

# Effect of Functional Electrical Stimulation on Gross Motor Abilities in Children with Spastic Hemiparetic Cerebral Palsy

Abdel Aziz Al i Sherief

Department of Physical Therapy for Disturbance of Growth and Development in Children and its Surgery, Faculty of Physical Therapy , Cairo University

## ABSTRACT

*The purpose of this study was to investigate the effect of electrical stimulation over the gastrocnemius-soleus muscle on gross motor skills in hemiparetic cerebral palsied children. **Subjects and Methods:** Thirty patients with spastic hemiparetic cerebral palsy (age ranges from three to eight years) were equally divided into two groups; control group (A) and study group (B). Group (A) received a designed physical therapy program, while group (B) received the same designed treatment program in addition to electrical stimulation over the gastrocnemius-soleus muscle complex. The subjects were evaluated and scored functionally, using the Peabody Developmental Motor Scale and objectively, using an Biodex balance system device utilized to obtain the Antroposterior stability, Mediolateral stability index at different time intervals; pretreatment and three months later during which they underwent the treatment program. **Results:** the results revealed statistically significant improvement in the measuring variables of both groups when comparing their pre and post treatment mean values. Cabperson between the two groups' post-treatment variables, significant difference is revealed in favor of the study group (B). **Conclusion:** The obtained results strongly support the using of electrical stimulation of gastrocnemius-soleus muscle as an additional procedure to the treatment of hemiplegic cerebral palsied children.*

**Key words:** Cerebral palsy, hemiparetic, gross motor abilities, electrical stimulation.

## INTRODUCTION

Children with cerebral palsy (CP) are a commonly treated group seen by pediatric physical therapists. Spasticity is the most prevalent form of motor dystonia<sup>30</sup>. Attributing spasticity as a major contributor to movement dysfunction may be a dated concept in the literature<sup>5</sup>. However, the concept is still relevant to most clinicians and is the premise of some treatment methods (eg, posterior selective rhizotomies). Various walking

problems can accompany spasticity such as poor power generation during the push-off period<sup>33</sup>, decreased peak force production during the late stance phase<sup>40</sup>, decreased maximal voluntary contractions of the ankle plantar flexors<sup>41</sup>, changes in timing and sequencing of muscle activation<sup>10</sup>, and decreased walking speed with higher cadence and shorter stride length<sup>31</sup>. Kinematic gait changes such as toe-walking and a running-like gait pattern are commonly observed in children with spastic CP<sup>15</sup>. The evidence available to support current physical therapy practices for improving locomotor function in children with spastic CP is limited and equivocal<sup>4,36</sup>. In recent developments, one type of intervention, functional electrical stimulation (FES), has been more widely used in clinical settings and has received more attention in the research literature<sup>7,8,9,26</sup>. Clinical research and clinical practice have focused on correcting a typical gait patterns by using electrical stimulation. For example, attempts to increase ankle dorsiflexion by applying neuromuscular electrical stimulation to the tibialis anterior muscle have met with limited success<sup>3,12,16,37</sup>. In contrast, the findings of a study by Carmick<sup>7</sup> suggested that gait improvement such as decreased excessive ankle plantar flexion occurred in three children with spastic CP when electrical stimulation was applied only to the gastrocnemius-soleus muscle complex (G-S) during walking. In a study of the application of FES on the G-S with a larger sample (N=14), Comeaux et al.,<sup>9</sup> showed positive effects such as increased ankle range of motion and ankle dorsiflexion at initial foot contact when compared with walking without FES. It seems paradoxical that stimulation of the ankle plantar flexors during the period they would normally be active results in an improvement in dorsiflexion at initial contact.

One possible reason that application of FES to the G-S may be effective in improving

the gait patterns is related to the dynamic resources available to children with spastic CP for locomotion. *Dynamic resources* refer to an individual's capability to generate, dissipate, or conserve the energy required to locomote<sup>13,14,18,19,20,23,32</sup>. The elements include the active contractile component of muscles that are capable of producing forces, elastic elements of soft tissues such as muscles and tendons that are capable of storing and returning elastic potential energy, viscous tissue properties for passively dissipating energy, rigid bony structures and body masses that are capable of storing gravitational potential energy and exchanging potential energy (elastic and gravitational) and kinetic energy during walking, and neural circuitry that delivers graded and timed muscle input. Dynamic resources of locomotion include the capability to actively produce appropriately timed muscle forces and to store elastic energy through soft tissues. Dynamic resources have been operationalized using abstract biomechanical models that treat the body as a force-driven or escapement-driven global pendulum and spring. Total forces during the push-off phase (impulse) and stiffness of the tissues were estimates derived from the escapement-driven pendulum and spring model of locomotion.

