>
<td>Posttest</td>
<td>155</td>
<td>54</td>
<td>95</td>
<td>Obese</td>
</tr>
<tr>
<td>Follow-up</td>
<td>157</td>
<td>56</td>
<td>95</td>
<td>Obese</td>
</tr>
<tr>
<td>3 Pretest</td>
<td>140</td>
<td>26</td>
<td>1</td>
<td>Underweight</td>
</tr>
<tr>
<td>Posttest</td>
<td>140</td>
<td>26.5</td>
<td>2</td>
<td>Underweight</td>
</tr>
<tr>
<td>Follow-up</td>
<td>140</td>
<td>26</td>
<td>1</td>
<td>Underweight</td>
</tr>
</tbody>
</table>

**Interobserver Agreement, Treatment Integrity, Safety**

Interobserver agreement was assessed during 78% of the pre-post treatment assessments and was 99% for the 10x5 m sprint (98% - 100%), and 96% for the 20m running start sprint (95% - 99%). Interobserver agreement for the probes was assessed during 33% of sessions and was 98% (96% - 99%) for the throw basketball, 98% for the broad jump (96% - 100%), and 99% for the vertical jump (99% - 100%).

Treatment integrity was assessed during 29% of the sessions and was 97% (95% - 99%). Several safety measures were included on the treatment integrity checklist (see Appendix E for the checklist). The length of the session, training heart rate, number of ground contact times, number of throws, and falls or other safety events were recorded each session (Table 4). The length of session and training heart rates were within the NSCA guidelines. Ground contact times and throw repetitions followed guidelines for beginning with low repetitions and increasing repetitions gradually. P 2’s initial number
of repetitions was high since the exercises were too easy for him. The exercise difficulty was adjusted the second session for P2.

All three children fell during the treatment condition. There were two, four, and 18 falls for P1, P2, and P3, respectively. P3 was given a hiking stick to use to help maintain balance when hopping on his right leg because he was falling frequently. There were no falls after initiating use of the hiking stick. P3 had a scraped knee and a bump on the head from the 1-pound ball. He was able to resume exercise after a short break. The complaints of fatigue occurred prior to beginning the session, therefore were assumed to be related to being tired from a busy day at school.

Height and weight were measured and percent BMI was calculated at the initial visit (see Table 2). P1 and P3 were in the CDC underweight category, and P2 was in the

| Safety of repetitions was high since the exercises were too easy for him. The exercise difficulty was adjusted the second session for P2. All three children fell during the treatment condition. There were two, four, and 18 falls for P1, P2, and P3, respectively. P3 was given a hiking stick to use to help maintain balance when hopping on his right leg because he was falling frequently. There were no falls after initiating use of the hiking stick. P3 had a scraped knee and a bump on the head from the 1-pound ball. He was able to resume exercise after a short break. The complaints of fatigue occurred prior to beginning the session, therefore were assumed to be related to being tired from a busy day at school. Height and weight were measured and percent BMI was calculated at the initial visit (see Table 2). P1 and P3 were in the CDC underweight category, and P2 was in the | 27 |
obese category. Because the participants were not in the healthy weight category, the hospital nutritionist was consulted. P1 and P2 both grew during the treatment condition, P1 grew 1.5 cm in 8 weeks, and P2 grew 3 cm in 14 weeks. P2 visited with the nutritionist his first visit because his mother expressed interest in exercise combined with weight loss. He decreased his BMI 1% over the 23 sessions. P1 and P3 were at risk of losing weight from increasing physical activity level. Parents were counseled to increase calories during the training program. P1 increased his BMI from 1% to 8%. P3 increased his BMI from 1% to 2% during the training program.

**Outcomes**

**Change in Gross Motor Ability, Agility, Running Speed and Power**

**Gross Motor Ability (GMFM), Table 5.** All three participants demonstrated changes in the standing section D of the GMFM either at the posttest or 6-week follow-up test. The changes for P1 (2.53) and P3 (2.56) met the minimum clinically important difference (MCID) (Oeffinger et al., 2008) values for a medium ES. P2’s change of 5.13 met the MCID value for a large ES. No participant met MCID values for change in the walk, run, jump section of the GMFM (Section E). All three participants met the MCID values for a large ES in the overall gross motor ability score (GMFM 66). P1 had a 3.18 point increase, P2 had a 15.95 point increase, P3 had a 4.16 point increase. There is an 80% probability of GMFM 66 scores varying 20% in calculated percentile rank in a one year time period, and a 50% probability of scores varying 10.5% (Hanna, Bartlett, Rivard, & Russell, 2008). P2 (64.67%) exceeded a 20% change in a 14-week time
period. P1 (13.56%) and P3 (16.26%) exceeded the 10.5% change in 8 weeks and 9 weeks, respectively.

**Agility (10X5 m test), Table 6.** All three participants improved in agility from pre-test to post-test. P1 had a 0.85 second (9.6%) improvement, P2 had a 1.84 second (9.3%) improvement, and P3 had a 3.21 second (9.1%) improvement.

