International Journal of Health Sciences and Research
www.ijhsr.org ISSN: 2249-9571

*Original Research Article*

# Effectiveness of Pediatric Endurance and Limb Strengthening (PEDALS) on Gait Parameters in Children with Spastic Lower Extremity

Suraiya S. Khan[1], Mandar Malawade[2], Shweta Kulkarni[2], Pallavi Rokade[1]

[1]Post Graduate Student, [2]Assistant Professor, Pediatrics Physiotherapy Department;
Dr. A P J Abdul Kalam College of Physiotherapy, PIMS, Loni-413736, Maharashtra.

Corresponding Author: Suraiya S. Khan

*Received: 04/05/2016* *Revised: 18/05/2016* *Accepted: 23/05/2016*

## ABSTRACT

**Background:** Walking is the main aspect of mobility and independence therefore emphasis should always be given to improve it in spastic children. There are many studies that are carried out to reduce spasticity with conventional physiotherapy approaches enhancing gait. But there is scarcity of studies where intervention including strengthening and endurance both applied for the same. Hence this study incorporates PEDALS to find out the improvement on gait parameter in children with spastic lower extremity.
**Objective:** To find out the effects of pediatric endurance and limb strengthening on gait parameters in children's with spastic lower extremity.
**Methodology:** 30 Children diagnosed with spasticity of lower limb between the age of 6 to 15 and Gross Motor Function Classification system levels II and III was recruited for this study. PEDALS protocol for 12 week period was given. Pre and post intervention values were measured. Outcome measures were Gross Motor Function Measure-88, 30 second walk test and gait parameters.
**Results:** Comparison between pre and post intervention heart rate showed extremely significant result ($p< 0.0004$), GMFM values showed significant result ($p< 0.05$) and gait parameter showed significant result ($p< 0.05$) respectively.
**Conclusion:** There was improvement in gait parameters of children with spastic lower extremity when treated with PEDALS protocol. Improvement was seen on gait parameters and GMFM-88 components.

***Key words:*** *Spastic lower extremity, gait parameters, GMFM-88, PEDALS.*

## INTRODUCTION

It is said that, "Walking is the world's oldest exercise and today's modern medicine". Locomotion or gait is defined as a translatory progression of the body as a whole produced by co-ordinated and rotatory movements of body segments. Normal gait is rhythmic, characterized by alternating propulsive and retropulsive motion of the lower extremities.

As seen in quadrupeds, the fore and hind limbs were evolved basically for weight bearing of the body and for locomotion. However, with the evolution of the erect posture in man, the function of weight bearing was taken over by the lower limb. Lower extremity is presented regionally, starting proximally and proceeding distally with specific regions like hip, knee, ankle and foot. Hip joint is the strongest joint in the lower limb; it has three degree of freedom (flexion/extension in sagittal plane, abduction/adduction in the frontal plane and internal/external rotation in transverse plane). The primary function of the hip joint is to support the weight of the head, arm and trunk both in static and dynamic erect postures such as ambulation, stair climbing and running. Knee complex plays a major role in supporting the body during dynamic and static activities. It has two degree of motion (flexion/extension occur in sagittal plane, medial/lateral rotation occur in transverse). Knee joint provides stability and mobility to the body during a variety of routine as well as difficult activities. Ankle and Foot absorbs the weight bearing stresses under a variety of surfaces. It also helps in activities that maximize stability and mobility. Gait initiation may be defined as the series or sequence of events that occur from the initiation of movement to the beginning of the gait cycle. [1]

Interpretation of a gait is a complex activity. Therefore, gait has been divided into number of segment that makes it possible to identify the events that are occurring. The gait cycle includes the activities that occur from the point of initial contact of one lower extremity to the point at which the same extremity touches the ground again. One gait cycle passes through two phases i.e. stance phase and swing phase. In "Stance phase" some part of the foot is in contact with the floor, which makes up about 60% of the gait cycle. The "Swing phase" makes up 40% of the gait cycle it begins as soon as the toe of one extremity leaves the ground and ceases before heel strike or contact of the same extremity. Step length, stride duration, stride length, Width of BOS, cadence, toe out angle and walking velocity (fig. 1) are the different gait parameters which can be measured while assessing the gait of an individual. [1]

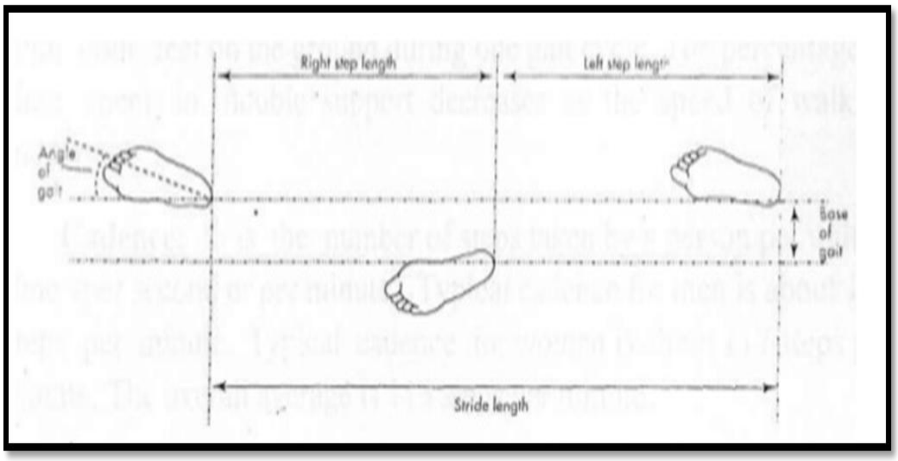



**Figure 1: Distance and temporal parameters of gait**
**(Step length, stride length, base of gait and angle of gait)**

James Lance (1990) defined spasticity as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyper excitability of the stretch reflex. [2] More recently, the definition of Lance was found too narrow and was suggested that it should be widened to disordered sensori-motor control, resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of muscles. [3]

