EFFECT OF TASK-ORIENTED CIRCUIT TRAINING ON GAIT KINEMATICS, PELVIC SYMMETRY AND ENDURANCE IN CHILDREN WITH HEMIPLEGIA

BY

Mohamed Salah El-Sayed Awad

M.Sc. in Physical Therapy, Cairo University, 2018

Submitted in Partial Fulfillment of the Requirements for Doctoral

Degree in the Department of Physical Therapy for Pediatrics

Faculty of Physical Therapy

Cairo University

2020

CHAPTER I

INTRODUCTION

Cerebral Palsy (CP) is a collection of motor disorders resulting from damage to brain that occurs before, during, or after birth. The damage to the child's brain affects motor system, and as a result the child has poor coordination, poor balance, or abnormal movement patterns or a combination of these characteristics **(Miller and Bachrach, 2017).**

Cerebral palsy is a disease characterized by gait abnormalities because of spasticity, and impaired movement, which is the most common cause of physical impairment in children **(Yu Y et al., 2019)**. According to **McKinnon et al. (2019)**, about 2.1 of 1000 births will have CP, while the prevalence in young people is as high as 74%**.**

Children with CP have difficulties in functional activities, which severely affect the children’s quality of life **(Pinto et al., 2018).** Impaired trunk control, pelvic asymmetry, balance, and gait asymmetry are some of the common impairments in children with CP **(Niklasch et al., 2015).**

The pelvis acts as a base in the sitting position and as a connecting link between the trunk and lower limbs while standing. It is proved that pelvic asymmetry is a common impairment in children with CP who often show weakened trunk control, which can, in turn, affect their daily functional tasks including reaching, sitting and walking. **(Niklasch et al., 2015).**

Children with hemiplegic CP have a tendency to develop impaired coordination of movement, diminished between limb synchronization, and less weight bearing on the involved side which sequentially can influence the capacity to keep an upright weight bearing position, as well as gait **(Woollacott and Cook, 2005).** They also have limited movement patterns that lead to decreased strength and endurance of the main muscle groups later in life Moreover, as children with hemiplegia have motor disabilities in one-half of the body, they present with limited postural adjustment of the lower extremities in specific external disturbances **(Blundell et al., 2003).**

Children with hemiplegic CP with level I and II GMFCS had poor core stability represented by weakness of frontal and dorsal trunk muscles. So, the ambulant hemiplegic CP still need training programs with more concentration on trunk muscles as well as extremities **(Sediek et al., 2016).**

Hemiplegic gait is characterized by asymmetry, decreased step and stride length, short stance phase on the affected side and slower walking speed **(Wang and Wang, 2012).** The development of trunk imbalance alongside the related pelvic obliquity, asymmetric weight bearing and increased postural sway can influence both standing balance and walking ability. Therefore, these children have malfunctioning movement patterns which bring about much waste of energy **(Tsirikos and Spielmann, 2007).**

Spasticity and weakness might be associated with the same affected muscle(s) in children with spastic CP **(Wiley and Damiano, 1998)**. Though various therapeutic approaches have been used to treat spasticity and muscle weakness, functional (goal) oriented exercises carried out in a circuit regimen is reported to be a promising intervention to improve muscle strength without aggravating aberrant motor control (spasticity) **(Kim and Lee, 2013).**

Task-oriented circuit training is an overall physical conditioning method in which a child with CP works out through a chain of exercise stations designed to improve muscle strength and endurance, and prevent somatic dysfunction associated with lack of mobility **(Scholtes et al., 2008).** Exercises are performed in short intervals of maximum intensity with only short breaks in between. In healthy individuals it leads to similar aerobic gains and improved anaerobic capacity in only a fraction of the time compared to moderate exercise training. The time efficiency would be of particular benefit for the population of children with CP who require exercise throughout their whole life and for whom motivation to train might be challenging **(Sperlich et al., 2010).**

Statement of the problem:

Does task-oriented circuit training have an effect on kinematic parameters of gait, pelvic symmetry and trunk endurance in children with hemiplegic CP?

Purpose of the study:

This study aims to:

- Investigate the effect of exercise-based task-oriented circuit training on gait kinematics in children with hemiplegic CP.
- Determine the effect of task-oriented circuit training on pelvic symmetry in children with hemiplegic CP.
- Examine the effect of task-oriented circuit training on trunk endurance in children with hemiplegic CP.

Significance of the study

Children with CP have lowered physical fitness levels because their motor impairments restrict their participation in daily physical activities **(Lauruschkus et al., 2013).** Children with hemiplegic CP may experience a variety of concomitant health conditions including, movement difficulty, postural and balance instability, muscle spasticity, difficulty with motor planning and control, and cognitive impairments **(Hillary et al., 2016).** They also have diminished force generation, debilitated proprioception around the core, lack of enough harmonization in core musculature and diminished capacity to adjust coupling between the trunk, pelvis and hip stabilizers leading to diminished proficiency of movement **(Heyrman et al., 2013).**

According to the concept of motor learning, training is considered to be most effective when the training task is specific to the intended outcome, as optimal improvement in function involves the practice of task specific activities. Due to the shift in focus on functional movements rather than muscle activity or movement patterns, there has been a task-oriented approach which is based on the system model of motor control providing motivation due to specific achievements that can be made **(Salem and Godwin, 2009).**

Task-oriented circuit training effectively provides various sensory stimulation and promotes functional activities for stroke patients; however more attention is becoming directed to children with CP to examine the effect of task-oriented circuit training program on functional performance in children with CP. Therefore, the aim of this study is to determine the effect of rehabilitation delivered as a task-oriented circuit exercise program on kinematic parameters of gait, pelvic symmetry and trunk endurance in children with hemiplegic CP.

Delimitations:

This study will be delimited to the following:

- Children with spastic hemiplegic CP from both sexes. Sample size estimation will be conducted to determine the number of recruited children using G power analysis.
- Age will range from 7 to 10 years.
- Degree of spasticity will range from mild to moderate according to the Modified Ashworth Scale **(Bohanon and Smith, 1987).**
- Motor function level will be I and II according to Gross Motor Function Classification System **(Palisano et al., 2008).**
- Assessment will be conducted using two-dimension gait analysis in order to measure kinematic parameters of gait. Palpation meter inclinometer will be used to measure anterior and lateral pelvic tilting. Trunk endurance tests will be used in order to measure the endurance of trunk muscles.
- Treatment will be applied using task-oriented circuit-based exercise training for the study group.

Null hypothesis

There is no effect of task-oriented circuit training program on the kinematic parameters of gait, pelvic symmetry and endurance in children with hemiplegic CP.

