Effect of Limb Strengthening on Gait Parameters in Spastic Diplegic Cerebral Palsied Children

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ABSTRACT

Background and purpose: *In the past, strengthening exercises were considered inappropriate for children with spastic cerebral palsy (CP) due to concern that they would escalate abnormalities including spasticity and abnormal movement patterns. The purpose of this study was to investigate the effect of stationary cycling as a form of muscle strengthening intervention on improving walking functional ability in sapastic diplegic cp children.* ***Subjects and procedures:*** *Thirty children with spastic diplegic CP ranged in age between 7 and 10 years recruited in this study. Participants were selected from outpatient clinic of faculty of physical therapy Cairo University and were randomly assigned into two groups of equal number the first group (control group) received a selected traditional physical therapy treatment program while the second group (study group) received in addition to the traditional program an intervention (cycling). The cycling intervention was divided into strengthening and endurance exercise phases. During the strengthening phase, the resistance during lower extremity cycling was progressively increased. The endurance phase focused on increasing the intensity and duration of cycling. Children were encouraged to exercise within a target heart rate (HR) range (70% maximum HR) for thirty six sessions over 12 weeks period. All children were evaluated before (baseline) and after (follow-up) the intervention period. Outcome measures were: gait parameters including step length, cadence and speed that were detected by using motion analysis system with six proreflex cameras.* ***Results:*** *children in the cycling group demonstrated a significant improvement in all measured parameters after the suggested treatment period compared to those of the control group (P<0.05).* ***Conclusion:*** *cycling as a form of strengthening exercise is an effective intervention in improving walking functional abilities in children with diplegic CP.*
Key words: *Cerebral palsy - Strength training - Cycling - Endurance.*

INTRODUCTION

Cerebral palsy is caused by an insult to the developing brain. The prevalence is between 1.5 and 2.5 per 1,000 live births in developed countries[22]. Spastic diplegia is the most common form of CP[2]. Children with diplegia exhibit weakness and low endurance[6,7,29,30]. Historically, programs to promote physical fitness, including strengthening and cardiorespiratory fitness exercise, were discouraged for patients with spastic CP due to the concern that spasticity and abnormal movement patterns would worsen[5].

Scientific evidence has not supported this concern[9,19] and some researches indicates that resistive exercise is an effective intervention to improve strength and function in children with CP[21]. However, a recent review of strengthening intervention studies concluded that more research is needed for detecting the effect of strengthening exercises on functional abilities of cerebral palsied children[14].

Cycling is a rehabilitation tool often used by physical therapists to improve strength and cardiorespiratory fitness[28] and has been promoted as an appropriate exercise to improve fitness for persons with CP[24]. Stationary cycling programs can provide progressive resistance exercise for lower extremity musculature, they have the potential to improve strength and cardiorespiratory fitness with minimal requirements for balance and motor control[17].

The purpose of this study was to evaluate the effectiveness of a stationary cycling intervention on functional gait parameters in children with spastic diplegic CP.

SUBJECTS, MATERIAL AND METHODS

Subjects

Subjects participated in this study included thirty children with a diagnosis of spastic diplegic CP. They were selected from outpatient clinic of faculty of Physical Therapy Cairo University according to the following inclusion criteria:

- Their ages ranged between 7 and 10 years.
- They had the ability to follow simple verbal instructions.
- They had good or fair selective motor control for at least one lower limb (can isolate knee and ankle joint motion out of synergy)[27].
- They had the ability to walk independently indoors, with or without assistive devices.

Exclusion criteria:

- Orthopedic and neurological surgery.
- Subjects who have bilateral poor selective motor control.
- Patients with cardiac disease, diabetes or uncontrolled seizures.
- Significant hip, knee or ankle joint contractures that may prevent passive movement of the lower limbs through the pedaling cycle.

Procedures

Evaluation procedures:

Assessment of gait parameters: Motion analysis system, which consists of:

- A camera system with six cameras (Pro Reflex).
- A wand kit that was used for calibration of the system.
- A personal computer with the Q Trac software installed.
- ACB- 530 serial interface adapter.
- A communication card, which was mounted in the PC.
- Eighteen reflected dots.
- Walkway of eight-meter length and 120 cm width.