Children with spastic hemiplegic CP show an increase in stiffness and a decrease in force during push-off for the affected limbs, while the nonaffected limbs show greater force during push-off and the same stiffness compared with children who were developing typically<sup>14,18</sup>. Holt et al.,<sup>18</sup> argued that children with spastic hemiplegic CP adapt their walking patterns to optimize the utilization of the different dynamic resources available to them, for example, by adopting a running-like pattern that maximizes the use of increased musculoskeletal stiffness. Thus, children with spastic hemiplegic CP have a shorter step length on the affected side due to the decrease in appropriately timed force production and an increase in step (and stride) frequency due to the increased stiffness when compared with children with typical development.

In addition, Fonseca et al.,<sup>13</sup> showed that children with hemiplegic CP showed an asymmetric gait pattern in which the

nonaffected limb raises the center of mass (COM) in a pendulum-like fashion and "drops" it onto the affected limb that absorbs and returns elastic energy in a similar way as a pogo stick. Furthermore, equines gait, in which the foot is plantar flexed at initial contact, is viewed as an adaptation to the weakness of the G-S. The pattern allows children with spastic CP to take advantage of the stiffness of the soft tissues in the leg to store elastic energy. Thus, the atypical pattern may be adaptive and "normal" in the sense that it takes advantage of the available resources (see Latash and Anson<sup>27</sup>. Holt and colleagues<sup>13,14,21</sup> have claimed that the relatively more consistent positive effects of FES applied to the G-S compared with the equivocal results of attempts to correct gait patterns by FES applied to the tibialis anterior muscle are because FES applied to the G-S addresses the decrease in the dynamic resource, namely the appropriately timed force production of the G-S during gait. Holt and colleagues proposed that, by providing the child with appropriately timed stimulation, the need for gait pattern adaptations such as a plantar-flexed foot or running-like gait that facilitate the use of greater stiffness may no longer be necessary.

## SUBJECTS MATERIALS AND PROCEDURES

### Subjects

Thirty hemiparetic cerebral palsy children were enrolled in the study. Their age ranged from three to eight years, and they were randomly divided into two groups of equal number fifteen patient each, one presented as control group (A) and study group (B).

Group (A): Consisted of ten males and five females, they received a selected physical therapy program for 60 minutes, three times a week for three months.

Group (B): Consisted of ten males and five females, they received a selected physical therapy program for thirty minutes as in group (A) combined with function electrical stimulation over the gastocnemus-soleus muscle thirty minutes, three times a week for three months.

***Inclusion criteria:***

(1) age range of three to eight years, (2) mildly involved CP with a Modified Ashworth Scale score of 3 or less, (3) able to ambulate independently without an assistive device or orthoses, (4) unable to achieve heel-strike at initial foot contact at a comfortable or fast walking speed, (6) no cardiovascular diseases, (7) no surgery within the previous 24 months, (8) no sensory defensiveness, and (9) ability to follow instructions.

***Materials***

***The following Materials were used during the study:***

***For evaluation:******Biodex Balance System:***

- Biodex balance system (Biodex Medical System Inc, Shirley, New York), which consists of a movable balance platform; which can be set at variable degrees of instability.
- This system is interfaced with computer software monitored through the control panel screen it includes:

***The foot platform:***

- The foot platform allows for approximately 20 degrees of surface tilt from horizontal in all directions. Platform diameter is 21.5 inches. On the surface of the foot platform appears the alphabetic letters from A to P (on the far ends of both sides) with parallel lines joining between them. On the lower most part of the platform surface appears the numbers from 1-21 with 21 parallel lines arising from them. On the upper most part of the surface of the platform appears angles from 0° to 45 with the lines which represent these angles/these lines are used to measure foot angles.

***Stability levels:***

- Biodex balance system allows for eight stability levels, which ranges from stability level one to stability level eight. The chosen stability level is selected on the screen.
- Stability level eight, is the most stable level as it allows the highest level of stability by making the platform to be least easily tilted. On the other hand, stability level one represents the least stable level and it becomes more difficult for the subject to maintain stability.

***Display panel keys:***

The display panel has many keys, which have different functions.

- The On/Standby key: located at the bottom left corner of the display panel. It is used to turn the system on or to stand by.
- From left to right directly under the display screen, the following function keys are present:
  - 1- Previous screen key: to return to the screen immediately prior to the current screen.
  - 2- Next screen key: to advance to the next logical screen.
  - 3- Start key: to activate the foot platform & clock, after training protocol screens have been completed.
  - 4- Stop key: when it is pressed at any time during testing or training, it allows immediate return of the foot platform to its fully locked position.
  - 5- Enter key: is used to confirm numeric entries, save a selected training parameter or coordinate, & to advance to the next logical field or screen where applicable.

This test was performed to test the child's ability to control the platform angle of tilt.