Basic assumptions

It will be assumed that:

- Appropriate evaluation and treatment procedures will be applied for all children.
- All children will attend the treatment program regularly.
- Assessment tools that will be used in the study are reliable and valid.
- All children will be cooperative and following the instructions given to them.
- The results of the study will be helpful for physical therapists dealing with similar cases in pediatrics.

CHAPTER II

LITERATURE REVIEW

Cerebral palsy is one of the most common motor disabilities in childhood, affecting approximately 2 per 1000 children, creating an important health burden for affected children, their families, and their communities. Biological risk factors for CP include placental abnormalities, major and minor birth defects, and preterm delivery **(Oskoui et al., 2016).**

Cerebral palsy is a group of permanent movement disorders that appear in early childhood. Signs and symptoms vary among people. Often, symptoms include poor coordination, stiff muscles, weak muscles, and tremors. There may be problems with sensation, vision, hearing, swallowing, and speaking. Often babies with cerebral palsy do not roll over, sit, crawl, or walk as early as other children their age. Difficulty with the ability to think or reason and seizures each occurs in about one third of people with CP. While the symptoms may get more noticeable over the first few years of life, the underlying problems do not worsen over time **(Schiariti et al., 2018).**

Exact cause of cerebral palsy is not clear, the brain damage can occur during pregnancy, at the time of birth or after the birth. 80% children with cerebral palsy show structural problem in white matter in their brain **(Yarnell, 2013).**

Typical causes during the intrauterine life are exposure to radiation, infections, hypoxia and birth trauma. Other causes that can lead to cerebral palsy are immaturity, head injury after birth, genetic factor, maternal infection, periventricular leukomalacia, cerebral dysgenesis, intracranial bleeding and asphyxiation. Most common risk factors for cerebral palsy are early delivery and pregnancy disorders, placental abruption, chorioamnionitis, prolonged rupture of membranes, intrauterine growth restriction, pre-eclampsia, multiple births, placenta previa, bleeding, cervical conization, and congenital malformation **(Tronnes et al., 2014).**

While in certain cases there is no identifiable cause, typical causes include problems in intrauterine development (e.g. exposure to radiation, infection, fetal growth restriction), hypoxia of the brain (thrombotic events, placental conditions), birth trauma during labor and delivery, and complications around birth or during childhood **(Beukelman et al., 1999).**

Spastic hemiplegic is a unilateral type of CP, where upper limbs more severely affected than the lower limbs. It is seen in 56% of term infants and 17% of preterm infants **(Sankar and Mundkur, 2005).**

Hemiplegia may happen before, during or soon after birth (up to two years of age approximately), when it is known as congenital hemiplegia (or unilateral CP), or later in life as a result of injury or illness, in which case it is called acquired hemiplegia **(Ki et al., 2015).**

Children with unilateral CP have resultant impairments in unimanual upper limb function include increased muscle tone, impaired sensation, reduced strength, reduced endurance, reduced range of motion, and decreased speed **(Woollacott and Shumway-Cook, 2005).**

Children with spastic hemiplegia experience decreased balance ability and abnormal gait because of decreased weight-bearing in the paretic leg. Diminished motor ability in the paretic leg causes weakness of the quadriceps, ankle plantar flexors, and ankle dorsiflexors **(Ki et al., 2015).** They show decrease in force during push-off the affected limb, while the non-affected limb shows greater force during push-off. They also have a shorter step length on the affected side mainly due to decrease in force production and increase in step frequency due to increased stiffness **(Kuo and Donelan, 2010).**

Human gait is the most common of all human movements. It is one of the more difficult movement tasks and only when this complex neuromuscular system is distributed by neurological damage, gradual degenerations, injury or fatigue it is possible to imagine this complex biomechanical system and its motor processes. **(Van Zwieten., 2011).**

Gait variability has become an important indicator for the assessment of human motor performance. Extreme levels of gait variability have been shown to correlate with the occurrence of previous falls **(Singh et al, 2012)** and show efficacy in predicting future fallers **(Herman et al.,2010)**. Gait variability itself is also known to be a functional measure for the quality of the sensorimotor system **(Hausdorff, 2009).**

Children with hemiplegic CP have longer gait, slower speed, and longer support phase compared with healthy children. The stance phase is longer than the swing phase in these children. There are significant differences in the angles of the hip, knee, and ankle joint between children with hemiplegic CP and healthy children when touching the ground and during pedal extension. The children with hemiplegic CP have poor motor coordination and balance during walking, which result in a short stride, increased stride frequency to maintain speed, more swing time, and poor stability **(Wang and Wang, 2012).**

Gait analysis is used for clinical identification of deviations from normal gait. Kinematic gait analysis is concerned with the description of gait components. It deals with movement as opposed to kinetic which deals with the forces acting on or exerted by the body. For this we can use distance (spatial), time (temporal) parameters and angular displacement for each joint during each subphase of gait cycle **(Haim et al., 2012)**.

According to **Bar-Ziv et al. (2013)** spatial and temporal parameters can be defined as follows

- **Step length** –This is the distance between corresponding successive points of heel contact of the opposite feet. If the gait is normal the right step length is equal to left step length. This parameter can give a great insight into a patient's problem.

- **Stride length** – This is the distance between successive points of heel contact of the same foot. In normal gait this is equal to double the step length.

Temporal parameters (time parameters) include:

- **Cadence** – This is the number of steps per unit time.
- **Speed** (Velocity) – This is the distance covered by the body per unit time, usually measured in m/s. Patients with problems tend to walk at a slower velocity in order to decrease the forces and moments they have to cope with in gait. If the patient's condition is improved the velocity should go up.
- **Single limb support**- This is the amount of time spent on a limb expressed as a percentage of the gait cycle. This parameter is of great importance as it has been shown that it decreases when there is a problem with the knee joint. This gives us an easy to use, functional, quantifiable, objective measure of the patient's problem.