Spasticity affects more than an estimated 12 million people worldwide. [4] the most common cause of spasticity in childhood is Cerebral palsy (CP) other causes are traumatic brain injury, spinal cord injury, central nervous system tumor or infarct, metabolic disorders and congenital anomalies such as spina bifida and related conditions. [5,6]

Spasticity of lower extremity can be seen in many conditions like diplegia, hemiplegia, quadriplegia, meningitis etc. The most commonest condition is diplegia followed by hemiplegia and quadriplegia.

The prevalence of spastic diplegia is highest in the most immature surviving infants and falls with increasing gestational age until after term when it may rise a little with post maturity. It affects bilateral lower extremities more than upper extremities, or lower extremities are solely involved. [7] The child's leg and hip muscles are tight. Legs cross at the knees, making walking more difficult. The gait is typically characterized by a crouch gait where the hips and knees are extensively flexed and ankles are in planter flexion. [8] Children with severe diplegia exhibited a lack of direction specificity in the leg muscles during backward body sway, which points to a basic deficit in balance and postural control. In addition, these children showed marked dysfunctions in the precise tuning of the balance and postural adjustments to task-specific conditions. [9]

Depending upon the presentation, spasticity is frequently classified into generalized, regional and focal spasticity. [10] Generalized spasticity affects the entire body whereas, regional spasticity affects one whole limb or a number of limbs and in focal spasticity there is impairment and activity limitation around one joint. [11]

Spasticity can be measured by various tools and scales such as Modified Ashworth Scale, Tardieu scale etc. Modified Ashworth Scale is a subjective, 5-point ordinal scale. It is used for grading the degree of spasticity which remains the gold standard. [12]

Gross Motor Function Classification System (GMFCS) is a universal classification system applicable to all forms of CP and uses a five-level system that corresponds to the extent of ability and impairment limitation where a higher number indicates a higher degree of severity. Each level is determined by an age range and a set of activities the child can achieve on his or her own. Using GMFCS helps determine the surgeries, treatments, therapies and assistive technology likely to result in the best outcome for a child. It addresses the goal set by organizations such as the World Health Organization (WHO) and the Surveillance of Cerebral Palsy in Europe (SCPE) which advocate for a universal classification system that focuses on what a child can accomplish, as opposed to the limitations imposed by his or her impairments. This system is useful to parents and caretakers as a developmental guideline which takes into consideration the child’s motor impairment. It assigns a classification level (GMFCS Level 1 - 5). The parent is then able to understand motor impairment abilities over time, as the child progresses in age. The GMFCS uses head control, movement transition, walking, and gross motor skills such as running, jumping, and navigating inclined or uneven surfaces to define a child’s accomplishment level. The goal is to present an idea of how self-sufficient a child can be at home, school, outdoor and indoor venues. GMFCS Classification Levels (GMFCS Level I - V). (Fig 2) [13]

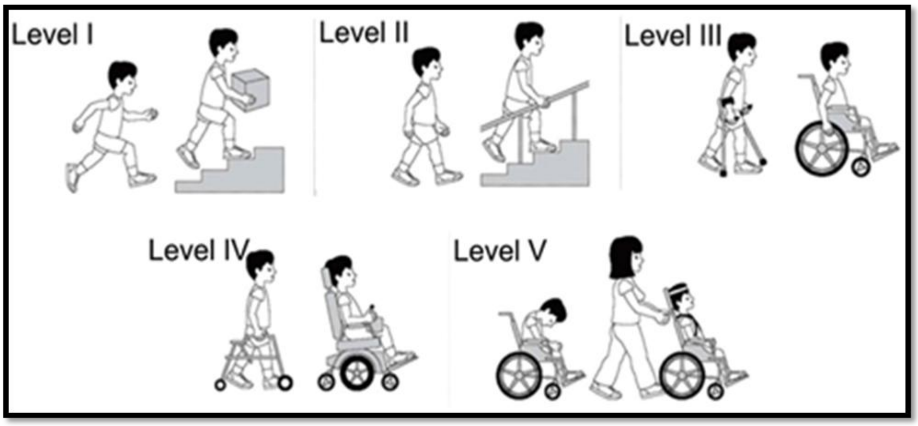



**Figure 2: GMFCS Level's**

Children with lower extremity spasticity have reduced mobility in their lumbar spine, pelvis, and hip joint and show limited asymmetric pelvic tilt or pelvic rotation during gait. To compensate their reduced mobility of lower extremity these children shift their weight and maintain balance by using excessive mobility through the head, neck, upper trunk, and upper extremities. The hips stays flexed and the knees may be either flexed or extended during stance. Adduction and internal rotation at their hip and approximation of the knees is found in severe cases. The feet may be in valgus or close together in a narrow base of support in plantar flexion with the heels off of the floor. [14]