Before starting capture, specific bony landmarks were marked by reflected dots that were fixed to the skin by adhesive straps on both sides of the body as illustrated in (fig.1). The following land markers were detected for placing the reflected dots:

- Knee joint line: In the middle of the lateral knee joint line.
- Suprapatellar.
- Tibial tuberosity.
- Ankle: At the lateral malleolus.
- Foot: Between the second and third metatarsals.
- Heel: on the posterior aspect of the calcaneus.
- Shoulder: At the superior surface of the acromion.
- 12th Thoracic vertebra.
- Sacrum.
- Anterior superior iliac spines.

After Markers placement, each child was asked to stand at the wooden walkway and to walk along its path while capturing started from its middle.

Fig. (1): The child with reflected dots on bony landmarks.

Treatment procedures:

Treatment for Control group:

Children in this group received traditional physical therapy treatment program including:

- Neuro-developmental technique.
- Training of active trunk extension.
- Facilitation of protective reaction from standing on the balance board.
- Exercises to maintain the optimum length of the muscles especially the tendoachilis, hamstrings, hip flexors and adductors in the lower limbs.
- Gait training exercises were applied as follows:
  - Weight bearing on each lower limb during standing and walking.
  - Sideway, forward and backward walking between the parallel bars in front of a large mirror.
  - Training for ascending and descending stairs.
  - Training for walking across different obstacles in the walking track.

Treatment for study group:

Children in this group received the previous traditional physical therapy treatment program given to the study group in addition to cycling intervention. Cycling was done by using bicycle ergometer (Monrak Rehab Trainer model 88 IE) it is supplied by an electronic monitor that can display pedal revolutions per minute and total cycling duration. Cycling was done in two phases:

Phase 1: lower extremity strengthening

The seat location was adjusted to ensure that knee joint angle between 15 and 20 degrees of flexion when the limb is maximally extended during cycling[8].

As the lower limb moves from maximum flexion into extension at the top of the pedal revolution assistance was given for the child who had difficulty transferring resistance from one limb to the other.

Children were instructed to avoid "locking" the knees in full extension near the bottom of the pedaling cycle, which might occur as a compensation for weakness.

Patient performed pedaling on the bicycle starting with unloaded cycling for 3 minutes as warming up, and then continuously incrementing work rate was added[8]. Once the subject was able to cycle in a smooth pattern without difficulty for ten complete pedaling revolutions, the resistance increased gradually.

The above protocol of gradual resistance increase was repeated until the subject either cannot cycle at the given resistance or the cycling pattern is not smooth.

Phase 2: endurance training

At the beginning of each session, resting heart rate (HR) was recorded after a period of quiet sitting. A target HR range of 70% maximum HR was calculated for each session using the Karvonen Formula[17] (Target HR = [(HR max – HR rest) × 0.70] + HR rest; where HR max = 220 - age).

Cycling began at a low level and was adjusted up or down according to the subject's ability. When the subject was able to cycle for

10 consecutive minutes within the target HR range, they were encouraged to gradually increase their exercise duration to a maximum of 30 minutes over the thirty six sessions. A cool-down period took place at the end of the intervention as the subject pedals without resistance until his/ her HR decreases to within 20 beats above baseline.

RESULTS

This work demonstrates the statistical analysis of gait parameters including (step length, cadence and speed) for thirty diplegic cerebral palsied children.

The collected data for both groups were statistically treated to show the mean values and standard deviation of all measured parameters before and after the suggested treatment period. The student t-test was applied to determine the significance of treatment among both groups.

1- Gait parameters for both control and study groups before treatment:

As shown in table (1) and illustrated in Figures (2a,b and c) there was statistically insignificant difference between both groups for measured gait parameters including step length, cadence and walking speed as the mean values for both control and study groups were 0.29±0.05 and 0.29±0.04 for the step length and 145.46±4.89 and 145.13±6.68 for cadence while for walking speed they were 0.31±0.05 and 0.29±0.030 respectively (P>0.05).

Table (1): Comparison between mean values of step length, cadence and speed before treatment for both control and study groups.