Table 5

**Gross Motor Ability Results**

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Time</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SCORE</td>
<td>CHANGE</td>
<td>SCORE</td>
</tr>
<tr>
<td>GMFM D</td>
<td>Pretest</td>
<td>92.34</td>
<td>94.87</td>
<td>94.87</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>94.87</td>
<td>*2.53</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>6-wk follow-up</td>
<td>92.31</td>
<td>^-2.56</td>
<td>100</td>
</tr>
<tr>
<td>GMFM E</td>
<td>Pretest</td>
<td>97.22</td>
<td>97.22</td>
<td>94.44</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>100</td>
<td>2.72</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>6-wk follow-up</td>
<td>98.61</td>
<td>^-1.39</td>
<td>100</td>
</tr>
<tr>
<td>GMFM 66</td>
<td>Pretest</td>
<td>86.52</td>
<td>84.05</td>
<td>85.62</td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>89.70</td>
<td>^3.18</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>6-wk follow-up</td>
<td>87.99</td>
<td>^-1.71</td>
<td>100</td>
</tr>
<tr>
<td>Percentile</td>
<td>Pretest</td>
<td>41.89</td>
<td>32.33</td>
<td>44.64</td>
</tr>
<tr>
<td>Rank</td>
<td>Posttest</td>
<td>55.45</td>
<td>13.56</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>6-wk follow-up</td>
<td>48.21</td>
<td>^-7.2</td>
<td>97</td>
</tr>
</tbody>
</table>

Change = Posttest – pretest; 6-week follow-up – posttest

The Gross Motor Function Measure (GMFM) section D, and E, are percent of total.
GMFM 66 scores = points possible out of 100.
The Percentile rank is compared to age and severity matched peers with CP.

Minimum clinically important difference (MCID) scores (Oeffinger et al., 2009)
GMFM Section D = ^2.14 medium effect size (ES), ^3.8 for large ES
GMFM Section E = *4 medium ES, ^6.5 large ES
GMFM66 = 1.7 medium ES, 2.7 Large ES)
### Table 6

**Agility, Running Speed and Power Test Results**

<table>
<thead>
<tr>
<th>Test</th>
<th>Test time</th>
<th>P1 Time</th>
<th>Change</th>
<th>% rank</th>
<th>P2 Time</th>
<th>Change</th>
<th>% rank</th>
<th>P3 Time</th>
<th>Change</th>
<th>% rank</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>23.41</td>
<td>26.38</td>
<td>25.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>22.56</td>
<td>-0.85</td>
<td>24.57</td>
<td>-1.81</td>
<td>22.92</td>
<td>-2.11</td>
<td>21.19</td>
<td>-1.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-week follow-up</td>
<td>24.40</td>
<td>1.84</td>
<td>23.65</td>
<td>-0.92</td>
<td>21.19</td>
<td>-1.73</td>
<td>22.92</td>
<td>-2.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Running speed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>4.60 (10%)</td>
<td>4.90 (&lt;10%)</td>
<td>4.23 (25%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>4.23 (25%)</td>
<td>-0.37 (15%)</td>
<td>4.65 (25%)</td>
<td>-0.25 (15%)</td>
<td>5.02 (15%)</td>
<td>0.79 (10%)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6-week follow-up</td>
<td>4.90 (&lt;10%)</td>
<td>0.67 (-15%)</td>
<td>5.3 (&lt;10%)</td>
<td>0.65 (-15%)</td>
<td>4.90 (&lt;10%)</td>
<td>-0.12 (-5%)</td>
<td></td>
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</tr>
<tr>
<td><strong>Power Throw</strong></td>
<td>basketball test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>25%</td>
<td>30%</td>
<td>&lt;10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>55%</td>
<td>30%</td>
<td>40%</td>
<td>10%</td>
<td>&lt;10%</td>
<td>0</td>
<td></td>
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<tr>
<td>6-week follow-up</td>
<td>75%</td>
<td>20%</td>
<td>25%</td>
<td>-15%</td>
<td>&lt;10%</td>
<td>0</td>
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<tr>
<td><strong>Power broad</strong></td>
<td>jump test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pretest</td>
<td>&lt;10%</td>
<td>&lt;10%</td>
<td>&lt;10%</td>
<td>45%</td>
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<td></td>
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<tr>
<td>Posttest</td>
<td>&lt;10%</td>
<td>0</td>
<td>&lt;10%</td>
<td>0</td>
<td>70%</td>
<td>25%</td>
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<td></td>
<td></td>
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<tr>
<td>6-week follow-up</td>
<td>&lt;10%</td>
<td>0</td>
<td>&lt;10%</td>
<td>0</td>
<td>60%</td>
<td>-10%</td>
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<tr>
<td><strong>Power vertical</strong></td>
<td>jump test</td>
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<td></td>
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<tr>
<td>Pretest</td>
<td>80%</td>
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<td>20%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Posttest</td>
<td>50%</td>
<td>-30%</td>
<td>25%</td>
<td>15%</td>
<td>50%</td>
<td>30%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-week follow-up</td>
<td>60%</td>
<td>10%</td>
<td>20%</td>
<td>-5%</td>
<td>40%</td>
<td>-10%</td>
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</tbody>
</table>

Agility = time in seconds (sec) for the 10X5 m agility test  
Running speed = time in seconds (sec) for the 20 m running start sprint
Running speed (20 m running start sprint), Table 6. P1 and P2 improved in the 20 m sprint test from pretest to posttest. P1 had a 0.23 s improvement, P2 had a 0.25 s improvement and P3 had a 0.79 s decline.