The various options available for the treatment of spasticity of lower limb includes conservative to surgical treatment. Pharmacological intervention includes drugs such as baclofen, botulinum toxin injections etc. Surgical intervention includes intrathecal baclofen, selective dorsal rhizotomy, excisional arthroplasty, arthrodesis etc. Physiotherapy may include stretching and strengthening exercises, gait training using braces or casts, limb positioning, application of cold pack and electrical muscle stimulator. [15,16] Vibratory stimuli or inhibitory techniques and robotics are used to relax muscles and reduce the intensity of spasticity. [17]

Along with various physiotherapy treatment stationary cycling can also be given for strengthening of lower extremity muscles. Current research indicates that resistive exercise is an effective intervention to improve strength and function in children with spasticity. Cycling is a rehabilitation tool often used by physical therapists to improve strength and cardiorespiratory fitness. [18] Muscle strength is a broad term that refers to the ability of contractile tissue to produce tension and a resultant force based on the demands placed on the muscle. Functional strength relates to the ability of the neuromuscular system to produce, reduce, or control forces, contemplated or imposed, during functional activities, in a smooth, coordinated manner. Insufficient muscular strength can contribute to major functional losses of even the most basic activities of daily living. The development of muscle strength is an integral component of most rehabilitation or conditioning programs for individuals of all ages and all ability levels which can be achieved by strength training. [19] Strength and endurance training has been promoted as an appropriate exercise to improve fitness for persons with spastic lower extremity. [20,21]

Stationary cycling programs can provide progressive resistance exercise for lower extremity musculature. Normative adult data has demonstrated significant muscle recruitment, based on electromyography (EMG), during cycling for the major lower extremity joint extensors and flexors. Mean recruitment was at least 50% of maximum EMG for the soleus, gastrocnemius, hamstring, vastus medialis/lateralis, rectus femoris and gluteus maximus muscles during the propulsive phase (limb extension) and tibialis anterior muscle during the recovery phase (limb flexion). [22]

Stationary cycling interventions for children with CP warrant further examination as they have the potential to improve strength and cardiorespiratory fitness with minimal requirements for balance and motor control. The pediatric endurance and limb strengthening (PEDALS) Project has examined the effect of stationary cycling for children with diplegic CP. [18] Therefore, this study is done to find the effect of pediatric endurance and limb strengthening (PEDALS) on gait parameter in children with spastic lower extremity.

## MATERIALS AND METHODS

The research design used for the study was Pre-test Post-test design.

**The sampling design used was convenient sampling.** The sample size was 30. Both boys and girls with clinical diagnosis of spastic lower extremity who were referred to Department of Pediatric Physiotherapy and willing to participate in the study. Participants between the age group of 6-15 years were selected based on the inclusion and exclusion criteria. The total intervention period was 12 weeks, thrice a week. Each treatment session lasted for 50-60 minutes with adequate rest periods.

**selection criteria:** The inclusion criteria for the study were as follows- Both boys and girls between the age group of 6 to 15 years, clinically diagnosed with spasticity of lower extremity, children with level II to III on Gross Motor Function Classification System (GMFCS), able to follow simple verbal commands, able to communicate verbally, spasticity range from 1 to 2 (MAS).The exclusion criteria for the study were as follows- Children with visual and auditory impairments, children with musculoskeletal deformity like scoliosis, congenital talipes equinovarus deformity (CTEV), subluxation or dislocation of hip, any Orthopedic surgery or Botulinum toxin injection taken to the lower extremities within 6 months of the study, serious medical conditions such as cardiac disease, diabetes or uncontrolled seizures, significant hip, knee or ankle joint contractures preventing passive movement of the lower limbs through the pedaling cycle.

**The outcome measures used were- Gross Motor Function Measure (GMFM 88), 30 second walk test (30 sec WT), Gait parameters**

**Gross Motor Function Measure (GMFM 88):** It is a standardized observational tool to measure Gross Motor Function in children with Cerebral Palsy. It assesses the children between 5 months to 16 years old. It has total 88 components. Highest reported reliability is 0.986. Motor activities in standing, walking, running, jumping and hoping were chosen as the outcome measures. [23]

**30 second walk test (30sec WT):** The 30 sec WT assesses child's ability to walk within the school environment. Children will be instructed to walk as if they were the leader in a line at school. The examiner will monitor time using a stopwatch. When 30 seconds have elapsed, the examiner will instruct the subject to "freeze" and not move until his or her foot position is marked. Outcomes will be the total distance walked, walking speed and heart rate. [18]

**Gait parameters:** Step length, stride duration, stride length, Width of BOS, cadence, toe out angle and walking velocity (fig.1) are the different gait parameters which can be measured while assessing the gait of an individual. For the purpose of this study Step length, Stride length, Cadence and Width of the BOS has been examined. "Step length" is the linear distance between two successive point of contact of opposite extremities, it is measured from heel strike of one extremity to heel strike of opposite extremity. "Stride length" is the linear distance between two successive events that are accomplished by the same lower extremity during gait. It is determined by measuring the linear distance from the point of heel strike of one lower extremity to the next heel strike of the same extremity. "Width of the BOS" is determined by measuring the linear distance between the midpoint of the heel of one foot and the same point on the other foot. "Cadence" is the number of steps taken by a person per unit of time. Limb length discrepancy, fractures, burns and spasticity are some of the causes which can hamper the gait of an individual. [1]

The study received approval from Institutional Ethical Committee of Pravara Institute of Medical Sciences, Loni (COPT/2015/1561/10). 40 participants taken from College of physiotherapy, Department of Pediatrics with clinically diagnosed with spasticity of lower extremity and were screened according to inclusion and exclusion criteria. After finding their suitability, 30 participants were included by Convenient Sampling. Participants and their parents were briefed about the nature of the study, duration of intervention of the study, intervention and its benefits in the language best understood by them. A written informed consent was obtained from their parents. Before starting the intervention baseline data of GMFM-88, 30 second walk test and gait parameter was collected and were recorded on the first day of intervention. A one week of trial session was given to the participants so that they are adapted to the intervention. After the trial session there were 2 participants who refused to participate in the study.