All subjects were given an explanatory session before the evaluative procedure to be aware of the different test steps. Each child in both groups was asked to stand on the center of the locked platform with two legs stance. Safety support rails and biofeedback display were adjusted for each child to ensure comfort and safety. The display adjusted so that the child can look straight at it.

The following test parameters were introduced to the device:

- Child's height and chronological age.
- Platform firmness (stability level): All children were tested on the stability levels; level eight (the most stable) and level three (less stable) during the same set of testing, beginning at level 8 and ending at level 3, for three times repetitions for each trial, the mean of the three trials was calculated and recorded.
- Test duration: all children were tested for two minutes for the three repetitions.

*Patient centering steps:*

It was performed to position the center of gravity (COG) over the point of the vertical ground reaction force. Centering was achieved by asking the child to stand on both feet while grasping the handrails. The child was instructed to achieve a centered position on slightly unstable platform by shifting his feet position until keeping the cursor (which represent the center of the platform) centered on the screen grid while standing in a comfortable and upright position. Once centering achieved and the cursor in the center of the display target, instruction was given to the child to maintain his feet position till stabilizing the platform. This followed by recording feet angles and heels coordinate from the platform. After introducing these angles into the Biodex system, the test then begins. As the platform advanced into an unstable state, the child was instructed to focus on the screen and maintain the cursor in the middle of the bulls eye on the screen. At the end of each test trial, a print out report was obtained. This report includes information regarding overall stability index, mediolateral stability index and anteroposterior stability index.

Overall stability index: represent the child ability to control his balance in all directions. High value indicates that the child had difficulty.

Anteroposterior stability index: represent the child's ability to control his balance in front to back direction. High value indicates that the child had difficulty.

Mediolateral stability index: represent the child's ability to control his balance from side to side. High value indicates that the child had difficulty.

The mean values of three trials of stability indices were calculated for each child individually before and after three months of treatment<sup>8</sup>.

*S2) Peabody developmental motor scale (PDMS-2):*

It is used for determining gross and fine motor skills, skills that are not completely developed and the plane of the instructional program to develop those skills. This scale is a standardised, valid and reliable assessment tool (folio and fewell, 2000) information

gathered on a child's performance during successive administrations of the test allows the examiner to make comparisons across administrations.

### Procedure

Thirty hemi paresis CP children were selected from the outpatient clinic of the faculty of physical therapy. They were assigned into two groups all subjects in two groups will be evaluated at the beginning of the study using both the biodex system for balance assessment and the locomotion subtest of the Peabody developmental motor scale for skill acquisition assessment.

Group (A) received a designed physical therapy program, while group (B) received the same designed treatment program in addition to electrical stimulation over the gastrocnemius-soleus muscle complex. The subjects were evaluated and scored functionally, using the Peabody Developmental Motor Scale and objectively, using an Biodex balance system device utilized to obtain the Anteroposterior stability, Mediolateral stability index at different time intervals; pretreatment and three months later during which they underwent the treatment program.

## RESULTS

The results of pre and post treatment values were compared with each group. The results revealed significant improvement in both groups.

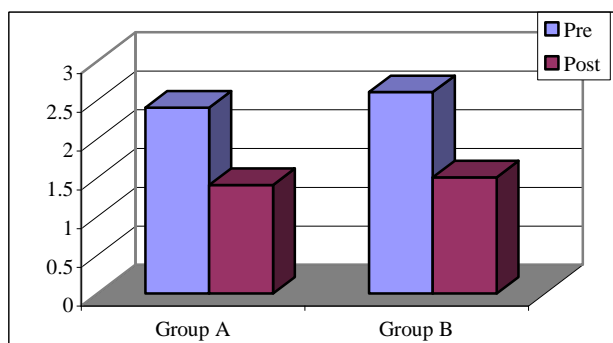
As revealed from table (1) and Fig. (1) was observed in mean values of anterior posterior balance measured in both groups at the end of treatment as compared with the responding mean values before treatment ( $P > 0.01$ ).

### Antero-Posterior Balance

Also table 1 and figure 1 showed significant improvement in mean value of OB measured in group B at the end of treatment as compared with the responding mean values before treatment ( $P > 0.01$ ).

**Table (1): Comparison between pre and post mean values of anterior posterior balance in both groups (A and B).**

	Group A		Group B	
	Pre	Post	Pre	Post
X	2.4	1.4	2.6	1.5
t-test	6.8		6.03	
±SD	±.18	±.19	±.17	±.18
P-value	0.001		0.001	
Sig.	Significant		Significant	

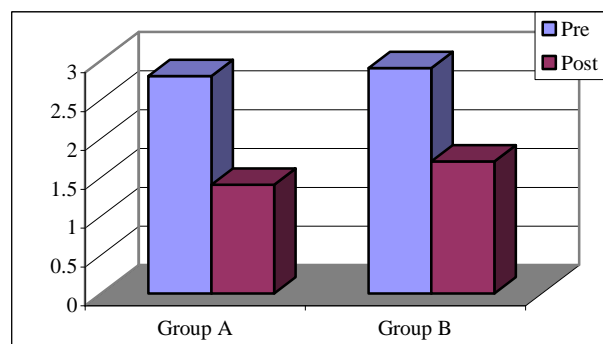
**Fig. (1): Mean values of anterior posterior balance in both groups (A and B).**

As revealed from table (2) and fig. (2) was observed in mean values of mediolateral balance measured in group A at the end of treatment as compared with the responding mean values before treatment ( $P>0.01$ ).