Throw basketball. All three participants demonstrated a low level of throwing distance in baseline. P1 and P2’s baseline throw distances were variable, and P3’s was stable. P1 demonstrated a zero trend, P2 a gradual descending trend, and P3 a zero trend.

Figure 1. Graph of the throw basketball distance measured in centimeters. Measurements were conducted each baseline, treatment, and follow up session for participants 1, 2, and 3.
Introduction of the treatment for P1 and P2 resulted in a low level, variable response initially, followed by a gradual and variable ascending trend with stability at the end of treatment. Introduction of the treatment for P3 resulted in an extremely variable response rate with a zero trend, followed by stability which ended treatment. Treatment increased the throw distance for P1 and P2.

**Broad jump.** P1 and P2’s baseline broad jump distance were extremely variable with a zero trend. P3 had a low variable baseline with a zero trend. Introduction of the

*Figure 2.* Graph of the broad jump distance measured in centimeters. Measurements were conducted each baseline, treatment, and follow up session for participants 1, 2, and 3.
treatment for P1 and P3 resulted in a low variable response rate and a medium level variable response rate for P2. There were gradually increasing trends for all three participants that were highly variable. Broad jump distance did not reach stability for any of the participants; P3 had a stable response rate in the last two sessions. Treatment increased the broad jump distance for all three participants.

**Vertical jump.** P1 had a high level gradual decline in vertical jump height in baseline. P2’s vertical jump height was extremely variable with a zero trend and P3 had a

![Graph of the vertical jump height measured in centimeters.](image)

*Figure 3.* Graph of the vertical jump height measured in centimeters. Measurements were conducted each baseline, treatment, and follow up session for participants 1, 2, and 3. P3 had extremely variable times at the beginning with a gradually declining trend in response times at the end of treatment.
low level stable vertical jump height with a gradually ascending trend. Introduction of
the treatment for P1 and P2 resulted in a high level jump height with moderate variability.
P1’s vertical jump distance resulted in a gradual but variable decreasing trend in response
to treatment. P2’s jump height was at a high variable level, with an increase at the end of
treatment. P3’s jump height was extremely variable with a zero trend in response to
treatment. The participants did not achieve stability in vertical jump height by the end of
treatment; however P2’s responses were stable in the last two sessions. Treatment
increased the vertical jump height for P2 and P3.

**Self-selected goal.** P1 and P3 both wanted to play soccer and chose to improve
soccer dribbling. They were timed while dribbling a soccer ball with both feet through a
set of six cones, placed six steps apart. Decreasing times indicate improvement. P1’s
time decreased at the beginning of treatment, and had a low level variable time in
response to practicing dribbling drills. He had two stable responses in the last two
sessions.

P2 chose to learn Tae Kwon Do. He was taught basic kicks, punches, blocks, and
stances and performed a series of techniques that increased in difficulty over the duration
of treatment. He was judged on a 3-point scale developed by the researcher on stance,
punch, block, kick, and body position during the technique drills. He received one point
for having correct body and limb position, one point for avoiding excessive side-to-side
movement, and one point for performing the series of techniques without verbal prompts.
Increasing scores or stable scores with more difficult moves indicate improvement.
These responses ascended quickly in the first 3 weeks followed by a high level, variable
response rate, and finally, a high level stable response rate by the end of treatment.
Figure 4. Graph of the self-selected goal performance. The time measured in seconds each treatment session for dribbling a soccer ball through three cones for participants 1, and 3. Decreasing times indicate improvement. The quality score rating participant 2 received each treatment session when performing a Tae Kwon Do routine. Increasing scores indicate improvement.

**Duration**

P1 reached stability in the throw basketball test in seven sessions (3.5 weeks). Further gains occurred in the second block until stability was achieved on the 16th session.
(8 weeks). P2 approached stability in seven sessions (3.5 weeks) and made further gains in throwing distance the second and third blocks until the 23rd session (14 weeks). P2 missed five sessions due to personal reasons during weeks 10, 11, and 12. P3 did not make gains in throwing distance during treatment and reached stability the 19th session (9.5 weeks).

**Maintenance**

P1’s throw distance, broad jump distance, and vertical jump height increased at the 6-week follow-up. P2’s and P3’s throw distance, broad jump distance, and vertical jump height decreased slightly. P1’s agility time, running speed time, and GMFM 66 score declined slightly at follow-up. P2’s agility time increased, running speed time decreased and GMFM 66 score stayed the same. P3’s agility time increased, running speed time increased, and GMFM 66 score stayed the same at follow-up.
DISCUSSION

The first purpose of the study was to evaluate the effectiveness of treatment on improving motor abilities. The four results that were replicated among participants were (a) an improvement in GMFM 66 scores from pretest to posttest; (b) a decrease in agility times (improvement) from pretest to posttest, (c) an improvement in broad jump distance with treatment; and (d) an improvement in consistency of performance of throwing distance, broad jump distance, and vertical jump height with treatment.