Muscular endurance is defined as the resistance to fatigue or the ability to withstand fatigue. It represents the capacity of an isolated muscle group to carry out repeated contraction during a specific duration with moderate intensity. It is one of the fundamental components of muscular performance that has strong relation to physical activity **(Mayer et al., 1995).** Muscle fatigability is a critical motor disorder that is expected to cause activity limitations in children with CP and has been essentially associated with deterioration of functional capacity, constraints in motor skills, and low life satisfaction **(Doorenbosch et al., 2012).**

A number of isometric tests for measuring trunk endurance have been described including prone plank test, timed partial curl up test, front abdominal power test and unilateral supine bridge test. These tests are safe and simple to be used in the clinical settings where performance is determined by measuring the maximum time an individual can hold the test position. Endurance of the core musculature may be more important to function than pure strength. Some of the muscles that make up the core are not amenable to individual muscle testing and therefore are tested as part of the core. Others form individual and specific functions and can be tested individually. However, when testing the core, all of these muscles are active **(Evans et al., 2007).**

The core muscles act as the center of the functional kinetic chain that contributes to smooth central movement. Control of core strength, balance, and motion maximizes all kinetic chains of the upper and lower extremity functions **(Akuthota and Nadler, 2004).** Movement coupling between the trunk and pelvis is essential for well-controlled leg movements required during walking **(Bruijn et al., 2006).** Therefore, weakness of the trunk muscles is one of the fundamental contributors to diminished gait efficiency **(Van de Walle et al., 2012).**

Children with CP have diminished force generation, debilitated proprioception around the core, lack of enough harmonization in core musculature and diminished capacity to adjust coupling between the trunk, pelvis and hip stabilizers leading to diminished proficiency of movement **(Heyrman et al., 2013).** Accordingly, poor core stability might correspond to a child's decreased functional capabilities and lower level of gross motor skills **(Dos Santos et al., 2012).**

It is proved that pelvic asymmetry is a common impairment in hemiplegic CP. Children with CP often show weakened trunk control, which can, in turn, affect their daily functional tasks including reaching, sitting and walking, but there is a scarcity of literature which shows the impact of the trunk on pelvis and pelvis on the trunk **(Niklasch et al., 2015).**

Children with hemiplegia often walk with abnormal pelvic motion patterns and reported deviations include increased anterior pelvic tilt, retraction of the affected side and contralateral pelvic drop (Trendelenburg gait) **(Aminian et al., 2003).** These alterations can occur as a result of one or a combination of different variables such as weakness, skeletal deformities, abnormal muscle activation patterns, leg length discrepancy and compensatory mechanisms **(O'Sullivan et al., 2007).** In the coronal plane, **Metaxiotis et al., (2000)** found a Trendelenburg sign (pelvic drop) in the non-affected side during single limb support in hemiplegic children using observational gait analysis.

Task-oriented training is defined as the repetitive training of significant functional activities or element of such activities, to acquire well-organized and effective motor skill **(Horak, 1990).** It used as a rehabilitation strategy to improve motor skill and as a rehabilitation program for improvement of muscle strength or function **(Leroux et al., 2006).** It should include specific tasks to improve function as an effective treatment for functional improvement of patients with disorders of the central nervous system **(Bayona et al., 2005).**

Task-oriented training helps with functional organization by repeatedly training on activity tasks associated with daily living based on motor learning. Task-oriented training efficiently promotes controlled movements that are actually used when performing functional tasks **(Blundell et al., 2003).**

Task-oriented training is a form of motor learning that focus on skill acquisition in the context of a particular functional activity. Task-oriented training with CNS patients result in motor relearning by enhancing skill in meaningful functional activity with presumably adaptive neuroplastic changes in the cerebral cortex, brain stem, cerebellum and spinal cord **(Kim et al., 2016).** It involves practicing real-life tasks, with the intention of acquiring or reacquiring a skill (defined by consistency, flexibility and efficiency). The tasks should be challenging and progressively adapted and should involve active participation. Children practice these motor abilities in functional situations and have an active role in finding solutions for motor problems (**Kumar and Kataria, 2013).**

Circuit training means that there are series of exercise activities. At the end of the last activity, the individual starts from the beginning and again moves through the series. The series of activities is repeated several times. Several exercise modes can be used involving large and small muscle groups and a mix of static or dynamic effort **(Holtgrefe, 2012).**

It was suggested that the exercise training can be structured as circuit training with a series of workstations providing opportunities for task-oriented practice. Using different workstations through circuit training allows patients to practice intensively in a meaningful and in progressive manner that was suitable for their individual needs and abilities. During circuit training the intensity of the exercise at each workstation can be progressed by for example; increasing the number of repetitions completed at each station and/or increasing the complexity of the exercise performed at each task **(Wevers et al, 2009).**

CHAPTER III

SUBJECTS, MATERIALS AND PROCEDURES

A. Subjects:

Children with spastic hemiplegic CP, from both sexes, will be recruited from Mansoura Specialized Hospital and New Mansoura General Hospital. Sample size estimation will be conducted to determine the number of recruited children using G power analysis.

Inclusive criteria:

- Their age will be ranged from 7-10 years.
- Their motor function will be at level I and II according to Gross Motor Function Classification System GMFCS **(Palisano et al., 2008).**
- The degree of spasticity will range from mild to moderate according to Modified Ashworth Scale **(Bohannon and Smith, 1987).**
- They will be able to follow instructions during evaluation and treatment.

Exclusive criteria:

Children will be excluded from the study if they have:

- Other types of cerebral palsy.
- Cardiovascular or respiratory disorders.
- Botulinium muscular injection in the last 6 months
- Surgical interference in lower limbs and/or spine.
- Muscloskeletal problems or fixed deformities in the spine and/or lower extremities.
- seizures.
- Visual or hearing impairment.

The selected children will be divided randomly by sealed envelopes into two groups of equal number. Children in group A (control group) received specially designed physical therapy program. While children in group B (study group) received the same program given to (group A) in addition to task-oriented circuit training program.

B. Materials:

I. For selection:

1. Modified Ashworth Scale:

Modified Ashworth scale is used to measure the degree of spasticity in upper motor neuron lesions which has been shown to be valid and reliable **(Bohannon and Smith, 1987) (Appendix A).**

2. Gross Motor Function Classification System:

The GMFCS is a reliable, valid and standard method for classifying gross motor function of children and young people with CP into five levels with emphasis on transfer, sitting and mobility from Level I (most able) to Level V (most limited), with an expanded conceptual framework to coincide with the International Classification of Functioning, Disability, and Health **(Palisano et al., 2008) (Appendix B).**

II. For evaluation:

1. Kinematic gait parameters:

- **Digital camera:**

Nikon camera, Model: 3200D, Lens: 18-55mm, Quality: 1080×1920-50fps.

- **Tripod stand:**

The digital camera was placed on adjustable tripod stand at 3 meters from the 4-meter walkway and placed at a height 1 meter from the ground at 90^0 for standardization **(Puig-Diví et al., 2019).**

- **Computer system:**

Laptop DELL was used for the Kinovea measurement analysis. The following parameters will be measured including (step length, stride length, walking speed and angular displacement for hip, knee and ankle joints).