**Procedure:**

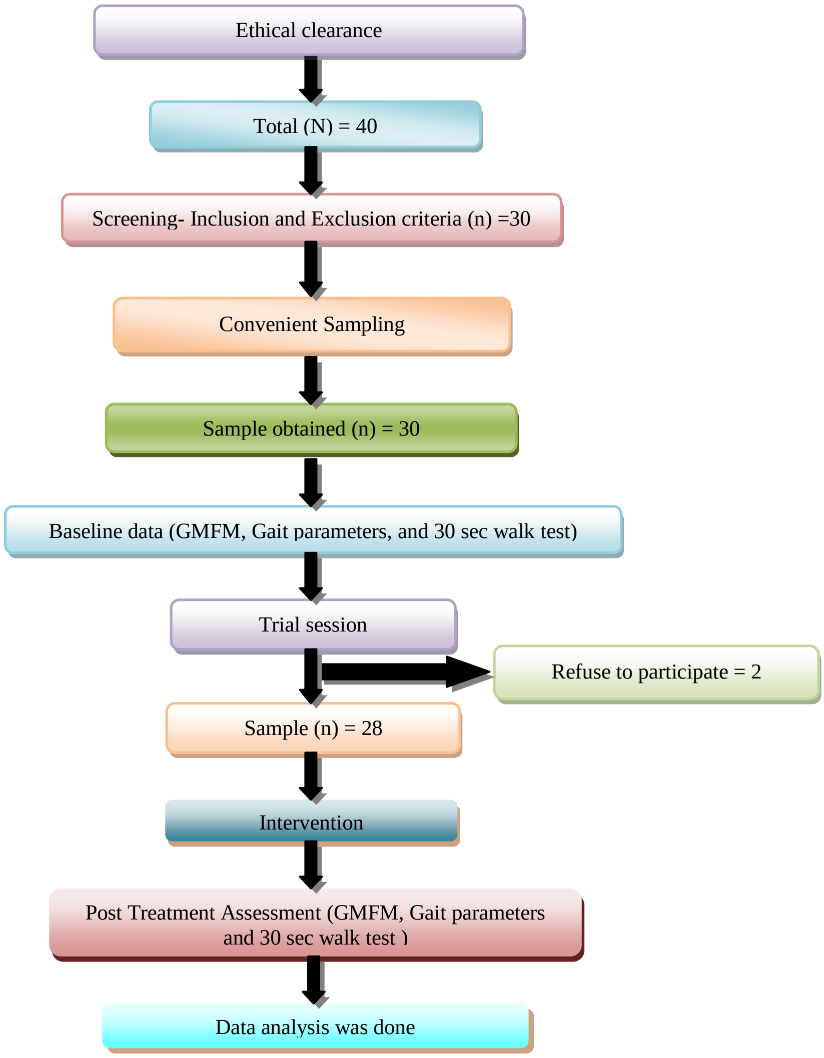



**Figure 3: Flow chart showing the procedure used in the study**

Therefore, 28 participants were further included in the study. Data was collected on 1st and 12th weeks of the intervention period. The training was given once a day, thrice a week for total 12 weeks. The training duration for each session was for 50-60 minutes with 5 minutes of rest period and. Reassessment was done after the end of 12th week and data analysis was done. The reading for the study were taken as follows-

Felt tip marking pens were taped to the back and front of the participants shoes so that the tip just reaches the floor when he/she is standing. Before the procedure, the participants were instructed to take a few steps at the side of the walkway to ensure that the markers are correctly positioned to indicate heel contact. Measurements were made of distance from each heel contact pen mark to next heel contact pen mark on the same side (Stride length) and on alternative sides (Step length) and of distances of width between successive marks (BOS). The middle three steps are averaged for each side to obtain the measurement. Cadence is calculated as steps per minute.

After the assessment was done the intervention begins. The treatment session lasted for approximately 50-60 minutes for 12 weeks. They received individualized instructions for an independent self stretching exercise program for bilateral hip flexor, knee extensor, knee flexor and ankle plantar flexor muscles as a 10-15 minute warm up prior to cycling.

Training period consist of cycling in which the participants were asked to do cycling for 15-20 minutes. The seat location was adjusted to ensure a knee joint angle between 15-20 degrees of flexion when the knee is maximally extended during cycling. If the child was feeling difficulty in the transition he/she was assisted by the therapist in moving the foot forward from the top of the pedaling cycle. The participants were instructed to avoid locking the knees in full extension near the bottom of the pedaling cycle because it might lead to compensation for weak muscle. During subsequent sessions the resistance was gradually increased. A variety of motivational strategies was used during the intervention to promote continued cycling and to increase intensity of effort like verbal encouragement, listening to music, pretending to play and counting the number of lower extremity revolution if possible.