Plyometric training resulted in medium to large changes in gross motor ability reflected in GMFM 66 score increases. The changes for two participants met the MCID scores for a large ES of 2.7 (Oeffinger et al., 2008). The changes for the other participant met the MCID score for a medium ES of 1.7. It appears that improvement in section D accounted for the change, since section D showed greater changes than section E. However, two of the participants scored 100% on section E. Thus, it seems that the lack of change may be attributable to a ceiling effect on the test. All three participants improved compared to age and severity-matched peers with CP by increasing their percentile points 13.56% for P1, 64.67% for P2, and 16.26% for P3. P2’s percentile point change was greater than 20%, indicating the change was greater than that made by 80% of his peers with CP between two assessments (Hanna et al., 2008).

The participants also demonstrated changes in agility with improvement in times of 9.6%, 9.3%, and 9.1%. Verschuren et al. (2010) published figures representing the 3rd, 25th, 50th, 75th and 97th percentile curves for children with CP by severity, gender, and height for the 10X5 m agility test. P1 and P3’s agility scores fell between the 75th and 97th percentile and P2’s between the 50th and 75th percentile at the pre- and post-treatment
assessment. However, since Verschuren et al. (2010) did not report actual values, it is not possible to determine improvement in percentile point change. Meylan and Malatesta, (2009) found a statistically significant improvement of 9.6% in an agility test in a group of typically developing 13-year-old boys who participated in an 8-week plyometric training program. The improvement in agility test times for the participants in this study (9.6%, 9.3%, and 9.1%) were similar to those reported in typically developing children.

The greatest amount of information about the effect of the plyometric training program was gathered from monitoring the participants’ responses to the power tests. The single subject design allowed flexibility to extend the intervention until throw distance plateaued, described the trajectory of change in the dependent variables that cannot be observed in before/after snapshots, and revealed the intra and inter-individual differences in variability of performance. Improvement was not linear for the three participants during treatment and alternated between showing ascending, descending or zero trends and varying amounts of session to session variability. When extreme variability was present in baseline, the introduction of treatment resulted in participants becoming more consistent in achieving their best baseline performance. For example, P1 had 25 cm variation in broad jump distance during baseline that was reduced to 3 cm during sessions 5 through 10. His highest jump distance in baseline was 104 cm and he achieved 101 cm during sessions 5 through 10 of the treatment condition. This finding was replicated in P2’s broad jump distance, P1’s vertical jump height, and P2’s vertical jump height. When performance had low variability in baseline, improvements in distance or height were observed. For example, P1’s highest throw distance was 404 cm
in baseline and increased to 545 cm during treatment. This finding was replicated in P2’s throw distance, P3’s broad jump distance, and P3’s vertical jump distance. A similar pattern of decreasing behavioral variability in throwing and jumping distance was seen during a plyometric training program for children with Neurofibromatosis Type 1 (Johnson, Salzberg, & Stevenson, 2012) where gains in consistency were seen prior to gains in distance.

The only parameter measured that did not change was P3’s throw distance. He had a very stable baseline measurement which showed a minimal response to treatment. Early brain lesions, like those in the three participants in this study, produce stereotypic movement patterns that can hinder the development of purposeful functional actions. The movement patterns that children with brain lesions produce may be atypical, but the most functional pattern for them. Hadders-Algra (2010) suggested that reduction in the variation of motor behavior (stereotypic behaviors) is likely to persist for the child with an early brain lesion and is unlikely to change with therapy. The benefits from therapy come from helping the child choose the best strategy to meet the demands of a variety of tasks. P3 had a more severe MACS classification and may not have had the same capacity as P1 and P2 for making gains in throw distance. Despite having very little improvement in throw distance, variability increased. Behavioral variability is defined by Dusing and Harbourne (2010) as a “general measure of the variety of different ways a task is completed and can be observed.” The ability to choose a motor strategy that fits the situation best is described by the general concept of adaptability (Dusing & Harbourne, 2010). Flexibility is increased by having a variety of strategies available to accomplish the same task under differing environmental conditions (adaptability).
However too much or too little variability impairs performance and can result in falls, missed targets, or failures to achieve desired outcomes (atypical variability). P3 also had the most falls during treatment. Children may persist with movements they have mastered in one context, even though they may not be functional for the new task. This lack of adaptability can result in atypical variability, either excessive or rigid variability (Fetters, 2010). Increased variability in throwing distance for P3 may indicate that he went from a very rigid performance to having more variability and adaptability. The plyometric training program provided a lot of practice (between 105 to 120 throws and 140 to 174 jumps per session), which encourages improved consistency in performance. The program also included a variety of throws and jumps, which provides the opportunity to learn a variety of strategies to address poor adaptability. The participants were allowed to try different strategies for the jumps and throws. For example, all three participants had difficulty doing the plyometric push up. All three were asked to come up with a way they could do the exercise. Suggestions were made to make it easier, like doing pushups with their hands on a picnic bench instead of on the ground. P1 did the push up on the bench; P2 came up with the idea of doing the push up on a small hill with his feet on the downhill side; P3 spread his feet wide and had me block his right foot with my foot for additional support. The participants were also asked to evaluate their performance, and prompted to come up with strategies to improve their performance. P3 rarely threw the ball straight. I asked him if he was letting go of the ball too soon, or too late. He tried letting go both too soon and too late. He saw the response and was soon able to identify what he was doing wrong and tried to correct his response. Feedback was rarely needed towards the end of treatment since the children were evaluating their own
performance and making changes independently. For instance, P2 said “I’m too close to the bench and I keep catching my toe when I jump. I’ll move back.” The amount of practice, the variety of activities, the amount of feedback, and the type of feedback may have all led to decreased variability and improved adaptability.

