

Effectiveness of Tens to Gluteus Medius on Gait Pattern of Children with Spastic Diplegia

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ABSTRACT

Background: Spasticity in hip adductor muscles has been managed pharmacologically and surgically to improve standing, gait, and personal hygiene. Surprisingly, non-pharmacological management of spasticity in hip adductors has not been documented thoroughly. TENS is a non- pharmacological method that was used to reduce spasticity in various muscles except hip adductors. **Purpose:** To study the short and relatively long-term effects of conventional TENS on spasticity of hip adductors and gait parameters of children with spastic diplegic CP. **Subject:** An experimental group of twenty seven ambulant spastic diplegic children and fifteen healthy children in the control group were voluntary participants in this study. The experimental spastic diplegic CP group received two different TENS management programs. The 1st TENS program was a short-term management program which included an ongoing application of conventional mode TENS on bilateral hip adductors during passive hip abduction, and during walking for a pre-determined distance. The 2nd TENS management program was a relatively long-term management program which included a 15 minute application of conventional TENS on bilateral hip adductors while walking, during three sessions per day for a week. **Stimulator:** Conventional mode TENS with self-adhesive electrodes was used with a frequency of 100 Hz, and pulse duration of 0.25 microseconds at tingling sensation. **Measurement out-come:** The effects of the TENS program was assessed using the balance master system, the Modified Ashworth Scale, and visual observations of knee positions. A significant improvement was recorded in spasticity of hip adductors, and in gait parameters of the experimental group. **Conclusion:** TENS applied bilaterally over the spastic hip adductors in spastic diplegic CP children can reduce the spasticity and improve the gait pattern.

INTRODUCTION

Cerebral palsy (CP) is a group of permanent disorders affecting movement, posture, and motor function that occur due to non-progressive disturbances in the developing fetal or infant brain. It is one of the leading causes of physical disability in children and may significantly affect their ability to perform daily activities independently. The clinical presentation of cerebral palsy varies according to the location and extent of the neurological injury and may include spasticity, muscle weakness, impaired selective motor control, abnormal reflexes, and difficulties with balance and coordination. Among the different types of cerebral palsy, spastic diplegia is characterized predominantly by increased muscle tone and motor impairment in both lower limbs, with the lower extremities generally being more affected than the upper extremities. These impairments can interfere with standing, walking, postural stability, and functional mobility, making gait rehabilitation an important component of pediatric physiotherapy.

Spastic diplegia commonly presents with increased resistance to passive movement, muscle stiffness, reduced muscle strength, and impaired coordination of the lower limbs. Children with this condition may demonstrate abnormal gait patterns, including excessive hip adduction, internal rotation of the lower limbs, knee flexion during stance, reduced step length, and difficulties maintaining appropriate foot placement. Some children may also exhibit scissoring gait, toe walking, and reduced walking speed. The severity and combination of these deviations depend on the child's functional abilities, muscle tone, musculoskeletal alignment, and level of motor control. These gait abnormalities can increase energy expenditure during walking, reduce walking efficiency, and limit participation in school and recreational activities. Therefore, improving gait performance and functional independence is a major objective of physiotherapy management in children with spastic diplegia.

Gait is a complex functional activity that requires coordinated interaction between the nervous system, muscles, joints, and sensory systems. Normal walking involves repeated cycles of stance and swing phases, with appropriate control of the pelvis, hip, knee, and ankle. Adequate muscle strength and timely activation of the hip muscles are essential for maintaining pelvic stability and controlling lower-limb movement during walking. In children with spastic diplegia, impaired neuromuscular control may disturb the timing and coordination of muscle activity, leading to compensatory movement patterns and reduced gait efficiency. Assessment of gait pattern is therefore important for identifying functional limitations and determining the effectiveness of therapeutic interventions.

The gluteus medius is an important muscle responsible for hip abduction and the stabilization of the pelvis during single-limb support. During walking, it helps control pelvic alignment and limits excessive contralateral pelvic drop when the opposite lower limb is in the swing phase. Appropriate activation of the gluteus medius contributes to frontal-plane pelvic stability, control of the hip joint, and efficient transfer of body weight from one limb to the other. Weakness or impaired activation of this muscle may contribute to pelvic instability, altered lower-limb alignment, and compensatory trunk movements during gait. In children with spastic diplegia, abnormalities in muscle activation, weakness, and altered movement coordination may affect the functional contribution of the hip abductors. Consequently, interventions targeting neuromuscular performance around the hip may be relevant to gait rehabilitation.

Transcutaneous electrical nerve stimulation (TENS) is a non-invasive electrotherapy modality that delivers electrical impulses through electrodes placed on the skin. It is commonly used in physiotherapy, particularly for pain modulation, and its effects depend on the stimulation parameters, electrode placement, and treatment objective. When electrical stimulation is applied over a muscle with the intention of producing a muscle contraction, the intervention is more specifically described as neuromuscular electrical stimulation (NMES) or functional electrical stimulation (FES), depending on the equipment and application. The distinction between these modalities is important when investigating their effects on muscle activation and functional movement.