- **Markers:**

Round markers 1.5cm in diameter will be attached to bony land marks (greater trochanter, lateral femoral epicondyle and lateral malleolus) using double face plaster.

- **Kinovea software:**

It is a software that uses the angle and track path tools to analyze position, velocity and acceleration data. It was successful in measuring both these parameters and poly articular angular movements **(Guzman-Valdivia et al., 2013).** It is a valid, precise and reliable (both inter- and intra-rater) program with which we can obtain angles and distance data from coordinates **(Puig-Diví et al., 2019).**

2. Palpation meter inclinometer

It consists of two caliper arms and an inclinometer. The inclinometer is a semi-circular arc with one-degree gradation ranging from 0 to 30 degrees on either side of the midline. The caliper arms are placed on the bony landmarks (Anterior superior iliac spine and posterior superior iliac spine). Pelvic tilting angles will be measured including; anterior and lateral tilting of the pelvis from standing position **(Herrington, 2011).**

It is a valid, reliable, and cost-effective clinical measurement instrument used to calculate the height discrepancy between landmarks **(Petrone et al., 2003; da Costa et al., 2010).** It has been used to measure static rotation of the ipsilateral anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) with intra-test reliability of 0.90, and the inter-test reliability of 0.85 **(Krawiec et al., 2003; Preece et al., 2008).**

3. Trunk endurance tests:

Endurance of the trunk muscles will be evaluated using four endurance tests designed to establish the isometric trunk muscles endurance including; prone plank test, timed partial curl up test, front abdominal power test and unilateral supine bridge test. A stop watch was used to record the time a child can maintain the test position.

- Prone plank test activates core musculature and consists of maintaining the spine in a neutral position while maintaining scapular adduction and a posterior pelvic tilt. The plank is a superb challenge to the abdominals and muscles of the shoulder girdle, particularly the pectoralis major and minor, serratus anterior, anterior deltoid, supraspinatus and infraspinatus. It has been shown to have acceptable validity and reliability **(Cortell-Tormo et al., 2017).**
- Timed partial curl up test uses the hook lying position and thus encourages hip flexor activation, it was found to be reliable and is proposed as an alternative method of evaluating abdominal strength and endurance **(Haff and Triplett, 2015).**
- Front abdominal power test assesses the power component of core stability prestability and poststability training. This test has demonstrated good validity and reliability (**Cowley et al., 2009).**
- Unilateral supine bridge test assesses lumbopelvic neuromuscular control. This test was found to be correlated with lab-based biomechanical measures of isolated core stability. It has good to excellent reliability (ICC >0.836) (**Butowicz et al., 2016)**

III. For treatment:

The following tools will be used for application of physical therapy program including; gymnastic mat, medical ball, different sizes of pediatric therapeutic wedges, different sizes of bolsters (rolls) and balance board and beam.

C. Procedures:

I. For evaluation:

1. **Two-dimension (2D) gait analysis**

Kinematic gait parameters will be measured using a 2D motion analysis system which has been shown to be valid and reliable. Tripod fixed with a video camera was placed 3 meters away from the walkway and focused on the middle part to record 3 gait cycles of sagittal plane motion.

The video will be analyzed in slow motion and monitored frame by frame. Proper frames will be selected and lines and arrows will be added to measure angles of ankle dorsiflexion in initial contact, knee extension in mid stance, hip extension in terminal stance. These three angles will be selected because they considered to be the most gait deviations related to kinematic gait parameters according to **Armand et al. (2016)** who reported that the absence of ankle first rocker in initial contact occur due to ankle dorsiflexors weakness, reduced selective motor control and/or plantar flexors overactivity. Also, reduced knee extension in midstance occurs due to hamstring overactivity or hip extensors or knee extensors weakness. Lack of hip extension in terminal stance is because of hip flexor overactivity or hip reduced range of movement as a result of anterior pelvic tilting.

The Kinovea software version 8.15.0 will be used to measure kinematic gait parameters. The measurement will involve walking at the preferred gait speed along the 4 meters' walkway **(Puig-Diví et al., 2019).**

A gait cycle in the middle part of the walkway will be selected for data processing. The initial contacts of each limb were marked on the video using the Kinovea software. The distance from the point of initial contact of one limb to the contralateral limb will be measured for step length. The distance from the point of initial contact of one limb to the same limb will be measured for stride length and stride time will be calculated from the sum of left and right step lengths and left and right step times. Gait speed will be calculated from stride length divided by stride time. Cadence will be calculated by determining number of steps per min.

2. **Assessment of pelvic symmetry:**

During the measurement, the participants will wear non-restrictive clothing, removed their shoes, and spread their feet (approximately 10~12 cm). They stood in an upright position, leaning the anterior aspect of the thighs against a stabilizing table **(Gnat et al., 2009).** The investigator palpated the prominence of the ipsilateral ASIS and PSIS and marked them with a black pen. The anterior pelvic tilt will be measured by placement of the caliper tips of the inclinometer in contact with the ipsilateral ASIS and PSIS. An anterior pelvic tilt angle is shown as a positive (+) value, and a posterior pelvic tilt angle as a negative (-) value **(Lee et al., 2011).** Lateral pelvic tilt will be measured by placing the caliper tips of the inclinometer in contact with both ASIS.

3. Assessment of trunk muscular endurance

Endurance of the trunk muscles will be evaluated using four endurance tests designed to establish the isometric trunk muscles endurance including:

A. Prone plank test:

From prone, ask the child to lift body weight onto toes and forearms. Elbows should be under the shoulders, with scapulae adducted and hips level with spine like a "plank". Count number of seconds the child's assume a plank position as shown in figure (1) **(Cortell-Tormo et al., 2017)**.