The gains in agility, running speed, and in the power tests may have been attributed to growth. Philippaerts et al. (2006) reported a relationship between growth and improvement in motor ability and fitness. These researchers followed a group of 10- to 13-year old soccer players over a 5-year period and reported that peak height and weight velocity (rapid growth) occurred at the same time as peaks in balance, running speed, agility, strength, power, and anaerobic capacity. Since two of the participants grew during treatment and follow-up, height and weight gains may have contributed to their improvements.

The second purpose of the study was to determine an optimum duration of training. The duration of plyometric training was 8 weeks for P1, 14 weeks for P2, and 9 weeks for P3. Improvement was made in the first block of treatment, sometimes as early as 2.5 weeks. There was no further benefit from extending treatment by adding a second block if gains had not occurred or if performance approached stability (P3’s throw, P1 and P2’s broad jump, P1 and P2’s vertical jump). However, when there had been continuous improvement in the first block, participants continued to make gains in the second block and approached stability by 8 weeks (P1 and P2’s throw, P3’s broad jump, and P3’s vertical jump). A third block was added for P2 in order to achieve stability in throw distance and may have been necessary because of missed sessions. The NSCA guidelines for resistive exercise in children recommend training for a minimum of eight
weeks. Our results suggest training should be a minimum of 5 weeks, with a second 5 weeks added if participants show continuous improvement. A third block may be necessary if motor performance does not approach stability. In sum, it is our recommendation that duration of treatment be determined individually based on session to session performance monitoring.

The final purpose of the study was to evaluate whether participants maintained the benefits gained after training was discontinued. The only consistent finding at the 6-week follow-up was a decline in running speed for all three participants suggesting speed related performance required ongoing training to be maintained. Responses were varied between and within participants and measures. Participants demonstrated slight declines or they maintained their performance at the 6-week follow-up. Their performance may have been within the variability observed during treatment; however, more than two post-test measurements would be necessary to determine this.
SUMMARY

Plyometric training resulted in improvements in GMFM 66 scores, agility, and broad jump distance for all three participants. Growth may have contributed to improvements and should be considered when interpreting outcomes in children. A pattern of improving consistency prior to making gains in distance or height was observed suggesting that measuring variability is important when evaluating the effectiveness of treatment. The time it took children to reach stability in performance differed between tasks and between children for the same task. There was no further benefit from extending treatment if gains had not occurred or if performance approached stability in the first five-week block. However, when there was continuous improvement in the first block, participants approached stability by 8 to 9 weeks when treatment was extended. Duration of training is likely dependent on the capacity of the child and the outcome measure chosen. Missed sessions may increase the duration of the training program. Duration was in line with the NSCA guidelines, given that continuous improvement was noticed in the first 5-week block, and adequate intensity, volume, frequency, variety, and a method for increasing exercise load are incorporated into treatment. The neuromuscular capacity of the child for change may also be an important consideration.

The three participants declined in running speed at the 6-week follow-up suggesting speed required ongoing training to be maintained. There were intra-and inter-participant differences at the 6-week follow-up in gross motor ability, agility, and the power tests. The slight declines or maintenance of performance may have been within
the variability that was observed during treatment. More frequent measurements would be necessary to make judgments about the maintenance of motor performance.
REFERENCES


APPENDICES
Appendix A
Assessment Data Sheet
### Assessment Data Sheet

**Study number:**

**Parent’s names:**

**Phone Number:** (Home)______________ (work)______________ (cell)______________

**Gross Motor Function Classification level**

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Appendix B
Gross Motor Function Score Sheet
Appendix B

GMFM SCORE SHEET
©Mac Keith Press, 2002

Item

D: STANDING SCORE NT

* 52. ON THE FLOOR: PULLS TO STD AT LARGE BENCH 0 1 2 3
* 53. STD: MAINTAINS, ARMS FREE, 3 SECONDS 0 1 2 3
* 54. STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS R FOOT, 3 SECONDS 0 1 2 3
* 55. STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS L FOOT, 3 SECONDS 0 1 2 3
* 56. STD: MAINTAINS, ARMS FREE, 20 SECONDS 0 1 2 3
* 57. STD: LIFTS L FOOT, ARMS FREE, 10 SECONDS 0 1 2 3
* 58. STD: LIFTS R FOOT, ARMS FREE, 10 SECONDS 0 1 2 3
* 59. SIT ON SMALL BENCH: ATTAINS STD WITHOUT USING ARMS 0 1 2 3
* 60. HIGH KN: ATTAINS STD THROUGH HALF KN ON R KNEE, WITHOUT USING ARMS 0 1 2 3
* 61. HIGH KN: ATTAINS STD THROUGH HALF KN ON L KNEE, WITHOUT USING ARMS 0 1 2 3
* 62. STD: LOWERS TO SIT ON FLOOR WITH CONTROL, ARMS FREE 0 1 2 3
* 63. STD: ATTAINS SQUAT, ARMS FREE 0 1 2 3
* 64. STD: PICKS UP OBJECT FROM FLOOR, ARMS FREE, RETURNS TO STAND 0 1 2 3