When the participants started expressing a high level of fatigue the level of resistance was decreased or the participants were instructed to slow the pedaling rate. The participants were encouraged to gradually increase the exercise duration up to 20 minutes over a period of 12 weeks. After cycling session was over a cool down was started for about 10 minutes in which the participants were asked to do slow pedaling without any resistance. Reassessment was done after the end of 12 weeks and data analysis was done.

***Statistical methods***

The data which was collected on 1$^{st}$ week and on 12$^{th}$ week was used to analyze the results. An average of 3 trials was taken. Comparison was made between the pre and the post intervention readings. Statistical analysis was done using Graph Pad Instat software. Various statistical measures such as mean, standard deviation (S.D) and test of significance such as Paired 't' test were utilized to analyze the data. The results were concluded to be statistically significant with $p < 0.05$, highly significant with $p < 0.01$ and extremely significant with $p < 0.0004$.

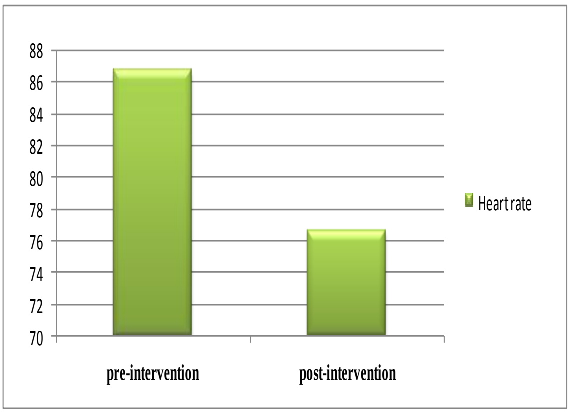
## RESULTS

A total of 40 children with spastic lower extremity were screened for the study from February 2015 to November 2015. Out of which 30 participants were selected based on the inclusion and exclusion criteria. Using convenient sampling 30 participants were eligible for the study. There were 2 dropouts during the intervention. A total of 28 participants were examined for the study. The mean age of the participants was 9.71 with standard deviation of ±2.94. The gender ratio of boys to girls in intervention group was 13 girls and 15 boys.

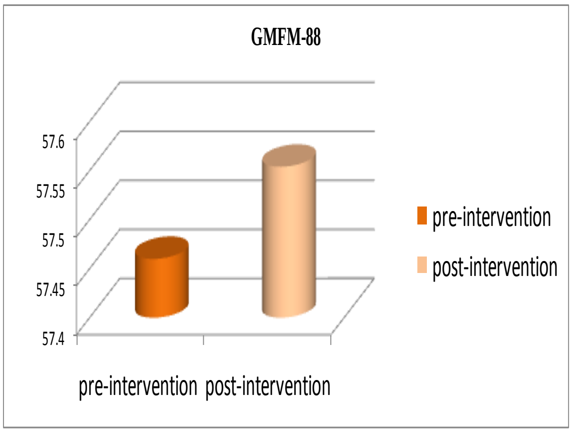
**Heart Rate:** The heart rate was measured with the help of the 30 second walk test. The pre intervention mean HR score was 86.786 ± 11.097 and the post intervention mean HR score was 76.571 ± 8.808. Using the 'paired t test' the difference in pre and post intervention mean HR score was statistically extremely significant that is 'p' $< 0.0004$, t value=3.815 with d.f= 54.

**Gross Motor Function Measure (GMFM-88):** The gross motor ability of the participant was measured with the help of the GMFM-88 score. The pre intervention mean GMFM-88 score was 57.460 ± 3.583 and the post intervention mean GMFM-88 score was 57.554 ± 3.634. Using the 'paired t test' the p value was 0.0130 which denoted significant differences as the value of p $<0.05$, t value= 2.660 with d.f = 27.

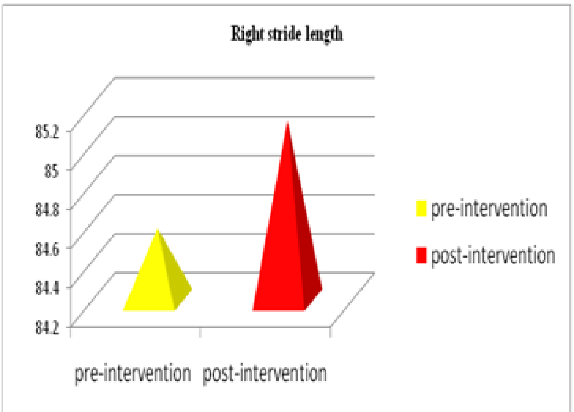
**Right Stride Length:** The pre intervention mean of right stride length score was 84.568cm ± 10.24cm and the post intervention mean of right stride length was 85.119cm ± 10.498cm. Using the 'paired t test' the p value was 0.0476 which denoted significant differences as the value of $p < 0.05$, t value=2.076 with d.f = 27.