The application of TENS over the gluteus medius may be investigated as an adjunct to conventional physiotherapy in children with spastic diplegia. However, conventional sensory-level TENS primarily targets sensory nerve stimulation and should not automatically be assumed to strengthen the gluteus medius or improve its motor recruitment. If the intended treatment is to facilitate gluteus medius contraction, the stimulation mode and parameters should be selected according to the intended physiological effect, and the intervention may be more appropriately classified as NMES. Electrical stimulation should be delivered by a qualified physiotherapist using child-appropriate parameters, suitable electrode placement, and appropriate monitoring of skin integrity, comfort, and muscle response.

Theoretically, improving the activation and functional performance of the gluteus medius may help support pelvic stability during walking. Better control of the pelvis may contribute to improved weight transfer, lower-limb alignment, and performance during the stance phase of gait. When combined with task-specific gait training and strengthening exercises, an intervention targeting the hip abductors may provide additional opportunities to improve functional walking. Nevertheless, the relationship between electrical stimulation applied over the gluteus medius and changes in gait pattern is influenced by several factors, including the child's age, severity of spasticity, gross motor function, baseline muscle strength, and the presence of fixed musculoskeletal deformities. Therefore, the effects of the intervention must be evaluated rather than presumed.

Gait pattern can be assessed through clinical and functional outcome measures selected according to the child's age and motor abilities. Relevant measures may include observational gait assessment, walking speed, step length, cadence, the Timed Up and Go test, and the 10-Meter Walk Test, where appropriate. Instrumented gait analysis may provide more detailed information about pelvic movement, hip kinematics, and lower-limb coordination when such facilities are available. The use of standardized and reliable outcome measures enables clinicians to compare pre-intervention and post-intervention performance and determine whether observed changes are clinically meaningful.

Conventional physiotherapy for children with spastic diplegia may include stretching, strengthening exercises, balance training, postural control activities, gait training, and functional task practice. These interventions aim to improve motor control, reduce the functional consequences of impairments, and promote greater independence in mobility. Although these approaches form the foundation of rehabilitation, adjunctive interventions may be investigated to determine whether they provide additional benefits. In particular, examining electrical stimulation directed at the gluteus medius may help clarify whether targeted intervention around the hip can contribute to improvements in gait-related outcomes when incorporated into a structured rehabilitation programme.

Despite the clinical importance of hip muscle function in walking, the specific effectiveness of TENS applied over the gluteus medius for improving gait pattern in children with spastic diplegia requires careful investigation. It is important to distinguish the effects of sensory-level TENS from those of stimulation intended to produce muscle contraction, as these approaches have different physiological purposes. A structured study using clearly defined stimulation parameters, an appropriate comparison group, and reliable gait outcome measures may provide useful evidence regarding the role of this intervention in pediatric rehabilitation.

Therefore, the present study, entitled “Effectiveness of TENS to Gluteus Medius on Gait Pattern of Children with Spastic Diplegia,” aims to investigate the effects of electrical stimulation applied over the gluteus medius on gait performance in children with spastic diplegia. By assessing gait-related outcomes before and after the intervention, the study seeks to determine whether the treatment is associated with measurable improvements in walking performance. The findings may contribute to a better understanding of targeted electrotherapy approaches in pediatric physiotherapy and help guide the development of individualized rehabilitation programmes aimed at improving gait efficiency, functional mobility, and independence in children with spastic diplegia.

METHODOLOGY

Study Design

The study was designed as a prospective, randomized, controlled clinical trial. The procedure of this study was ethically revised and approved by the Deep hospital

Subjects

This study included two groups of children: a healthy control group, and an experimental spastic diplegic CP group.

Parents of the children were informed about all aspects of the study including the objectives, the experimental procedure and the management programs. Written consents were taken from these parents before the employment of the study.

Healthy Control Group

A sample of fifteen healthy children participated in this study, with a mean age of 9.2 ± 1.5 years, a mean height of 128.6 ± 12.08 cm, and a mean weight of 30.8 ± 8.6 kg. All of them were able to follow instructions and had no history of any disabling diseases.

Experimental Spastic Diplegic CP Group

Twenty seven children with confirmed spastic diplegic CP with a mean age of

10.22± 2.21 years, a mean height of 130.09± 13.04 cm, and a mean weight of 25.61± 7.99 kg were selected from physical therapy departments at rehabilitation centers and hospitals in Riyadh city. They had secondary compensatory mechanism of knockknees during walking as a result of spasticity in hip adductor muscles to improve the base of support. They were able to walk few steps without an assistant, follow instructions adequately, and cooperate sufficiently during the experimental procedure. Their mean disability degree was (83.05±3.17) according to gross motor function measures (GMFM)

Children who had hip adductor surgery, obturator nerve blockage, hip dislocation, pseudo-hip adduction, under medication affecting spasticity, or with severe associated problems were excluded from the study.