TOTAL DIMENSION D

Item E: WALKING, RUNNING & JUMPING SCORE NT

* 65. STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO R 0 1 2 3
* 66. STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO L 0 1 2 3
* 67. STD, 2 HANDS HELD: WALKS FORWARD 10 STEPS 0 1 2 3
* 68. STD, 1 HAND HELD: WALKS FORWARD 10 STEPS 0 1 2 3
* 69. STD: WALKS FORWARD 10 STEPS 0 1 2 3
* 70. STD: WALKS FORWARD 10 STEPS, STOPS, TURNS 180°, RETURNS 0 1 2 3
* 71. STD: WALKS BACKWARD 10 STEPS 0 1 2 3
* 72. STD: WALKS FORWARD 10 STEPS, CARRYING A LARGE OBJECT WITH 2 HANDS 0 1 2 3
* 73. STD: WALKS FORWARD 10 CONSECUTIVE STEPS BETWEEN PARALLEL LINES 20cm (8") 0 1 2 3
* 74. STD: WALKS FORWARD 10 CONSECUTIVE STEPS ON A STRAIGHT LINE 2cm (3/4") 0 1 2 3
* 75. STD: STEPS OVER STICK AT KNEE LEVEL, R FOOT LEADING 0 1 2 3
* 76. STD: STEPS OVER STICK AT KNEE LEVEL, L FOOT LEADING 0 1 2 3
* 77. STD: RUNS 4.5m (15’), STOPS & RETURNS 0 1 2 3
* 78. STD: KICKS BALL WITH R FOOT 0 1 2 3
* 79. STD: KICKS BALL WITH L FOOT 0 1 2 3
* 80. STD: JUMPS 30cm (12") HIGH, BOTH FEET SIMULTANEOUSLY 0 1 2 3
* 81. STD: JUMPS FORWARD 30 cm (12”), BOTH FEET SIMULTANEOUSLY 0 1 2 3
* 82. STD ON R FOOT: HOPS ON R FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE 0 1 2 3
* 83. STD ON L FOOT: HOPS ON L FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE 0 1 2 3
* 84. STD, HOLDING 1 RAIL: WALKS UP 4 STEPS, HOLDING 1 RAIL, ALTERNATING 0 1 2 3
* 85. STD, HOLDING 1 RAIL: WALKS DOWN 4 STEPS, HOLDING 1 RAIL, ALTERNATING 0 1 2 3
* 86. STD: WALKS UP 4 STEPS, ALTERNATING FEET 0 1 2 3
* 87. STD: WALKS DOWN 4 STEPS, ALTERNATING FEET 0 1 2 3
* 88. STD ON 15cm (6") STEP: JUMPS OFF, BOTH FEET SIMULTANEOUSLY 0 1 2 3

TOTAL DIMENSION E

Was this assessment indicative of this child’s “regular” performance?  YES/ NO

GMFM-66 Gross Motor Ability Estimator Score (from the Gross Motor Ability Estimator (GMAE) Software)
Appendix C
Plyometric Exercise Description
Appendix C

Lower Extremity Exercises

*Horizontal Emphasis*

- **Bounding** - Moving forward foot to foot in an exaggerated running motion.
- **Forward jumps** – Perform one forward jump with maximum effort. Mark the starting and stopping position with cones. Swing arms and perform a two footed jump forward as far as possible. Attempt to perform consecutive jumps forward between cones without pausing.
- **Forward hop** – Perform one forward hop with maximum effort. Mark the starting and landing position with cones. Hop forward as far as possible between cones. Attempt to perform consecutive hops forward between cones without pausing.
  Repeat on opposite foot.
- **Counter jumps** – Place hands on hips and jump with two feet side to side between 2 cones. Set the cones as far apart as possible. Attempt to perform consecutive jumps without pausing. Counter jumps can be performed side to side, forward and back, or in a square pattern.
- **Lateral leaps** – Stand facing sideways to the direction you want to move. Stretch one leg out to the side and hop off the other foot in a sideways motion. Attempt to leap to the side as far as possible landing on one foot.
  Repeat the lateral leap without pausing.
- **Jumping in a square pattern** – Hands on hips. Jump forward, to the left, backwards, and to the right. Attempt to perform consecutive jumps without pausing.
• Counter hops – Hands on hips, stand on 1 leg and hop side to side. Attempt to perform consecutive hops without pausing. Repeat on opposite foot.

*Vertical Emphasis*

• Stride jump - Hands on hips, start in stride stance. Alternate forward foot in between jumps. Attempt to perform consecutive jumps without pausing. Squat jump – Squat down until your thighs are parallel to the floor and touch the floor with your hands, spring up vertically driving your arms up as high as possible. Attempt to perform consecutive squat jumps without pausing. Hold a weighted ball to increase difficulty.