**Graph 1: Comparison between pre and post intervention mean heart rate score**

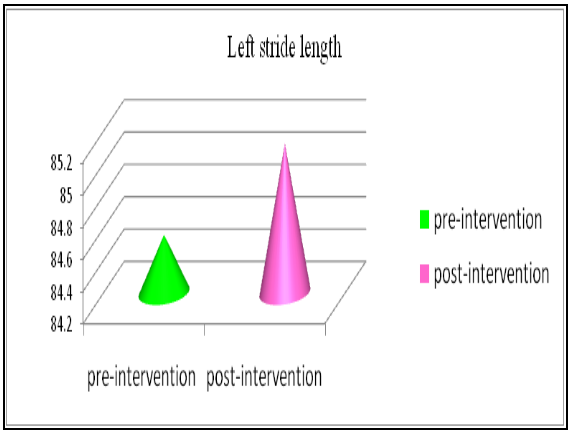



**Graph 2: Comparison between pre-intervention and post-intervention mean GMFM-88 score.**



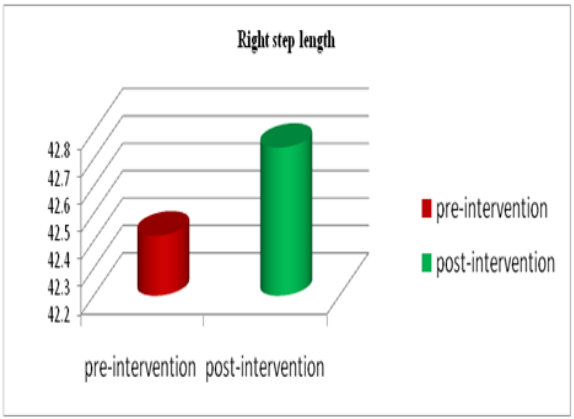

**Graph 3: Comparison between pre and post intervention mean value of right stride length**

**Left stride length:** The pre intervention mean of left stride length score was 84.559cm ± 10.226cm and the post intervention mean of left stride length was 85.123cm ± 10.399cm. Using the 'paired t test' the p value was 0.0458 which denoted significant differences as the value of $p < 0.05$, t value=2.093 with d.f = 27.



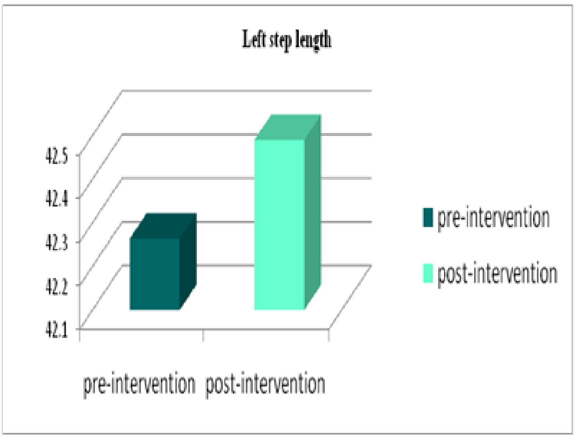

**Graph 4: Comparison between the pre and post intervention mean value of left stride length**

**Right Step Length:** The pre intervention mean of right step length score was 42.420cm ±5.153cm and the post intervention mean of right step length was 42.741cm ± 5.788cm. Using the 'paired t test' the p value was 0.0314 which denoted significant differences as the value of $p < 0.05$, t value= 2.269 with d.f = 27.



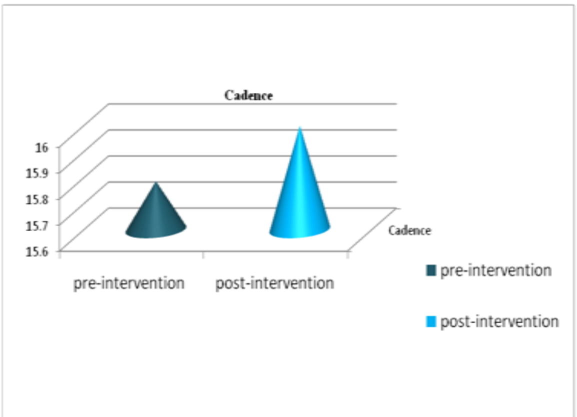

**Graph 5: Comparison between the pre and post intervention mean value of right step length**

**Left Step Length:** The pre intervention mean of left stride length score was 84.559cm ± 10.226cm and the post intervention mean of left stride length was 85.123cm ± 10.399cm. Using the 'paired t test' the p value was 0.0458 which denoted significant differences as the value of $p < 0.05$, t value=2.093 with d.f = 27.

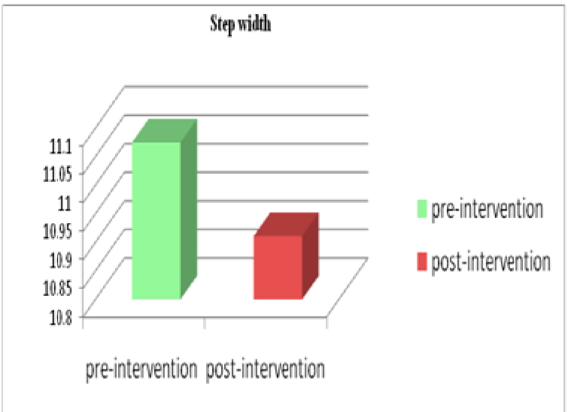



**Graph 6: Comparison between the pre and post intervention mean value of left step length**

**Cadence:** The pre intervention mean of cadence score was 15.786steps/min ±2.515 steps/min and the post intervention mean of cadence score was 16.000 steps/min ±2.653 steps/min. Using the 'paired t test' the p value was 0.0114 which denoted significant differences as the value of $p < 0.05$, t value=2.714 with d.f = 27.