TENS Management Program

The experimental group received short and relatively long-term TENS management programs in two different sessions. The short-term management program was designed to evaluate the short-term effect of TENS on spasticity in hip adductor muscles and gait. It was an ongoing application of conventional mode TENS on bilateral hip adductors during two different conditions: (a) passive hip abduction, and (b) walking for 300 cm of the total length of the balance master platform.

The relatively long-term management program was designed to evaluate the relatively long-term effect of the home program of TENS on spasticity in hip adductor muscles and gait. It included an application of conventional mode TENS of bilateral hip adductors while walking for 15 minutes, 3 times a day for one week. It was conducted by the children's parents at home after teaching them how to use and apply the TENS unit safely.

TENS Stimulator

A portable two-channel conventional mode TENS (MEDISANA ECO- TENS; type WL-2102M; RATING: 9V battery; type 6LR61) was used with a pulse duration of 0.25ms, a frequency of 100Hz and intensity to cause just a tingling sensation. Four standard disposable self-adhesive stimulation electrodes (3x5cm) were used to transmit TENS to the children in the experimental group.

Procedure

A- The short-term management program

Once the child arrived to the lab, she/he was asked and helped to remove her/his clothes leaving the underwear on. Then the child moved to a supine position on the examination table. The skin of the inner thigh over the hip adductors of both lower extremities was cleaned and moistened with an alcohol swab to reduce skin resistance. Self-adhesive/ carbon stimulation electrodes were placed bilaterally over the bulk of the hip adductors (adductor longus).

The negative electrode of the TENS unit was placed on the belly of the adductor longus muscle while the positive electrode was placed 3cm distally in line with the negative electrode (figure 3). The electrodes were connected to the TENS unit. The intensity was increased gradually until the child reported a comfortable feeling of a tingling sensation. This feeling was maintained for approximately 1-2 minutes to allow the child to get used to the new sensation and kept throughout the assessment of muscle spasticity and gait. The TENS unit was attached to a waist belt during gait assessment. The hip adductors fill in the triangular space at the upper part of the thigh, between the femur and the pelvis. They perform the contour of the medial border of the thigh. When the adductor longus is in action, its upper tendon stands out as a prominent ridge running obliquely downward and laterally from the area of the pubic tubercle, forming the medial border of the femoral triangle.

B - The relatively long-term management program

At the end of the short-term management program, operational instructions, application, demonstration, re-demonstration and precautions of the TENS were explained to the parents to prepare them for conducting this program safely at home. Red and black color marks were drawn, using a permanent color pen, over the right and left adductor longus muscles so the parent would know where to place the TENS self-adhesive electrodes.

The instructions for the parent were:

1. Sit your child in a comfortable position exposing the medial border of both thighs.
2. Moisten the skin over the red and black marks with an alcohol swab.
3. Place the self-adhesive electrodes over the marks on both hip adductors, make sure that the black wire electrodes (negative electrodes) are placed over the black marks – the belly of the adductor longus – and the red wire electrode (positive electrode) is placed over the red marks – 3cm distally and in line with the black marks.
4. Turn on the TENS unit and gradually increase the intensity till your child reports feeling of a tingling sensation.
5. Attach the TENS unit to your child waist belt and ask him to stand and walk for 15min.
6. After 15 min, ask your child to sit again and turn off the unit.
7. Repeat the above procedures three times a day for a week with a period of no less than 3 hours between sessions.
8. An extra battery was given to the parent who was instructed to contact the researcher whenever necessary.

Assessment Procedure

Hip adductor spasticity, gait performance, and knee position were assessed to determine the efficacy of the management programs.

Spasticity of Hip Adductor

The child wearing only underwear was placed in a supine position on the examination table. The degree of spasticity of hip adductors was determined using the Modified Ashworth scale 37 during passive hip abduction from a neutral position to approximately 20 degrees, within 5 seconds. The modified Ashworth scale consisted of 6 grading points, which were,

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 range of motion.

1+ = slight increase in muscle tone, manifested by a catch followed by minimal resistance throughout the remainder of the range of motion. 2 = more marked increase in muscle tone throughout most of the range of motion, but the affected part is easily moved.

3 = considerable increase in muscle tone, passive movement is difficult.

4 = affected part is rigid in flexion or extension.

Three trials of the test were carried out with 3 minutes rest intervals, and the average was taken. During the passive abduction, the therapist stabilized the pelvis with one hand and abducted the hip with the other hand from just below the knee joint (figure 4). The spasticity in only one hip adductor muscle was assessed and selected randomly. The spasticity in hip adductors was assessed in three different assessment sessions one week apart. The aims of the first and second assessment sessions were to establish the spasticity baseline, to study test-retest reliability within and across sessions, and to determine the effect of short-term management program on muscle spasticity. The aim of the third assessment session was to determine the effect of relatively long-term management program on muscle spasticity. To minimize study bias, a new sheet of the modified Ashworth scale was used to determine the degree of spasticity in the hip adductor.

First assessment session, spasticity in the hip adductor was assessed in two different conditions, which were:

1. Immediately, as the child arrived at the gait lab and adopted a supine position.
2. After 10 minutes of resting in a supine position.