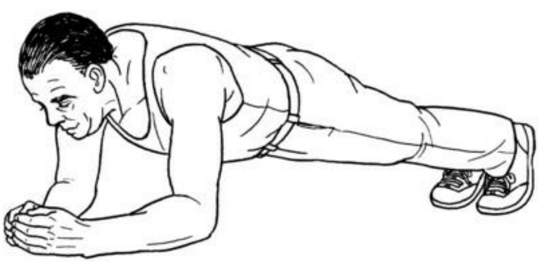


Figure (1): Prone Plank Test

B. Timed partial curl up test:

It is a strength test for abdominals. The child position is supine in hook lying position on a mat with arms at sides, palms facing down, and the middle fingers touching a piece of tape affixed to the surface parallel to the hand. Count number of seconds the child's assume this position as shown in figure (2) **(Haff and Triplett, 2015).**

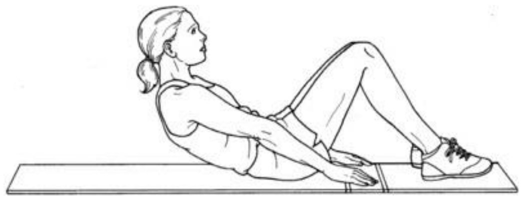


Figure (2): Timed Partial Curl Up Test

C. Front abdominal power test:

It assesses the power component of core stability. The child is lying supine on a mat with arms at sides, feet shoulder width apart, and knees bent to 90°. Place a 2-kg medicine ball into the child's hands. Then ask child to lift arms overhead and explosively project the medicine ball forward keeping the arms straight. Feet and buttocks should remain on the floor throughout the test. Measure the distance the ball was projected from the tips of the feet to the point where the ball landed. Child should be sitting upright after the ball is thrown as shown in figure (3 A and B). **(Cowley et al., 2009).**

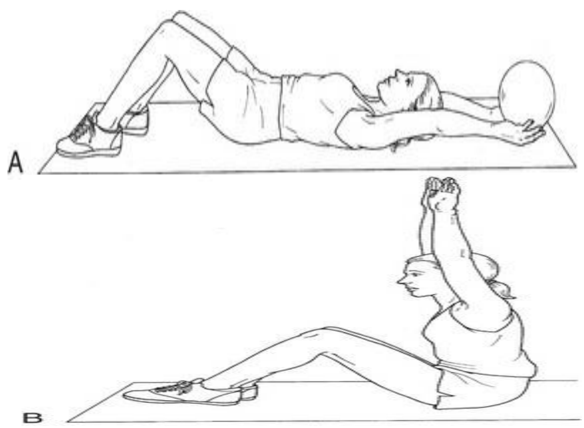


Figure (3): Front Abdominal Power Test

A. Starting position – B. Ending position

D. Unilateral supine bridge test:

The position of child is supine with arms across chest with knees in hook lying. The therapist stands to side of child. Ask child to lift both hips into a double-leg bridge. When neutral spine and pelvis positions are achieved, ask child to extend one knee so leg is straight and thighs parallel to one another then ask child to hold position as long as possible, timing the effort. Test is terminated when child is no longer able to hold a neutral pelvic position, as noted by a 10° change in transverse or sagittal plane alignment as shown in figure (4) **(Butowicz et al., 2016).**

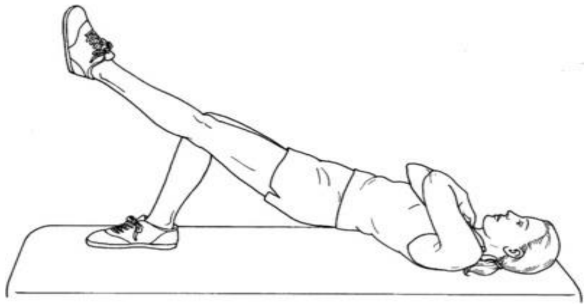


Figure (4): Unilateral Supine Bridge Test

For each trunk endurance measure, the examiner will instruct the child to hold the test position as long as possible prior to all testing. Each position will be tested three times and the average time will be recorded.

II. Procedures for intervention:

Control group will receive a selected physical therapy program for 90 minutes, 3 times/week for 3 successive months including the following exercises:

-Facilitation of balance reactions from standing position including; standing on one leg, weight shifting from standing position, stoop and recover from standing, squat from standing and standing on balance board.

-Facilitation of counterpoising mechanism through instructing the child to kick ball from standing position as well as catching and throwing ball with his hands.

-Gait training activities including: walking using different obstacles (rolls, wedges, stepper) and walking up and down stairs.

-Facilitation of protective reaction from standing position by pushing the child in different directions.

-Facilitation of rising mechanism through changing position as well as returning back to the original position e.g.: from lying to standing and from sitting to standing.

-Strengthening exercises for back and abdominal muscles as well as upper and lower limbs.

-Jumping in place and jumping a board.

Task-oriented circuit training program:

Children allocated to the study group will receive the same selected physical therapy program given to the control group for 45 minutes in addition to 45 minutes task-oriented circuit training program. The frequency of the whole program will be three times per week, for three months.

The task-oriented circuit training program consisted of 14 workstations. Time spent at each station will be 1.5 minutes. The children will complete the activity at one station and move to another station. The whole circuit will be completed in 21 minutes and it will be repeated twice per session with 3 minutes rest interval between the 2 circuits. Children will be encouraged to work as hard as possible at each workstation and will also be given verbal feedback and instructions aimed at improving performance. The progression of the task will be considered according to each child's ability and progressed as tolerated. Progressions include increasing the number of repetitions and increasing complexity of the exercise performed at each workstation, such as the distance reached in standing, reducing the height of the chair during sit-to stand, changing the height of blocks or by increasing speed of movement. Warm-up and cool-down will be performed before and after exercise, respectively in the form of stretching and light activity exercises (**Kumar and Kataria, 2013).**

According to **Kumar and Ostwal, (2016) and Schranz et al., (2018),** the 14 workstations will include the following exercises:

1. Standing and reaching in different directions for objects located beyond arm's length and progress by increasing the distance reached in standing.
2. Sit-to-stand from various chair heights.
3. Stepping forward, backward and sideways onto blocks of various heights and progress by increasing height of the blocks.
4. Alternating heel and toes raising and lowering while maintaining a standing posture.
5. Squatting exercise: Progress by changing the depth of squat and progress further by increasing the time or by adding weights to hands.
6. Supine straight leg raising exercise. Progress further by adding a small cuff weight to child's leg.
7. Stairs walking: Progress by repetition and progress further by adding a small cuff weight to child's leg.
8. Backward walk: Start near the wall then progress to center of workstation and progress further to shuttle runs.
9. Balance beam: Step over balance beam, leading with alternate feet. Progress by increasing the speed of movement.
10. Crunch core exercises: From supine with knees bent to 90°, children will be asked to curl their shoulder up of the floor to about 30° angle and hold for 15–30 sec, progress further by repetition.
11. Supine bridge exercises: From supine with knees bent to 90°, children will be asked to lift up the pelvis off the supporting surface and hold for 15–30 sec, progress further by repetition.
12. Prone opposite arm/leg raise exercise: From prone position with arms extended over heads, children will be instructed to lift one arm along with

their head while simultaneously lifting the opposite leg and holding the position for 15–30 sec. The same was repeated on the other arm and leg.