**Graph 7: Comparison between the pre and post intervention mean value of Cadence**




**Graph 8: Comparison between the pre and post intervention mean value of step width**

**Step Width:** The pre intervention mean of step width score was 11.075cm ±1.589cm and the post intervention mean of right step width was 10.911cm ±1.694cm. Using the 'paired t test' the p value was 0.0011 which denoted significant differences as the value of $p < 0.01$, t value=3.659 with d.f = 27.

## DISCUSSION

In some studies there was significant improvements found in cycling ability, duration of pedaling, speed and resistance and they concluded that a relatively short, clinically feasible training program on a static bicycle can lead to valuable improvements in functional ability in young people with CP. Heather and Teresa also concluded that a relatively short training program on a stationary bicycle adapted to provide additional postural support associated with a clinically relevant improvement in standing and walking abilities of young people with CP who are non-ambulant and suggested that this form of safe and effective treatment for young people with CP should be considered for clinical practice.

Gait or locomotion is very important for an individual to move from one place to another place for the means of daily activity. The result of right and left stride length was assessed prior to the intervention and on 12$^{th}$ week of intervention. Its shows significant difference it concludes that there is improvement in forward rotation of the pelvis and extension of the hip and knee on the weight bearing side. Increased in stride length and plantar-flexor generating power at push off after training was seen. This could be explained by better stability around both hip and knee that increases stability in stance and which makes it easier for the ankle plantar-flexors to push off actively. The increased stride length and push off corresponds well with the increase in muscle strength around the hips and with the increase in balance as visible on the GMFM.

The result of right and left step length shows significant difference which concludes that there is improvement in ground clearance which suggests that there is improvement in dorsiflexor strength and appropriate hip-knee flexion is achieved.

Weakness of quadriceps and hip extensor muscles was shown to be a factor in crouch gait and contribute to the walking impairment. The observed improvement in the intervention group can be attributed to the effect of cycling intervention through repeated pedaling controlled motion that resulted in training of the muscles to perform in a specific way that mimic normal body movement. Strengthening the lower limb muscles may regulated the ratio between excitatory and inhibitory impulses and resulted in decreasing the co-contraction of both agonist and antagonist group of muscles. Strength training works to reduce the chances of developing contracture by keeping the muscles strong and limber and regulate the ratio between both excitatory and inhibitory impulses of the spastic muscles. Hence, Pedaling exercise improves the strength of the weak muscle which in turn helps to decrease spasticity and improve the gait pattern. [24]

There is also gradual decrease in base of support and increase in number of steps which tells that there is improvement in balance and co-ordination. Stationary cycling is an exercise that minimizes the need for balance and coordination providing children with CP the opportunity to exercise at a higher intensity than is otherwise possible. Adaptations can be made to the stationary cycle to accommodate individual impairments. During cycling, agonists and antagonists of the hip, knee, and ankle may be strengthened simultaneously. Research has shown that children with CP can cycle independently but demonstrate differences in muscle recruitment patterns, joint kinematics and pedal forces compared to children without CP. [25]

The results of the current study is supported by the work of Ross and Engsberg, who recorded improvement in linear gait variables (speed, stride length, cadence) in Ninety-seven participants with spastic diplegia CP who ambulated with or without an assistive device, and concluded that strength training was highly related to walking functional abilities. The results of the current study also comes in agreement with Andersson and Colleagues who reported significant improvements in muscle strength, motor function, and gait speed in 22 spastic diplegic patients treated by strength training and concluded that strength exercises could improve function, maintain ADL status, and prevent deterioration in CP children.

The studies has been documented that children with cerebral palsy use excessive muscle co-contraction during voluntary movement, a clinical concern is the potential for inadvertent strengthening of the spastic antagonist muscle during training of the agonist through persistent co-contraction or other neural mechanisms. [26] The study by Unger et al used a 3-D gait analysis video recording system which assessed gait using the GMFM goal dimensions. A major criticism of all the trials is that none assessed the cost of their trial relative to clinical practice. Unger et al. applied a combination of resistances, to the upper and lower limbs to promote muscle strength, but measured gait (length, velocity and cadence) and perceptions of body image and functional competence as outcomes. Basic strength training exercises focused on strengthening specific postural muscle groups especially in the lower limbs may not necessarily increase gross motor functioning measured as outcomes in these studies. Specific task-oriented activity training may have been more appropriate, were it integrated in trials to facilitate integration of strength, with balance and coordination components, that normalize dynamic movements. Therefore, the given information is insufficient to support the use of strength-training programs for specific muscle groups, in the rehabilitation of children and adolescents with CP. [27]

The result of the current study may be clarified by the concept that strength and endurance exercises improved the general condition of the participated children that may result in improving physical fitness, delay of occurrence of fatigue and increasing the ability of the child to cycle for longer duration. Many authors reported that children with disabilities tend to be weaker and more susceptible to early fatigue than their peers. They have higher metabolic, cardiorespiratory, and mechanical costs of mobility, which cause early fatigue and decreased exercise performance. Strength and endurance training are components of physical fitness that may prevent secondary complications, lower energy costs of movement and enhance quality of life for disabled children. Improvement in the strength and endurance increases the balance and dissociate the movement which is required for the normal gait.

## CONCLUSION

Children with spastic lower extremity have an improvement in gait parameters when rehabilitated with PEDALS for 12 weeks.