Second assessment session, spasticity in the hip adductor was assessed in three different conditions, which were:

1. Immediately, as the child arrived at the gait lab and adopted a supine position.
2. After 10 minutes of resting in a supine position
3. During ongoing application of conventional TENS on bilateral hip adductors in a supine position as a part of a short-term management program.

Third assessment session, spasticity was measured in a supine position next day from completing of the relatively long-term management program.

Gait Performance

Gait performance was assessed using walk across (WA) mode of functional ability tests of the balance master system (Neuro Com system version 8.2.0).

The Balance Master System is one of the force-plate recording systems. It determines a baseline of patient function, facilitates the design of custom treatments, evaluates the effectiveness of the therapeutic program, and provides the means to compile clinical databases for research. The most important components of the Balance Master System are the force-plate and the computer. The force-plate is about 150cm in length and 46cm in width. It is set into the platform base. It has force sensors to measure the vertical forces exerted by the patient's feet. The measured forces are carried via cable to the computer to be displayed on screen, analyzed and stored on hard disk.

The balance master system has two categories of test assessments:

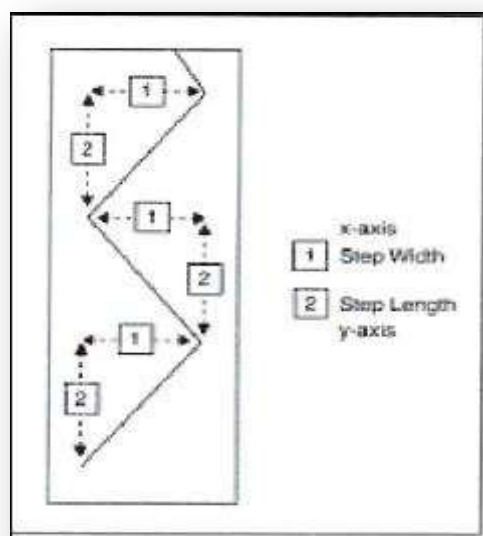
- 1) The impairment test measures the sensory and motor skills such as weight bearing and active weight shifting.
- 2) The functional ability test measures specific movement characteristics during functional activity such as walking across or rising from sit to stand.

The WA mode quantified the mean step width, length and speed of gait as the child walked from one end of the platform to the other. The mean step width is defined as the average lateral (x-axis) distance between successive initial contacts, expressed in centimeters (cm). It was calculated by adding the x-axis distance in centimeters of each step and dividing it by the number of steps.

The mean step length is defined as the average longitudinal (y-axis) distance between successive initial contacts on successive steps expressed in centimeters. It was calculated by adding the y-axis distance in centimeters of each step and dividing it by the number of steps. The mean speed is defined as the average velocity of forward progression, expressed in centimeters per second.

WA assessment procedures

The child was sitting on a bench with both feet relaxed on the floor in front of the walking platform of the balance master system. Then he/she was asked to stand and walk across and off the other end of the platform at a normal self-selected walking speed with head erect and gaze horizontal. Three practice runs of the trials were performed followed by three actual trials recorded and averaged for statistical analyses.



WA for the healthy group was assessed in two different assessment sessions one week apart to determine test-retest reliability of the assessment procedure within and across sessions. For the experimental groups, WA was assessed in three different assessment sessions one week apart. The goal of the first and second assessment sessions was to study test-retest reliability of the assessment procedure within and across sessions, to establish baseline and to determine the effect of short-term management program on the gait of the experimental group participants. The goal of the third assessment session was to determine the effect of relatively long-term management program on the gait of the experimental group participants.

First assessment session

Gait Performance for healthy and experimental groups was assessed in two different conditions, which were:

1. Immediately, as the child arrived at the gait lab.
2. After 15 minutes of resting in a supine position.

Second assessment session

Gait performance for both groups was assessed again as follows:

1. Immediately as the child arrived to the gait lab for both groups.
2. During ongoing application of the TENS on bilateral hip adductors of the experimental group participants, as a part of short-term management program.

Third assessment session

Gait performance of the experimental group participants was assessed next day from completing the relatively long-term management program.

Knee Position Assessment

Knee position was assessed subjectively while walking by using a Yes/No scale. “Yes” was defined as knees laterally apart exceeding two parallel longitudinal lines 2 cm apart drawn on the force-plate (figure 4-8 a). “No” was defined as knees not laterally exceeding the two parallel longitudinal lines (figure 8). Yes/No score was determined during WA assessment, while the examiner observed knees interiorly

RESULTS

Table 1. Means, SD, and p-value of physical characteristics for both group.

	Healthy group	Experimental group	p-value
	Mean + SD	Mean + SD	
Age (yr)	9.2 + 1.5	10.22 + 2.21	0.12
Weight (kg)	30.8 + 8.6	25.61 + 7.99	0.06
Height (cm)	128.6 + 12.08	130.09 + 13.04	0.7

Table 2. Mean and SD of the gait parameters for both groups.