Gait parameters	Step length (m)		Cadence (steps/min)		Speed (m/s)	
	control	study	control	study	Control	study
$\bar{X}$ ± SD	0.29±0.05	0.29±0.04	145.46±4.89	145.13±6.68	0.31±0.05	0.29±0.03
MD	0.002		0.33		0.02	
t value	0.15		0.29		0.94	
P value	P>0.05		P>0.05		P>0.05	
Significance	NS		NS		NS	

$\bar{X}$: Mean SD: Standard deviation MD: Mean differences P-Value: probability value
NS: Non Significance t value: Paired t value

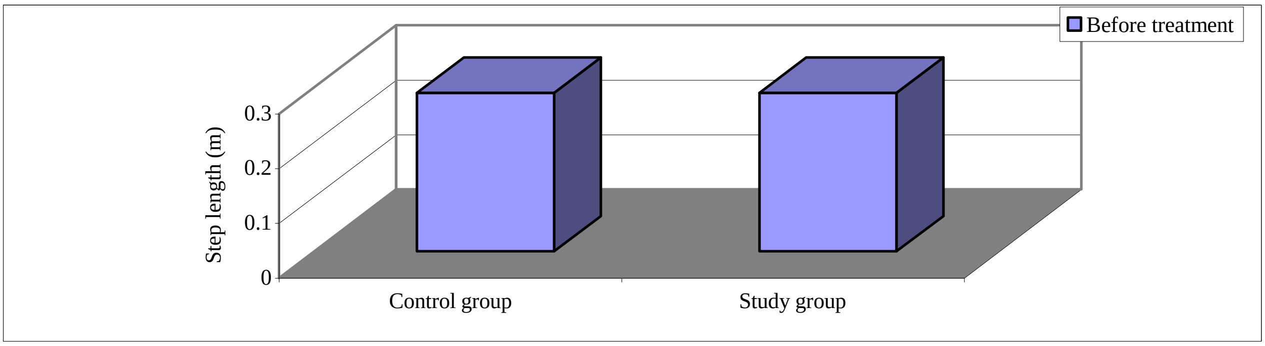

Fig. (2a): Mean values of step length (in meters) before treatment for both control and study groups.

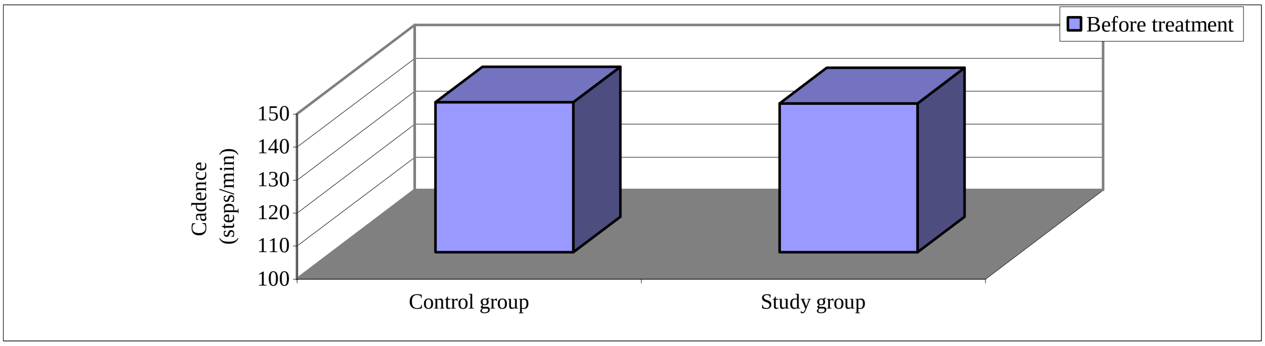

Fig. (2b): Mean values of cadence before treatment for both control and study groups.

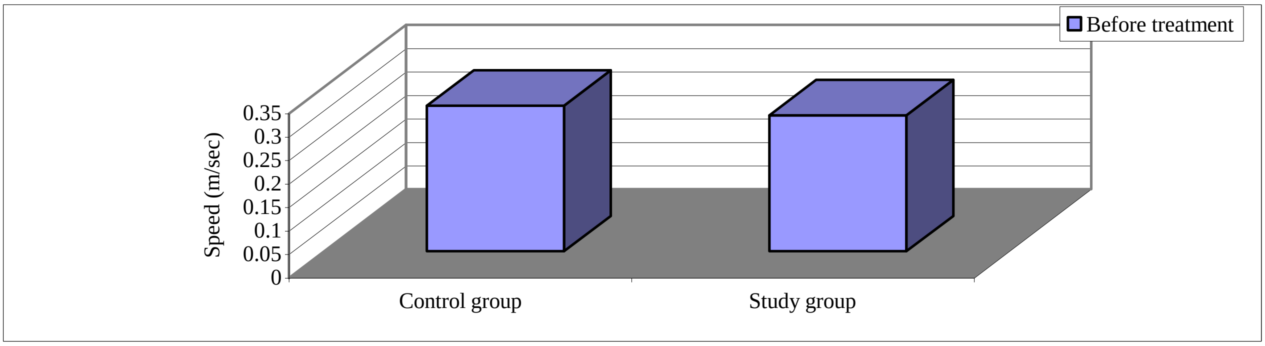

Fig. (2c): Mean values of speed before treatment for both control and study groups.