13. Side bridge exercises: while children lying on one side with their legs out straight, they will be asked to prop themselves up on their elbows and to hold this position for 15–30 sec. The top arm placed on the top hip. Then, they were asked to lift their pelvis up off the floor. The same was repeated on the other side.
14. Cycle training using a stationary bicycle and progress further by changing direction, repetition or by resistance.

Data analysis

The data obtained will be statistically analyzed using statistical package of social sciences (SPSS) version 26 including:

1-Descriptive statistics:

- The mean and standard deviation will be calculated for demographic characteristics including age, weight and height and also for all measured variables.

2-Inferential statistics:

- Paired t-test will be used for within group comparison before and after the intervention.
- Independent t-test was used to compare the demographic data and the baseline characteristics of both groups as well as the pre- and post-treatment mean differences in all measured variables.
- The statistical significance level will be set at 0.05.

REFERENCES

Akuthota V, Nadler SF (2004): Core strengthening. Arch Phys Med 535 Rehabil; 85: S86-92.

Aminian A, Vankoski SJ, Dias L, and Novak RA (2003): Spastic hemiplegic cerebral palsy and the femoral derotation osteotomy: effect at the pelvis and hip in the transverse plane during gait. *Journal of Pediatric Orthopaedics*, *23*(3), 314-320.

Armand S, Decoulon G, Bonnefoy-Mazure A (2016): Gait analysis in children with cerebral palsy. EFORT Open Rev;1:448-460.

Bar-Ziv Y, Debbi EM, Ran Y, Benedict S, Halperin N, and Beer Y (2013): Long-Term Effects of AposTherapy in Patients with Osteoarthritis of the Knee: A Two-Year Followup. Arthritis, 2013, 689236.

Bayona NA, Bitensky J, Salter K, and Teasell R (2005): The role of task-specific training in rehabilitation therapies. *Topics in stroke rehabilitation*, *12*(3), 58–65.

Beukelman David R, and Mirenda Pat (1999): Augmentative and Alternative Communication: Management of severe communication disorders in children and adults (2nd ed.). Baltimore: Paul H Brookes Publishing Co. pp. 246–249.

Blundell SW, Shepherd RB, Dean CM, Adams RD, and Cahill BM (2003): Functional strength training in cerebral palsy: a pilot study of a group circuit training class for children aged 4-8 years. *Clinical rehabilitation*, *17*(1), 48–57.

Blundell SW, Shepherd RB, Dean CM, Adams RD, and Cahill BM (2003): Functional strength training in cerebral palsy: a pilot study of a group circuit training class for children aged 4–8 years. *Clinical rehabilitation*, *17*(1), 48-57.

hannon RW, and Smith MB (1987): Interrater reliability of a modified

Ashworth scale of muscle spasticity. Physical therapy, 67(2), 206–207.

Bruijn S, Lamoth C, Kingma I, Meijer O, van Dieën J (2006): Coordination between pelvis, thorax and leg movements in gait. Gait Posture; 24(2): S10-1.

Butowicz CM, Ebaugh DD, Noehren B, and Silfies SP (2016): Validation of two clinical measures of core stability. International journal of sports physical therapy, 11(1), 15.

Cortell-Tormo JM, García-Jaén M, Chulvi-Medrano I, Hernández-Sánchez S, Lucas-Cuevas ÁG, and Tortosa-Martínez J (2017): Influence of Scapular Position on the Core Musculature Activation in the Prone Plank Exercise. Journal of strength and conditioning research, 31(8), 2255–2262.

Cowley PM, Fitzgerald S, Sottung K, and Swensen T (2009): Age, weight, and the front abdominal power test as predictors of isokinetic trunk strength and work in young men and women. Journal of strength and conditioning research, 23(3), 915–925.

da Costa BR, Armijo-Olivo S, Gadotti I, Warren S, Reid DC, and Magee DJ (2010): Reliability of scapular positioning measurement procedure using the palpation meter (PALM). Physiotherapy, 96(1), 59–67.

Doorenbosch C, Dallmeijer A, Pollice A, Steenbergen M, Houdijk H (2012): Muscle fatigue in children with cerebral palsy compared to typically developing children and young adults. Gait Posture; 36: 564-5.

Dos Santos AN, Pavao SL, de Campos AC, Rocha NA (2012): International classification of functioning, disability and health in children with cerebral palsy. Disabil Rehabil; 34: 1053- 5498.

Evans K, Refshauge K, Adams R (2007): Trunk muscle endurance tests: reliability, and gender differences in athletes. J Sci Med Sport; 10: 447-55.

Gnat R, Saulicz E, Biały M, and Kłaptocz P (2009): Does pelvic asymmetry always mean pathology? Analysis of mechanical factors leading to the asymmetry. Journal of Human kinetics, 21(1), 23-32.

Guzmán-Valdivia CH, Blanco-Ortega A, Oliver-Salazar MA, and Carrera-Escobedo JL (2013): Therapeutic motion analysis of lower limbs using Kinovea. Int J Soft Comput Eng, 3(2), 2231-307.

Haff GG, and Triplett NT (Eds.). (2015): Essentials of strength training and conditioning 4th edition. Human kinetics.

Haim A, Rubin G, Rozen N, Goryachev Y, and Wolf A (2012): Reduction in knee adduction moment via non-invasive biomechanical training: a longitudinal gait analysis study. Journal of biomechanics, 45(1), 41–45.

Hausdorff JM (2009): Gait dynamics in Parkinson's disease: common and distinct behavior among stride length, gait variability, and fractal-like scaling. Chaos (Woodbury, N.Y.), 19(2), 026113.

Herman T, Mirelman A, Giladi N, Schweiger A, and Hausdorff JM (2010): Executive control deficits as a prodrome to falls in healthy older adults: a prospective study linking thinking, walking, and falling. The journals of gerontology. Series A, Biological sciences and medical sciences, 65(10), 1086–1092.

Herrington L (2011): Assessment of the degree of pelvic tilt within a normal asymptomatic population. Manual therapy, 16(6), 646–648.

Heyrman L, Desloovere K, Molenaers G, Verheyden G, Klingels K, Monbaliu E (2013): Clinical characteristics of impaired trunk control in children with spastic cerebral palsy. Res Dev Disabil; 34: 327-34.

Hillary L, Sara H, Nicole K, Kyra W, and Antonette D (2016): Effectiveness of Exercise on Functional Mobility in Adults with Cerebral Palsy: A Systematic Review. Physiother Can.; 68(4): 398–407.

Horak FB (1990): Assumptions Underlying Motor Control for Neurologic Rehabilitation, In. Jodi Crompton, Christine Imms, Anne T McCoy, et al. (2007) Group-based task-related training for children with cerebral palsy: a pilot study. Phys Occup Ther Pediatr 27: 43-65.