	Healthy group	Experimental group		
	Walking test	Baseline	Short-term management program	Relatively longterm management program
	Mean + SD	Mean + SD	Mean + SD	Mean + SD
Step width (cm)	11.46±2.3	16.41±6.64	18.09±6.27	17.82±5.6
Step length (cm)	47.9±6.38	29.16±9.58	35.68±11.57	39.14±15.27
Speed (cm/ min)	70.6±11.72	40.31±14.1	47.63±19.41	50.39±20.24

Table 4.3. p- values for gait parameters of both groups

	Experimental group Baseline VS. Healthy group.	Experimental group baseline VS. Shortterm management program	Experimental group Baseline VS. Long-term Management program	Short-term management Program VS. Long-term Management program	Short-term management Program VS. Healthy group.	Long-term management program VS. Healthy group
Step width	0.01	0.082	0.113	0.629	0.001	0.0001
Step length	0.0001	0.008	0.001	0.062	0.001	0.043
Speed	0.0001	0.021	0.008	0.127	0.0001	0.001

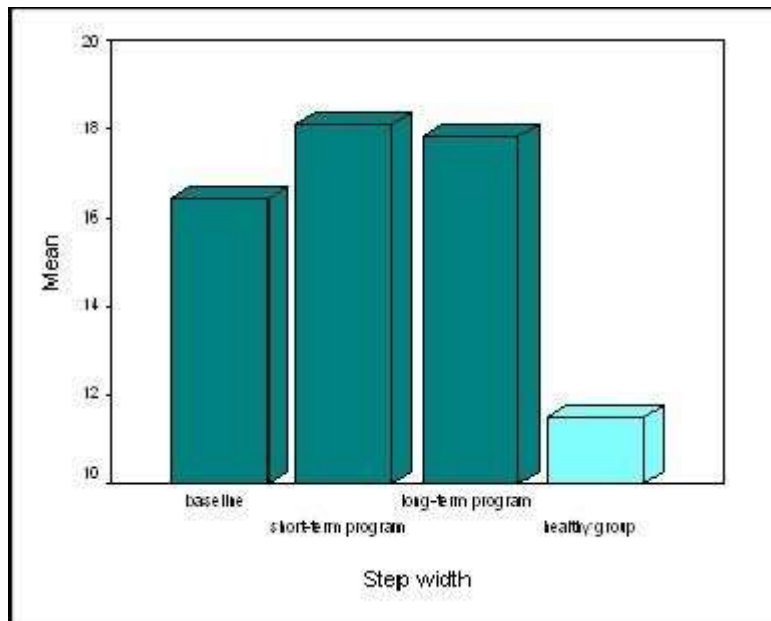


Figure 1 TENS effects on the step width of the experimental group compared to the healthy group.

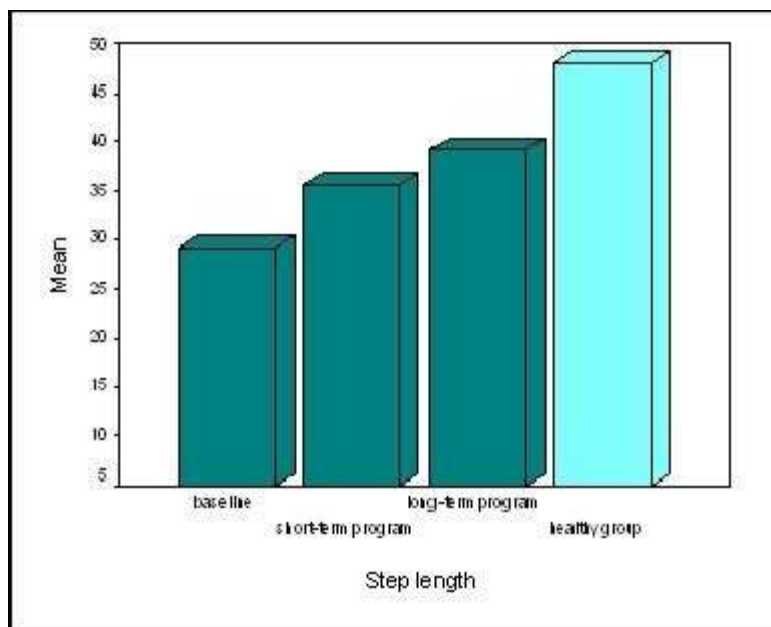


Figure 2 TENS effects on the step length of the experimental group compared to the healthy group.