## REFERENCES


1. Pamela K, Cynthia Norkin. Joint Structure and Function: Gait. Fourth edition. New Delhi: JAYPEE; page no-517,519-522.
2. Edgar T S. Spasticity. Current management in child neurology. Third edition. BC Decker Inc; page no-257-264.
3. Dijkstra E J. Modelling of the upper limb. University of Twente [Internet]. Available at:http://essay.utwente.nl/60134/1/openbrr_EJ_Dijkstra_s0142395_Repert.pdf
4. AANS- Spasticity, 2006. Available at: http://www.aans.org.
5. Tilton A, Adams JV, Delgado MR. Pharmacologic Treatment of Spasticity in Children. Seminars in Pediatric Neurology. 2010: 17:261-267.
6. Spasticity (Pediatric). Department of Neurosurgery, NY. Available at: http://neurosurgery.med.nyu.edu/conditions-we-treat/z-conditions-guide/ spasticity.
7. Sankar C, Mundkur N. Cerebral Palsy-Definition, Classification, Etiology and Early Diagnosis. Indian Journal of Pediatrics. October 2005:865-868
8. Sellier E, Surman G, Himmelmann K, et al. Trends in prevalence of cerebral palsy in children born with a birth weight of 2,500 or over in Europe from 1980 to 1998. European Journal of Epidemiology.2010: 25(9):635-642.
9. Brogren E, Forssberg H, Hadders M. Influence of two different sitting positions on postural adjustments in children with spastic diplegia. Developmental Medicine & Child Neurology 2001:43:534-546.
10. Bandi S, Ward AB. Spasticity. International Encyclopedia of Rehabilitation; 2010. [http://cirrie.buffalo.edu/encyclopedia/pdf/fr/la_spasticite.pdf]
11. International Brain Injury Association: Focal and multi-focal problems of spasticity. Available at: http://www.internationalbrain.org/articles/focal-and-multifocal-problems-of-spasticity.
12. Richard W, Melissa S. Interrater Reliability of a Modified Ashworth Scale of Muscle Spasticity. Physical therapy journal. February 1987:67 (2):206,207.
13. Palisano R, Rosenbaum P, Walter S, Russell D, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Development Medicine and Child Neurology. 2008:50:5.
14. Jan Tecklin. Pediatric Physical Therapy. fourth edition. Philadelphia:Lippincott Williams and Wilkins;2008.
15. Available at: http://www.aans.org /PatientInformation/ConditionsandTreatments/Spasticity.aspx.
16. Stokes M. Physical Management in Neurological Rehabilitation. Second Edition. Elsevier Mosby, Chapter 4; 48 ,50.
17. Sunnerhagen KS, Olver J, Francisco GE. Assessing and treating functional impairment in poststroke spasticity. Neurology 2013: 80.
18. Eileen G Fowler, Loretta M Knutson, Sharon K DeMuth, Mia Sugi1,et al. Pediatric endurance and limb

strengthening for children with cerebral palsy (PEDALS)- a randomized controlled trial protocol for a stationary cycling intervention. BioMed Centeral Pediatrics. 21 March 2007:7 (14):1-9.
19. Carolyn K, Lynn C. Therapeutic exercise: Foundations and Techniques. Fifth edition. Philadelphia: Davis Company; 2002.
20. United Cerebral Palsy Research and Education Foundation. Exercise Principles and Guidelines for Persons with Cerebral Palsy and Neuromuscular Disorders 1999. [http://www.ucpaindy.org/wp-content/uploads/2010/03/Exercise-Principles-and-Guidelines-for-Persons-with-Cerebral-Palsy-and-Neuromuscular-Disorders.pdf]
21. Rimmer J H. Physical fitness levels of persons with cerebral palsy. Developmental Medicine and Child Neurology 2001:43:208-212.
22. Ryan MM, Gregor RJ. EMG profiles of lower extremity muscles during cycling at constant workload and cadence. Journal of Electromyography and Kinesiology. 1992:2 (2): 69-80.
23. Lisa M, Dianne J, Parminder S, Stephen D , et al . Rasch Analysis of the Gross Motor Function Measure:Validating the Assumptions of the Rasch Model to Create an Interval-Level Measure. Arch Phys Med Rehabilitaion. May 2003:84: 697-705.
24. Manal Salah El Dien. Effect of Limb Strengthening on Gait Parameters in Spastic Diplegic Cerebral Palsied Children, Bull. Fac. Ph. Th. Cairo Univ.Jan 2008:13 (1):223-232.
25. Siebert K L, DeMuth S K, Knutson L M, Fowler E G. Stationary Cycling and Children with Cerebral Palsy: Case Reports for Two Participants. Physical & Occupational Therapy in Pediatrics 2010:30 (2):125-138.
26. Diane L, Mark F. Functional outcomes of strength training in spastic cerebral palsy. Arch Phys Med Rehabilitation. February 1998:79:119-125.
27. Verschuren O, Ada L, et al. Muscle Strengthening in Children and Adolescents With Spastic Cerebral Palsy: Considerations for Future Resistance Training Protocols. Physical therapy. 5 May 2011:91:1130-1139.

How to cite this article: Khan SS, Malawade M, Kulkarni S et al. Effectiveness of pediatric endurance and limb strengthening (PEDALS) on gait parameters in children with spastic lower extremity. Int J Health Sci Res. 2016; 6(6):199-210.

***********