Ki Kyong, Mi-Sun Kim, Young Moon, and Jong-Duk Choi (2015): "Effects of auditory feedback during gait training on hemiplegic patients' weight bearing and dynamic balance ability." Journal of physical therapy science 27, no. 4

Kim SH, Park JH, Jung MY, Yoo EY (2016): Effects of task-oriented training as an added treatment to electromyogram-triggered neuromuscular stimulation on upper extremity function in chronic stroke patients. Occup Ther Int.

Kim Y, and Lee BH (2013): Clinical Usefulness of Child-centered Task-oriented Training on Balance Ability in Cerebral Palsy. Journal of physical therapy science, 25(8), 947–951.

Krawiec CJ, Denegar CR, Hertel J, Salvaterra GF, and Buckley WE (2003): Static innominate asymmetry and leg length discrepancy in asymptomatic collegiate athletes. Manual therapy, 8(4), 207–213.

Kumar C and Ostwal P (2016): "Comparison between Task - Oriented Training and Proprioceptive Neuromuscular Facilitation Exercises on Lower Extremity Function in Cerebral Palsy-A Randomized Clinical Trial". J Nov Physiother 6: 291.

Kumar C, and Kataria S (2013): Effectiveness of task oriented circuit training on functional mobility and balance in cerebral palsy. Indian Journal of Physiotherapy and Occupational Therapy-An International Journal, 7(4), 23-8.

Kuo A and Donelan J (2010): Dynamic principles of gait and their clinical implications. Physical therapy; 90(2): 157.

Lauruschkus K, Westbom L, Hallström I, Wagner P, and Nordmark E (2013): Physical activity in a total population of children and adolescents with cerebral palsy. Research in developmental disabilities, 34(1), 157–167.

Leroux A, Pinet H, and Nadeau S (2006): Task-oriented intervention in chronic stroke: changes in clinical and laboratory measures of balance and mobility. Am J Phys Med Rehabil, , 85: 820–830.

Mayer T, Gatchel R, Betancur J, Bovasso E (1995): Trunk muscle endurance measurement. Isometric contrasted to isokinetic testing in normal subjects. Spine; 20: 920-7.

McGill SM, Childs A, Liebenson C (1999): Endurance times for low back stabilization exercises: Clinical targets for testing and training from a normal database. Arch Phys Med Rehabil; 80: 941-4.

Mckinnon CT, Meehan EM, Harvey AR, Antolovich GC, and Morgan PE (2019): Prevalence and characteristics of pain in children and young adults with cerebral palsy: a systematic review. Developmental medicine and child neurology, 61(3), 305–314.

Metaxiotis D, Accles W, Siebel A, and Doederlein L (2000): Hip deformities in walking patients with cerebral palsy. *Gait and Posture*, *11*(2), 86-91.

Miller F, and Bachrach SJ (2017): Cerebral palsy: A complete guide for caregiving. JHU Press.

Niklasch M, Döderlein L, Klotz MC, Braatz F, Wolf SI, and Dreher T (2015): Asymmetric pelvic and hip rotation in children with bilateral cerebral palsy: uni- or bilateral femoral derotation osteotomy? Gait and posture, 41(2), 670–675.

Oskoui M, Messerlian C, Blair A, Gamache P, and Shevell M (2016): Variation in cerebral palsy profile by socio-economic status. Developmental medicine and child neurology, 58(2), 160–166.

O'sullivan R, Walsh M, Jenkinson A, and O'brien T (2007): Factors associated with pelvic retraction during gait in cerebral palsy. *Gait and posture*, *25*(3), 425-431.

Palisano RJ, Rosenbaum P, Bartlett D, and Livingston MH (2008): Content validity of the expanded and revised Gross Motor Function Classification

System. Developmental medicine and child neurology, 50(10), 744–750.

Petrone MR, Guinn J, Reddin A, Sutlive TG, Flynn TW, and Garber MP (2003): The accuracy of the palpation meter (PALM) for measuring pelvic crest height difference and leg length discrepancy. Journal of orthopaedic and sports physical Therapy, 33(6), 319-325.

Pinto T, Fonseca ST, Gonçalves RV, Souza TR, Vaz DV, Silva P, and Mancini MC (2018): Mechanisms contributing to gait speed and metabolic cost in children with unilateral cerebral palsy. Brazilian journal of physical therapy, 22(1), 42–48.

Preece SJ, Willan P, Nester CJ, Graham-Smith P, Herrington L, and Bowker P (2008): Variation in pelvic morphology may prevent the identification of anterior pelvic tilt. The Journal of manual and manipulative therapy, 16(2), 113–117.

Puig-Diví A, Escalona-Marfil C, Padullés-Riu JM, Busquets A, Padullés-Chando X, and Marcos-Ruiz D (2019): Validity and reliability of the Kinovea program in obtaining angles and distances using coordinates in 4 perspectives. PloS one, 14(6), e0216448.

Salem Y, and Godwin EM (2009): Effects of task-oriented training on mobility function in children with cerebral palsy. NeuroRehabilitation, 24(4), 307–313.

Sankar C, and Mundkur N (2005): Cerebral palsy-definition, classification, etiology and early diagnosis. *Indian journal of pediatrics*, *72*(10), 865–868.

Schiariti V, Fowler E, Brandenburg JE, Levey E, Mcintyre S, Sukal-Moulton T, and Vogtle L (2018): A common data language for clinical research studies: the National Institute of Neurological Disorders and Stroke and American Academy for Cerebral Palsy and Developmental Medicine cerebral palsy common data elements version 1.0 recommendations. Developmental Medicine and Child Neurology, 60(10), 976-986.

Scholtes VA, Dallmeijer AJ, Rameckers EA, Verschuren O, Tempelaars E, Hensen M, and Becher JG (2008): Lower limb strength training in children with cerebral palsy--a randomized controlled trial protocol for functional strength training based on progressive resistance exercise principles. BMC pediatrics, 8, 41.

Schranz C, Kruse A, Belohlavek T, Steinwender G, Tilp M, Pieber T, and Svehlik M (2018): Does Home-Based Progressive Resistance or High-Intensity Circuit Training Improve Strength, Function, Activity or Participation in Children With Cerebral Palsy?. Archives of physical medicine and rehabilitation, 99(12), 2457-2464.

Sediek RH, El-Tohamy AM, and Nassar I (2016): Relation Between Core-Stability and Functional Abilities in Children with Spastic Cerebral Palsy. Trends in Applied Sciences Research, 11(1), 19.