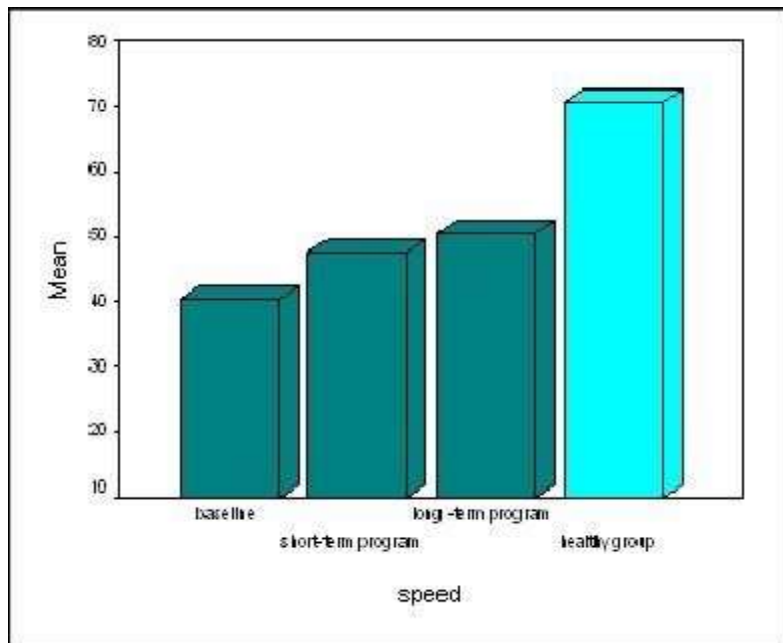


Figure 3 TENS effects on the speed of the experimental group compared to the healthy group

Table 4 Mean and SD of hip adductor spasticity as measured by the Modified Ashworth Scale.

Baseline	Short-term management program	Relatively long-term management program
Mean + SD	Mean + SD	Mean + SD
2.57+0.51	1.57+0.66	1.77+0.81

Table 5 P-value for hip adductor spasticity.

Baseline VS. short-term management program	Baseline VS. Relatively long-term management program	Short-term management program VS. Relatively long-term management program
0.001	0.001	0.103

Table 6 Knees position assessment

	Knees position first assessment at baseline		Knee position during short-term Management program		Knee position at the end of relatively long-term management program	
	Frequency	percent	frequency	percent	Frequency	percent
NO	27	100	3	11.1	6	22.2
YES			24	88.9	21	77.8

Table 7 Gait performance baseline of both groups.

	Healthy group			Experimental group		
	First assessment session			First assessment session		
	Immediately	After 15 min	Second assessment session	Immediately	After 15 min	Second assessment session
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Step width (cm)	11.46 $\pm$ 2.3	11.4 $\pm$ 2.7	11.6 $\pm$ 2.73	16.41 $\pm$ 6.64	16.54 $\pm$ 6.7	16.54 $\pm$ 6.4
Step length (cm)	47.9 $\pm$ 6.38	48.02 $\pm$ 6.1	48.8 $\pm$ 6.91	29.16 $\pm$ 9.58	28.56 $\pm$ 11.8.4	29.33 $\pm$ 9.9
Speed (cm/ min)	70.6 $\pm$ 11.72	69.6 $\pm$ 11.7	72.1 $\pm$ 13.05	40.31 $\pm$ 14.1	39.21 $\pm$ 13.5	39.8 $\pm$ 13.3

Table 8 Modified Ashworth Scale baseline of the experimental group.

Experimental group			
First assessment session		Second assessment session	
Immediately	After 10 min	Immediately	After 10 min
Mean + SD	Mean + SD	Mean + SD	Mean + SD

2.57 + 0.51	2.52 + 0.51	2.43 + 0.59	2.43 + 0.59
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Table 9 P-values for the test-retest reliability study for the gait performance of both groups

	Healthy group		Experimental group	
	Within sessions	Between sessions	Within sessions	Between sessions
Step width cm	0.79	0.51	0.19	0.46
Step length cm	0.79	0.23	0.81	0.31
Speed cm/min	0.37	0.48	0.28	0.77

Table 10 P-values for test-retest reliability study for the Modified Ashworth Scale.

Experimental group	
Within sessions	0.32
Between sessions	0.08

Gait performance Baseline Group Comparisons

Age, weight and height of the healthy and experimental group were significantly alike, ($p < 0.12$, $p < 0.06$, $p < 0.7$). The results of this study showed that the gait performance of the experimental group was significantly different from that of the healthy group. The Step width of the experimental group (16.41 ± 6.64 cm) was significantly wider than that of the healthy group (11.46 ± 2.3 cm) with p -value $p < 0.01$. The Step length of the experimental group (29.16 ± 9.58 cm) was significantly shorter than that of the healthy group (47.9 ± 6.38 cm) with $p < 0.0001$. Furthermore, the speed proved to be significantly slower in the experimental group (40.31 ± 14.1 cm/min) compared with the healthy group (70.6 ± 11.72 cm/min) with $p < 0.0001$.

Experimental Group The TENS Management Programs

The study results showed that the TENS programs significantly improved the step length and speed, but not the step width of the experimental group. The short and relatively long-term managements programs had no significant effect on the step width of the experimental group ($p < 0.082$; $p < 0.113$). Step width was (16.41 ± 6.64 cm) at the baseline, (18.09 ± 6.27 cm) at the short-term management program, and (17.82 ± 5.6 cm) at the end of the relatively long-term management program.

The step length of the experimental group significantly improved ($p < 0.008$) from (29.16 ± 9.58 cm) at the baseline to (35.68 ± 11.57 cm) at the short- term management program. Further improvement in step length (39.14 ± 15.27 cm) was also noticed after the completion of the relatively long-term management program ($p < 0.001$). However, there was no statistically significant difference between the improvement in step length recorded during the short-term and at the end

of the relatively long- term management programs ($p<0.62$). These improvements after the short and relatively long-term management programs did not reach the level of the healthy group ($p<0.001$, $p<0.043$).