2- Gait parameters for both control and study groups after treatment:

As shown in table (2) and illustrated in Figures (3a, b and c) there was statistically significant difference between both groups for measured gait parameters including step length, cadence and walking speed as the mean values for both control and study groups were 0.31±0.04 and 0.36±0.07 for the step length and 143.53±5.13 and 140.26±7.33 for cadence while for walking speed it was 0.38±0.07 and 0.43±0.04 respectively (P<0.05).

Table (2): Comparison between mean values of step length, cadence and speed after treatment for both control and study groups.

Gait parameters	Step length (m)		Cadence (steps/min)		Speed (m/s)	
	control	Study	control	study	control	study
$\overline{X}$ ± SD	0.31±0.04	0.36±0.07	143.53±5.13	140.26±7.33	0.38±0.07	0.43±0.04
MD	0.05		3.27		0.05	
t value	2.37		2.39		2.03	
P value	P<0.05		P<0.05		P<0.05	
Significance	S		S		S	
% of changes	16.12%		2.27%		13.15%	

$\overline{X}$: Mean SD: Standard deviation MD: Mean differences P-Value: probability value
S: Significance t value: Paired t value

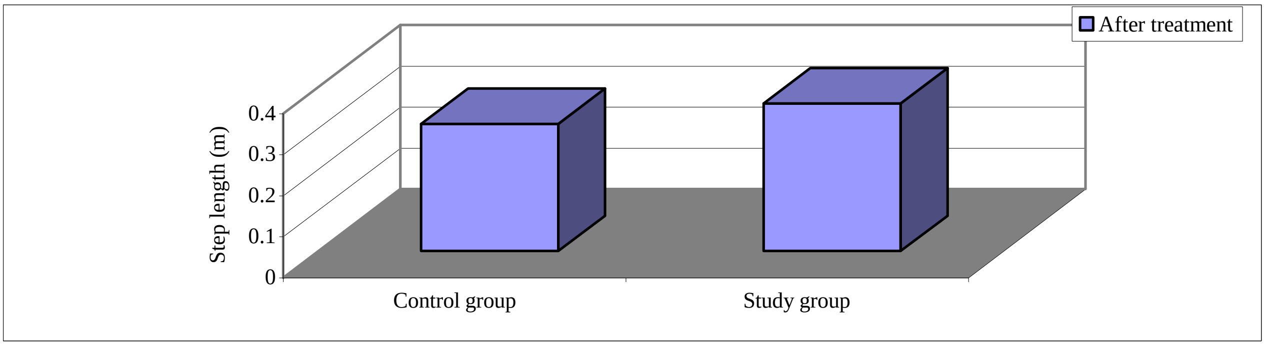

Fig. (3a): Shows the mean values of step length after three months for both control and study groups.

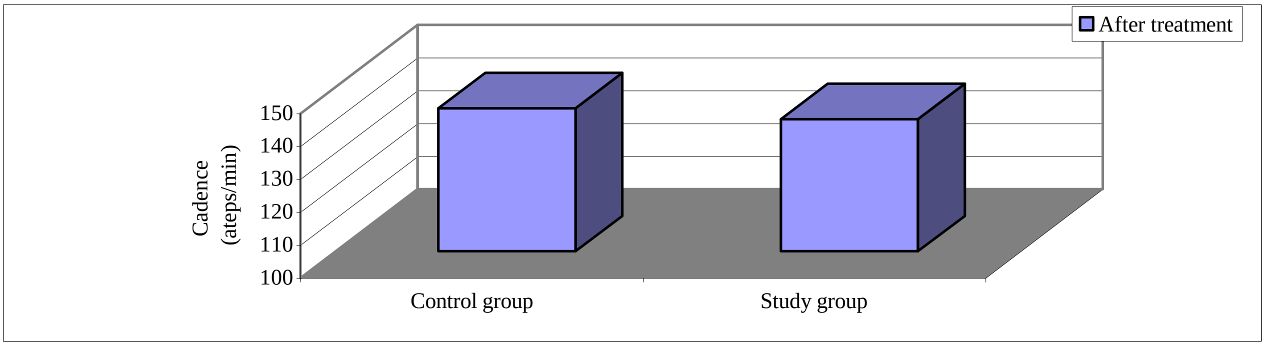

Fig. (3b): Shows the mean values of cadence after three months for both control and study groups.