Singh NB, Ko¨ nig N, Arampatzis A, Heller MO, Taylor WR (2012): Extreme levels ofnoise constitute a key neuromuscular deficit in the elderly. PLoS ONE;7 (11):e48449

Sperlich B, Zinner C, Heilemann I, Kjendlie PL, Holmberg HC, and Mester J (2010): High-intensity interval training improves VO(2peak), maximal lactate accumulation, time trial and competition performance in 9-11-year-old swimmers. European journal of applied physiology, 110(5), 1029–1036.

Trønnes H, Wilcox AJ, Lie RT, Markestad T, and Moster D (2014): Risk of cerebral palsy in relation to pregnancy disorders and preterm birth: a national cohort study. *Developmental medicine and child neurology*, *56*(8), 779–785.

Tsirikos AI, Spielmann P (2007): Spinal Deformity in Pediatric Patient with Cerebral Palsy. Curr Orthop Relat Res, 21:122–134.

Van de Walle P, Hallemans A, Truijen S, Gosselink R, Heyrman L, Molenaers G (2012): Increased mechanical cost of walking in children with diplegia: the role of the passenger unit cannot be neglected. Res Dev Disabil; 33(6): 1996-2003.

Van zwieten KJ, Narain F and SchmidT K (2011): “Paradoxical increase” of pacing frequency (Hz) in early Multiple Sclerosis (MS) patients is unraveled by clinical observation, focusing on gait analysis, ISVD, Vol. 12(6), 9–10.

Wang X, and Wang Y (2012): Gait analysis of children with spastic hemiplegic cerebral palsy. Neural regeneration research, 7(20), 1578–1584.

Wiley ME and Damiano DL (1998): Lower-extremity strength profiles in spastic cerebral palsy. Developmental medicine and child neurology, 40(2), 100–107.

Woollacott MH and Shumway-Cook A (2005): Postural dysfunction during standing and walking in children with cerebral palsy: what are the underlying problems and what new therapies might improve balance?. Neural plasticity, 12(2-3), 211–272.

Yarnell J and O'Reilly D (Eds.) (2013): Epidemiology and disease prevention: A global approach. Oxford University Press.

Yu Y, Chen X, Cao S, Wu D, Zhang X and Chen X (2019): Gait synergetic neuromuscular control in children with cerebral palsy at different gross motor function classification system levels. *Journal of neurophysiology*, *121*(5), 1680–1691.

Holtgrefe K (2012): Principles of Aerobic Exercise. In Kisner C. (ed). Therapeutic exercise foundation and techniques,6th Edition. Pp 241- 259.

Wevers L., Van De Port I., Vermue M., Mead G., and Kwakkel G., (2009): Effects of task-oriented circuit class training on walking competency after stroke:A systematic review. Stroke; 40(7):2450-2459.

APPENDIX (A)

The Modified Ashworth Scale

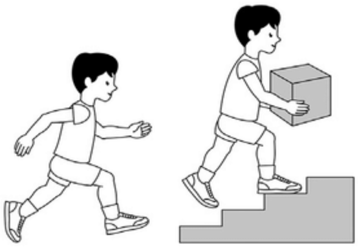
Grade	Description
0	No increase in muscle tone
1	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the ROM when the affected part(s) is moved in flexion or in extension
1+	Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the reminder (less than half) of the ROM
2	More marked increase in muscle tone throughout most of the ROM, but affected part(s) easily moved
3	Considerable increase in muscle tone, passive movement is difficult
4	Affected part(s) rigid in flexion or extension

(Bohannon and Smith, 1987)

APPENDIX (B)

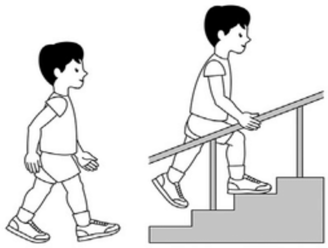
Gross Motor Function Classification System

GMFCS E & R between 6th and 12th birthday: Descriptors and illustrations



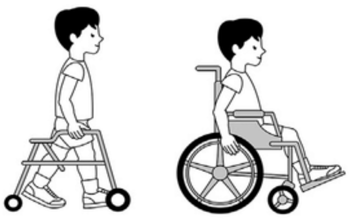
GMFCS Level I

Children walk at home, school, outdoors and in the community. They can climb stairs without the use of a railing. Children perform gross motor skills such as running and jumping, but speed, balance and coordination are limited.



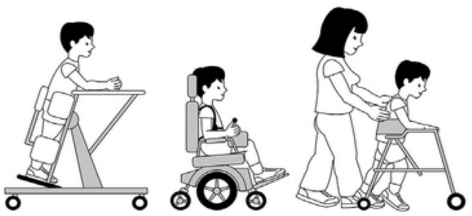
GMFCS Level II

Children walk in most settings and climb stairs holding onto a railing. They may experience difficulty walking long distances and balancing on uneven terrain, inclines, in crowded areas or confined spaces. Children may walk with physical assistance, a hand-held mobility device or used wheeled mobility over long distances. Children have only minimal ability to perform gross motor skills such as running and jumping.



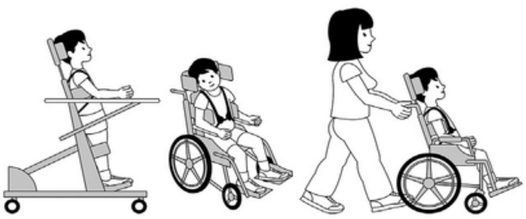
GMFCS Level III

Children walk using a hand-held mobility device in most indoor settings. They may climb stairs holding onto a railing with supervision or assistance. Children use wheeled mobility when traveling long distances and may self-propel for shorter distances.



GMFCS Level IV

Children use methods of mobility that require physical assistance or powered mobility in most settings. They may walk for short distances at home with physical assistance or use powered mobility or a body support walker when positioned. At school, outdoors and in the community children are transported in a manual wheelchair or use powered mobility.



GMFCS Level V

Children are transported in a manual wheelchair in all settings. Children are limited in their ability to maintain antigravity head and trunk postures and control leg and arm movements.

GMFCS descriptors: Palisano et al. (1997) Dev Med Child Neurol 39:214-23
CanChild: www.canchild.ca

Illustrations Version 2 © Bill Reid, Kate Willoughby, Adrienne Harvey and Kerr Graham, The Royal Children's Hospital Melbourne ERC151050

(Palisano et al., 2008)

تأثير التدريب الموجه الدائري على القياسات الوصفية للمشي ، ميل الحوض والتحمل عند الأطفال المصابين بالفالج الشقي