The management programs significantly improved the speed of the experimental group from (40.31 ± 14.1 cm/min) at the baseline to (47.63 ± 19.41 cm/min) during the short-term management program ($p<0.02$), and (50.39 ± 20.24 cm/min) after the end of the relatively long-term management program ($p<0.008$). But, the recorded improvement in speed during the short and relatively long-term management programs was not significantly different ($p<0.127$), and was far below the level of healthy group ($p<0.0001$, $p<0.001$).

Knee Position Assessment

All of the children in the experimental group (100%) walked with touched or crossed knees. The short-term and the relatively long-term management programs improved the position of the knees during walking of the majority of the children in the experimental group. 88.9% of the children walked with knees significantly apart during the short-term management programs compared to 77.8% of them at the end of the relatively long-term management program.

Hip Adductor Spasticity

Hip adductor spasticity was significantly reduced from ($2.57+0.51$) at the baseline to ($1.57+0.66$) during the short-term management program and ($1.77+0.81$) at the end of the relatively long-term management program with ($p<0.001$).

However, the difference between the recorded reduction in spasticity during the short-term and at the end of the relatively long-term management programs was not statistically significant ($p<0.103$).

DISCUSSION

Management of muscle tone and gait abnormalities in children with spastic diplegic CP is challenging. Electrical stimulation and other managements such as tone-altering medications, physical therapy and musculoskeletal and neurological surgeries are often prescribed in an effort to decrease spasticity and improve the alignment of patients' limbs, prevent the progression of bone deformities, and increase the walking ability. The present study was another effort to improve gait and muscle tone in children with CP. The study has included short and relatively longterm management programs of TENS of bilateral spastic adductor muscles of the hips during walking for a determine distance.

The results of our study showed that the gait parameters of the experimental group were significantly impaired in comparison with the healthy group. This was expected and comparable with other studies. Neurological impairments and complication associated with CP is reported to be the causes for such gait disturbances. They encourage imbalance between the agonist and the antagonist muscles and exaggerate the reaction of muscles to biomechanical changes.

Muscle imbalance has been reported to alter the biomechanical alignment of the joints of children with CP. It is documented to negatively effect the joint angle profiles, velocity of forward progression and stride length, impairing the swing phase duration. Muscle imbalance due to spasticity in hip adductor severely impairs the biomechanics of hip joint in children with CP. It limits the work of the hip abductor muscle during initial swing, leading to decrease in forward velocity and step length, it causes scissoring which grossly impairs motion and stability. The adductor longus acts as a hip flexor as well as an adductor. Spasticity in this muscle contributes to limitation hip flexion movement, decrease the swing limb advancement and reduce the step length. It may limit the work of the hip extensor, impairing stability while walking.

The exaggeration in the reaction of muscle spindle to sudden biomechanical changes is also reported to impair gait parameters in children with CP. Normal control of muscle function requires excitation of the muscle by the anterior motor neurons and continuous feedback of information from each muscle to the nervous system. This information is provided by two special types of sensory receptors: (1) Muscle spindles, which send information to the nervous system about either the muscle length or the rate of change in its length. (2) Golgi tendon organs, which transmits information about tension or the rate of change in tension. Muscle spindle has two types of sensory endings (Ia fiber and II fiber)

and are supplied with two types of motor efferent fibers (gamma and alpha efferent fibers). Spasticity produced from loss of descending inhibitory input through the reticulospinal tract and other systems increases the excitability of gamma and alpha neurons subsequently, muscle spindles over react to any external stimulus during walking.

The Ia fibre makes a monosynaptic excitatory connection with alpha moto- neurons of its muscle of origin, as well as of synergistic muscles. It also monosynaptically connects with an inhibitory inter-neuron that project directly to the alpha motor-neurons of antagonist muscles. When a muscle is stretched, excitation of homonymous and synergistic moto-neurons, combined with inhibition of antagonists' sub-serves the mechanism of reciprocal inhibition. There is evidence for impairment of this mechanism in children with spastic CP exaggerating the response of muscle spindle to mechanical changes during walking.

Results of this study showed that TENS programs significantly improved hip adductors spasticity and gait parameters of the experimental group. Such improvement was also reported in other studies using various management programs. This could indicate that management of the hip adductor muscles spasticity play an important role in gait performance. It could also support the believe that proximal muscles in lower limbs play a very important role in stabilizing pelvis, maintaining balance and generating the most of power needed during walking. In CP selective motor control is better proximally than distally. Therefore, children with CP tend to use proximal compensations to offset distal gait deviation. Therefore, therapist should consider hip adductor management as part of daily physical therapy program.