• Tuck jumps – Jump up bringing knees toward chest. Attempt to perform consecutive tuck jumps without pausing.

• Hurdle jump – Two footed jump forward over an ankle high hurdle. Attempt to perform consecutive jumps over hurdles without pausing. Hurdle height can be increased to shin or knee depending on the capability of the participant.

• Step jumps – Stand facing the step. Jump up onto a step, jump down, repeat. Attempt to perform consecutive jumps without pausing.

• Step hops – Stand facing the step. Hop up onto a step, hop down, repeat. Attempt to perform consecutive hops without pausing.

• Lateral step jumps – Stand parallel to the step. Jump sideways onto the step, land on top of the step, and jump off the other side without pausing. Attempt to perform consecutive lateral jumps back and forth across the step without pausing.
- Lateral step hops – Stand parallel to the step. Hop sideways onto the step, land on top of the step, and hop off the other side landing on the opposite leg. Attempt to perform consecutive lateral hops back and forth across the step without pausing.

Upper Extremity Exercises

*Horizontal Emphasis*

- Chest throw – Stand opposite a partner and hold the ball against the chest with arms flexed. Throw the ball forward forcefully to the partner. Have the partner toss the ball back to you. Catch the ball and attempt to release it quickly without pausing.

- Side throw – Stand with your side to a partner. Hold the ball with both hands at shoulder level with arms completely extended. Keep elbows straight and twist away from the partner. Twist quickly toward the partner releasing the ball and throwing it as far as possible. Have partner toss the ball back and repeat the side throw without pausing.

- Shot put – Hold the ball with one hand with the ball resting at your shoulder. Extend the opposite arm with the elbow extended at shoulder level. Push the ball forward and attempt to push it as hard as possible. Have the partner catch the ball and throw it back. Repeat throws with correct technique and trying to release the ball as quick as possible.

- Soccer throw in – Stand with feet hip width apart and holding ball with both hands over head. Bend backwards then forcefully throw the ball forward as far as possible to a partner. Catch the ball as your partner tosses the ball back and repeat the soccer throw in.
• Bench Pushup – Have the participant assume the push up position with hands on the step bench. Have the participant flex elbows to 90 degrees and then push up as hard as possible lifting the hands from the step. Catch self on hands and repeat the push up as fast as possible. This exercise can be made easier by having the participant stand and placing feet about two feet from wall.

_Verical Emphasis_

• Double arm overhead throw – Stand with feet hip width apart and hold the ball with two hands near the chest. Extend the arms upwards and attempt to throw the ball as high as possible. Catch the ball or have a partner catch the ball. Attempt to perform consecutive catches without pausing or dropping the ball.

• Single arm overhead throw – Stand with feet hip width apart and place the ball at the side of one foot. Squat down and grasp the ball. Explode upward throwing the ball overhead with one arm. Catch the ball with two hands or have a partner catch the ball, transfer the ball to the same hand and repeat. Repeat with the opposite arm.

• Over back toss – Stand with feet hip width apart holding ball with arms extended straight out at shoulder level. Squat forward slightly bringing ball down, then extend knees and arms overhead tossing the ball to the partner behind you. Have partner toss the ball back to you, repeating the backward toss.

• Basketball shot – The participant will hold the ball with one hand with the ball resting on the shoulder. Push the ball up by extending the elbow and flexing the wrist similar to a basketball shot. Attempt to push the ball up as high as possible. Catch the ball or have the partner catch the ball and throw it back. Repeat throws
trying to release the ball as quick as possible using correct technique. Repeat with
the opposite arm.

- **Woodchopper** – Stand with feet hip width apart and holding ball at shoulder level
  with arms extended. Reach the ball down towards one foot, extend arms over the
  opposite shoulder throwing the ball as far as possible to a partner. Catch the ball
  as your partner tosses the ball back and repeat the throw.

The exercise descriptions were adapted from the following sources:
advisor.com/plyometricexercises.html](http://www.sport-fitness-advisor.com/plyometricexercises.html)

Monterey, CA: Healthy Learning.

Appendix D
Exercise Log
Appendix D

Exercise Log

Start time: | End Time: | Participant number: | Date: | Week: | Session One Emphasis: Horizontal power
Warm up:

Ball Throw Distance Trial 1 | Trial 2 | Broad Jump Distance Trial 1 | Trial 2
Goal Trial 1 | Trial 2 | Vertical Jump Distance Trial 1 | Trial 2

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<tr>
<td>Forward hops to cone</td>
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Cool Down: _____________________________________________________________

Total Jumps: | Total Throws: | HR: |

Start time: | End Time: | Date: | Week: | Session Two Emphasis: Vertical power
Warm up:

Ball Throw Distance Trial 1 | Trial 2 | Broad Jump Distance Trial 1 | Trial 2
Goal Trial 1 | Trial 2 | Vertical Jump Distance Trial 1 | Trial 2

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Cool Down: _____________________________________________________________

Total Jumps: | Total Throws: | HR: |

Technique Scale: 1 point for each component, upright posture, avoiding excessive side to side movement, correct body alignment, soft landing, instant recoil for next jump. 5 possible points
Appendix E
Treatment Fidelity Checklist
### Appendix E