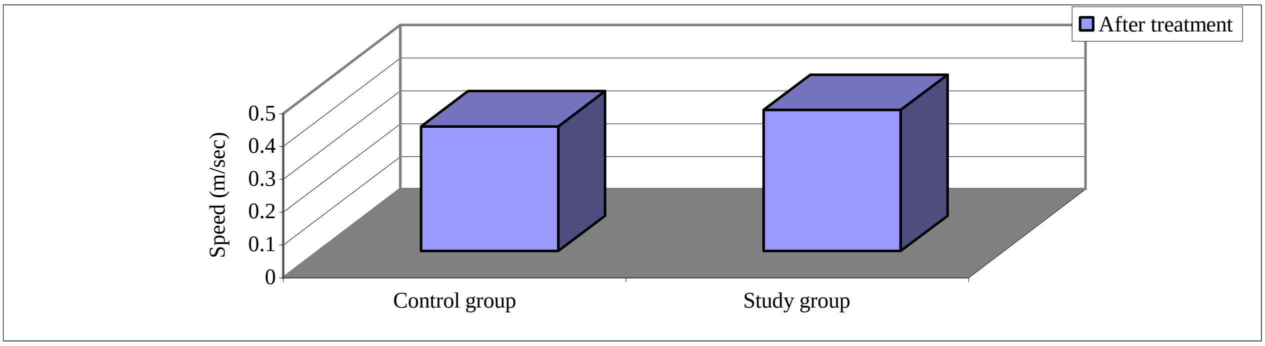

Fig. (3c): Shows the mean values of speed after three months for both control and study groups.

DISCUSSION

The effect of cycling as a form of strengthening exercises on changing walking functional abilities of spastic diplegic cerebral palsied children was the issue of the current study. Gait parameters including step length, cadence and walking speed were used in this study as indicators for detecting the effect of cycling intervention on linear gait parameters of diplegic CP children.

The results of the present study revealed statistically insignificant difference in the pre treatment mean values of the two groups and a significant improvement was recorded in the study group when comparing its post-treatment mean values to their corresponding values in the study group.

The abnormal gait parameters in both groups before treatment application may be attributed to many factors as spasticity, muscle weakness and cocontraction of both agonist and antagonist muscle groups during walking activity. This is supported by previous studies[10,26] who reported that, CP disrupts the ratio of excitatory and inhibitory impulses from afferent nerves, resulting in cocontraction of the agonist and antagonist muscle groups at the same moment. 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 study 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 cocontraction of both agonist and antagonist group of muscles.

The obtained results is supported by many authors[11,16,18,23] who recorded that weakness and resultant lack of physical activity is a major problem affecting the function and health of children with CP. Those children often have difficulty engaging in activities like freely move and stretch their muscles and tendons as they walk, run or perform daily functions, causing their muscles to grow slower than their bones. That results in contracture which is one of the most serious complications of cerebral palsy. 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.

The results of the current Study also illustrate that strength training for people with cerebral palsy lead to increased walking speed and efficiency of walking activity which clarified that there was a correlation between leg muscle strength and walking ability, indicating that people with weaker leg muscles exhibit a tendency to crouch more in their gait.

The results of the current study is supported by the work of Ross and Engsberg[25] 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[1] who reported significant improvements in muscle strength, motor function, and gait speed in 22 spastic diplgic patients treated by strength training and concluded that strength exercises could improve function, maintain ADL status, and prevent deterioration in CP children.

The results of the present study is supported by the work of Berg[3] on five boys with CP between the ages of five and seven years participated in an eight-week program included lower limb cycling on an aerobic exercise intervention. Children cycled an average of 30 minutes per day. Parents gave the cycling a high ranking indicating that their children exhibited greater mobility and improved cardiorespiratory fitness.

The results of the current study is also supported by the work of Eagleton et al.,[12] who recorded significant increase of the distance walked in 3 minutes, gait velocity, step length, and a decrease in the cadence and energy expenditure index of 13 children with cerebral palsy who could ambulate at least 45 m and underwent a strength training program including progressive resistance and flexibility exercises for the lower extremities.

The results 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 resulted in improving physical fitness, delay of occurrence of fatigue and increasing the ability of the child to cycle for longer duration.