TENS is believed to activate sensory Ia afferent fibers switching on presynaptic inhibition mechanisms leading to reduction in spasticity.⁶² This appears obviously in the reduction of the H-reflex amplitude. H-reflex is an indirect indicator of spinal motor neuron excitability. It is similar to, and involves the same neural circuits as, the stretch reflex. Many studies document that inhibition in H-reflex amplitude and stretch reflex is associated with decrease in spasticity. Abnormal reflexes and spasticity of the lower limbs lead to an abnormal tonic balance between agonist and antagonist muscles with co-contract in both agonist and antagonist muscles during the gait. Normal movement requires turning off or controlling abnormal reflexes and reducing the spasticity. The gait improvement reported in the present study could indicate that TENS controls abnormal reflexes and restore the balance between agonist and antagonist muscles by decreasing the tone of the spasticity in hip adductors. This was one way to explain the mechanism of the reduction of spasticity in hip adductor and the improvement in the gait parameters during and after the application of TENS.

Moreover, TENS has been reported to indirectly affect the sympathetic outflow from the spinal cord by stimulating peripheral afferent fibers which increase the blood flow in the muscles. Increased blood flow in the spastic muscle is reported to improve its efficiency, oxygen uptake, and waste product removal. These changes may also contribute to the improvement in gait parameters in the present study. New and strange tingling sensations of TENS used in the present study may push the child to abduct and externally rotate hips. This assumption could be supported by the fact that the knees of the majority of the children in the experimental group were not touching or crossing during the short-term and at the end of relatively long-term managements programs. Pushing the child frequently to abduct and externally rotating hips may activate reciprocal inhibition between the hip abductors and adductors muscles, causing further reduction in spasticity in hip adductor muscle and strengthening the hip abductor and external rotator muscles. New and strange feeling of external stimulus such as brushing, tapping, massage, vibration and cryotherapy have been actually used to reduce spasticity, improve functional tasks and restore normal movement patterns by stimulating dominant or non-dominant spastic muscles of children with CP and other neurological conditions.

TENS has been reported to reduce the spasticity in patients with spinal cord injury, multiple sclerosis, spastic hemiplegic, and CP. This was consistent with our results. We believe that TENS may reduce spasticity regardless of age, complication, type and onset of the disease. It could also imply that mechanical and physiological characteristic of spasticity are similar in various neurological conditions.

Furthermore, Improvement in spasticity and gait parameters that resulted from TENS programs did not reach the level of healthy matching children. This probably indicates that normalization of neuromuscular changes associated with CP cannot be achieved, or may required more TENS sessions, or a combination therapy. TENS application reported in previous studies was applied by means of surface skin electrodes over either, spastic muscles, or the nerve that supplies the targeted muscle. Clinical reduction of spasticity was noticed in both applications. In our study, TENS was applied directly over the spastic muscle because it was difficult to reach the nerve which supplies the adductor muscles of the hip.

In this study, step width (base of support) of the experimental group was significantly wider than that of the healthy group. This could be due to balance and stability disturbance as results of the impaired postural control, abnormal muscle tone and pathological biomechanical changes. It is well known that imbalance and instability push some children with spastic diplegic CP to adopt knock knees with wide step width. The step width in the experimental group did not change significantly with TENS management programs. This may be due to the development of knee valgus deformity in the experimental group. Such imbalance, instability, deformity, and the variation in step with definition may explain why the previous studies have focused on the velocity, cadence, step length, and stride, rather than step width to determine the improvement of the gait.

This study supports the previous reports on the positive effect of TENS in management of spasticity. It showed that TENS can instantly reduce spasticity with no obvious side effects. TENS is simple, cheap, and applicable at home. In contrast, most of the techniques that are used to reduce spasticity have some disadvantages. They are either painful, invasive, costly and may not be available for all patients (e.g. neurological surgery), Affect the patient physically (e.g. medications), or take a long time to reach the desired effect (e.g. serial casting), or even take big part of the session as in prolong muscle stretch. The results of the present study indicates that both modified Ashworth Scale and balance master were simple and reliable methods to be used within and across sessions. These findings are in agreement with previous studies. This could imply that the examiners' experience, testing conditions and medical condition of CP have no significant effects on reliability of the used out-come measure. It could also confirm that the improvement in spasticity and gait parameter during and at the end of short and long-term management programs was real.

Recommendations:

The use of TENS during physical therapy sessions for children with spastic diplegic cerebral palsy.

- 1) The use of TENS during gait training.
- 2) Using TENS as part of the home program, while walking.

Suggestions:

We suggest more studies about the issue of using TENS.

- 1) Using a three-dimensional gait analysis, instead of a two- dimension gait analysis for a clearer picture of the gait parameters.
- 2) Applying TENS in different types of CP to reduce the spasticity and improve the gait.
- 3) Designing a research proposal to study the effect of TENS on gait of CP when combined with other treatment modality.

CONCLUSION

This study provided evidence that TENS applied to the spastic hip adductor muscles reduces the spasticity of the muscles in children with spastic diplegic CP. Previous studies were also reported a similar results with different muscle in various neurological disorders, indicating that TENS is a suitable management for reducing muscle spasticity. The use of TENS as described in this study was effective partially in improving the gait parameters of children with spastic diplegic CP. However, the improvement in gait did not reach the level of healthy children.

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