**Treatment Integrity**

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<td>, trial 2</td>
<td></td>
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<table>
<thead>
<tr>
<th>Vertical jump trial</th>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>, trial 2</td>
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<table>
<thead>
<tr>
<th>Broad jump trial</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>, trial 2</td>
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<table>
<thead>
<tr>
<th>Individual goal trial</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>, trial 2</td>
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</table>

Appropriate focus for the session (vertical or horizontal power)

<table>
<thead>
<tr>
<th>Four upper extremity exercises performed</th>
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<tbody>
<tr>
<td># of exercises</td>
<td></td>
<td></td>
</tr>
<tr>
<td>, Total # of reps</td>
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<table>
<thead>
<tr>
<th>Four lower extremity exercises performed</th>
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<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>, Total # of reps</td>
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Therapist assured correct technique and appropriate feedback

<table>
<thead>
<tr>
<th>Each exercise lasts</th>
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<tbody>
<tr>
<td>10 to 15 seconds (+ or -)</td>
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<table>
<thead>
<tr>
<th>30 to 90 second rest between lower extremity exercises (+ or -)</th>
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</table>

<table>
<thead>
<tr>
<th>30 to 90 second rest between upper extremity exercises (+ or -)</th>
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<th></th>
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</table>

Exercise load increased appropriately (+ or -)

<table>
<thead>
<tr>
<th>Increase in number of repetitions, weight, distance or height</th>
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</thead>
</table>

Therapist was able to facilitate the child’s best effort (+ or -)

Warm up and cool down performed (+ or -)

Concerns reported: 0= no concern, 1= sprain/strain, 2=muscle soreness, 3= safety concern, 4=fatigue, 5= injury, 6= fall

<table>
<thead>
<tr>
<th>Start time</th>
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<table>
<thead>
<tr>
<th>End time</th>
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<table>
<thead>
<tr>
<th>Total length of session</th>
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CURRICULUM VITAE

Barbara A. Johnson, PT, MSPH

Current Position

2000-present    Shriners’ Hospital    Salt Lake City, UT
Physical Therapist
Clinician in the movement analysis laboratory performing comprehensive assessments including physical examination, functional assessment, split view videography, kinematic and kinetic analyses of gait, surface and fine wire EMG during gait and energy expenditure. Data collection and study coordinator for several research studies on children with orthopedic impairments and children with neuro-developmental disabilities.

2003 – 2009    University of Utah    Salt Lake City, UT
Clinical faculty in the physical therapy program. Responsible for teaching Physical Therapy 7250 management of the pediatric patient.

Experience

Previous positions at Jordan school district, in pediatric private practice, and at Children with Special Health Care Needs program performing evaluations, providing recommendations, and physical therapy treatment of children with disabilities birth to 21.

Education

1975–1980    University of Utah    Salt Lake City, UT
B.S., Major Physical therapy.

2005-2007    Walden University
Master of Science in Public Health

2008-2012    Utah State University Logan, UT
Doctoral student in the Disability Studies PhD program

Professional

2. Member Gait & Clinical Motion Analysis Society
3. Doctoral student representative USU, Special Education & Rehabilitation
4. Development of motor training program, Early Intervention Credential for the Baby Watch Early Intervention Program.
6. Participated in the Utah Leadership Education in Neurodevelopmental
Disabilities grant as a trainee during 2003.
7. Presentation at the November 2003 Clinical Instructors Symposium “Predicting outcomes in ambulatory cerebral palsy: The intersection of gait laboratory data and published research”
10. Presentation at the UT Chapter of the American Physical Therapy Association December 2003 “Physical Therapy for Children with Cerebral Palsy” Predicting outcomes in ambulatory cerebral palsy: The intersection of gait laboratory data and published research”
11. Presentation at the Gait and Clinical Movement Analysis Society April 2004 “Predicting outcomes in ambulatory cerebral palsy: The intersection of gait laboratory data and published research”
16. Lecturer Pediatric Rehabilitation 7250, University of Utah Physical Therapy, 2010.
20. Research Committee liaison to UPTA for Pediatric Special Interest Group 2011.
21. Discussion Forum Manager UPTA Pediatric Special Interest Group (2 year term, elected 10/12).

Publications


**Research**

**Ongoing Research Support:**

02830-3    Stevenson (PI)    1/2010-1/13
Effects of Physical Training on Bone Architecture, Muscle Strength, and Motor Coordination in Children with Neurofibromatosis Type 1
This study is a randomized control trial to evaluate the effects of a physical therapy intervention in children with neurofibromatosis type 1 (NF1).
Role: Co-investigator

4145    Johnson (PI)    1/2012-12/13
Evaluation of the optimum duration and effectiveness of a plyometric training program for improving the motor abilities of youth with cerebral palsy.
This study utilizes a single subject research design to evaluate the effects of a plyometric training program in children with unilateral spastic
cerebral palsy.
Role: Primary investigator

**Completed Support**
Nicholson, (PI) 01/01/2008 - 12/31/2011
Shriners Hospitals for Children
A Multi-center Project: FARG II- A Cross-sectional and Longitudinal Study of Strength, Body composition and Outcome Assessments in ambulatory children with Cerebral Palsy
Role: Coordinator 2008-2010, co-investigator 2010-2011