This comes in agreement with many authors[7,10,13] who 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 (force-generating capacity of muscle) training and endurance training are components of physical fitness that may prevent secondary disorders, lower energy costs of movement, and enhance quality of life for those children.

The post treatment results of the current study comes in agreement with Blundell et al.,[4] who reported improvement in strength, Walking speed, stride length, cadence and functional performance that was maintained over time as walking speed increased from 0.70 m/s at baseline to 0.88 m/s after 4 weeks of short specific task-specific strengthening exercise training.

McBurney et al.,[20] investigated the positive and negative outcomes of strength-training program for young people with CP and reported that the program generated positive outcomes with only minor negative responses in strength, flexibility, posture, walking, and the ability to negotiate steps had improved. In addition, participants reported psychological benefits such as a feeling of increased well-being and improved participation in school and leisure activities.

The post treatment results of the present study is supported by the work of Dodd et al.,[9] who evaluated the effects of a six-week strength-training program on lower limb strength and physical activity of 21 young people with spastic diplegic CP and reported increased lower limb strength, the ability of standing, walking, running and jumping, and faster stair climbing.

The results of the current study is supported by Williams and Pountney[31] who investigated the effects of strengthening exercise on the motor function of 11 cp children using an adapted stationary bicycle.), they recorded significant improvements in GMFM including Standing, Walking, Running, and Jumping over the intervention period. Significant improvements were 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[15] 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.

Conclusion

From the obtained results it can be concluded that strength exercises should be included in the physical therapy rehabilitation program for cerebral palsied children and static bicycle provided a safe, effective means of exercise to a population with very limited activity.

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الملخص العربي

تأثير تقوية العضلات على المعايير القياسية للمشي عند الأطفال المصابين بالشلل المخى التشنجي

الخلفية والهدف : في الماضي كان يستبعد تقوية العضلات من برامج تأهيل الأطفال المصابين بالشلل التشنجى نظراً للاعتقاد أنها من الممكن أن تزيد من التوتر النغمى للعضلات ونسبة التشنج للعضلة. وقد أظهرت العديد من البحوث الحديثة أن دراسة تأثير برامج تقوية العضلات على تحسين الأداء الوظيفى عند الأطفال المصابين بالشلل المخى التشنجى يحتاج الى المزيد من البحث . لذا تهدف هذه الدراسة الى تحديد تأثير استخدام العجلة الثابتة (كأحدى الوسائل المستخدمة فى تقوية العضلات) على المعايير القياسية للمشى من حيث طول الخطوة وعدد الخطوات فى الدقيقة وكذلك سرعة المشي . **عينة البحث :** تم إجراء البحث على ثلاثون طفلاً تراوحت أعمارهم بين 7و10 سنوات من المصابين بالشلل المخى التشنجى تم اختيارهم يعانون من درجة متوسطة من التشنج العضلى ويستطيعون المشى بمفردهم حتى ولو باستخدام احدى الوسائل المساعدة . وقد تم اختيارهم من العيادة الخارجية لكلية العلاج الطبيعى- جامعة القاهرة . **طريقة البحث :** تم تقسيم الأطفال عشوائياً الى مجموعتين متساويتين فى العدد وتلقت المجموعة الأولى (الضابطة) البرنامج التقليدى للعلاج بينما تلقت المجموعة الثانية (التجريبية) نفس البرنامج بالاضافة الى استخدام العجلة الثابتة مع الزيادة التدريجية للمقاومة حسب استجابة الطفل . **النتائج :** أظهرت النتائج عدم وجود فروق ذات دلالات احصائية بين كلتا المجموعتين قبل بدء العلاج بينما وجد فروق ذات دلالات احصائية بين كلتا المجموعتين فى كل المعايير المقاسة بعد الفترة المحددة للعلاج لصالح المجموعة التجريبية . **المناقشة والملخص :** يمكن إرجاع التحسن في الكفاءة الوظيفية للمشي إلى استخدام برنامج تقوية العضلات عن طريق العجلة الثابتة الذى أدى الى تقوية كلاً من العضلات المتقلصة والمواجه لها مما انعكس على اعادة التوافق النغمى بين العضلات وتقليل الانقباض المزدوج بينهما . **التوصيات :** تم التوصية باضافة برامج تقوية العضلات الى برامج التأهيل الخاصة بلأطفال المصابين بالشلل المخى التشنجي .