Also table 2 and figure 2 showed significant improvement in mean value of mediolateral balance measured in group B at the end of treatment as compared with the responding mean values before treatment ( $P>0.01$ ).

**Table (2): Post treatment mean values of - MEDIO-LATERAL BALANCE in both groups (A and B).**

	Group A		Group B	
	Pre	Post	Pre	Post
X	2.8	1.4	2.9	1.7
t-test	6.2		6.1	
±SD	±.18	±.19	±.17	±.18
P-value	0>0.01		0>0.01	

**Fig. (2): Mean values of mediolateral balance in both groups (A and B).**

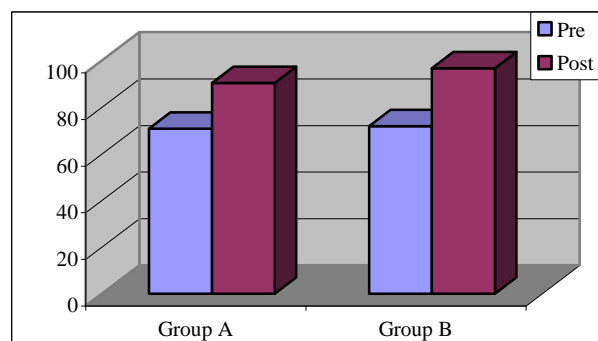
As revealed from table (3) and Fig. (3) was observed in mean values of locomotive subtest of Peabody developmental motor scale (PDMS-2).

Measured in group A at the end of treatment as compared with the responding mean values before treatment ( $P>0.01$ ).

Also table 3 and figure 3 showed significant improvement in mean value of locomotive subtest of Peabody developmental motor scale (PDMS-2): measured in group B at the end of treatment as compared with the responding mean values before treatment ( $P>0.01$ ).

**Table (3): Comparison between pre and post mean value locomotive subtest of (PDMS-2): (A and B).**

	Group A		Group B	
	Pre	Post	Pre	Post
X	70.8	90.4	71.9	96.7
t-test	24.2		32.1	
±SD	±1.18	±3.19	±.17	±.18
P-value	0>0.01		0>0.01	

**Fig. (3): Mean values of mean value locomotive subtest of (PDMS-2): in both groups (A and B).**

## DISCUSSION

The results of this study indicate that there are discernable effects of FES children with CP. The major finding is that FES successfully increases the impulse generated during the push-off phase of the gait cycle. However, translating that energy into increased speed and stride length and decreasing the adapted stiffness probably may require a longer period of training with FES than was used in this study. Nevertheless, the fact that immediate benefits of increased impulse, decreased stiffness, increased stride length, and decreased stride frequency were obtained in 3 out of 9 children (participants 2, 4, and 7) suggested that the use of FES in this manner warrants further investigation.

Predictions for an increase in impulse with FES were supported, but the expected decrease in stiffness was not supported. The largest median impulse was observed for children with CP in the FES condition in which the speed-normalized dimensionless values were more than twice of those of the children who were developing typically and more than 150% of those of the children with CP in the no-FES condition. This finding suggests that to walk at speeds comparable to those of children who were developing typically, children with CP require a much greater impulse. From a mechanical perspective, given that the stiffness does not change, this finding would be expected. Stiffer systems, by definition, require greater amounts of force to produce an equivalent amplitude of oscillation (s, the greater impulse observed in the FES condition does not translate into greater.

The predicted immediate effects of FES on decreased stiffness were not observed. In retrospect, this finding might have been expected. Some of the mechanisms responsible for increased stiffness, such as increased reflex gain<sup>25,28</sup>, morphological changes resulting in shorter muscle bellies and longer tendons<sup>42</sup>, and muscle fibrosis<sup>43</sup>, are slowly developing adaptations. System stiffness of children with spastic CP that results from the underlying pathophysiology adapts gradually over time according to the demands of locomotion in the gravitational force field. Morphological

changes that increase stiffness are particularly resilient to change, and probably take much longer to adapt. The observation that older children do not respond as well to stimulation of the G-S as children around 3 years of age<sup>7,8</sup> may be due to the fact that the morphological changes are well established in this older population. Our children ranged in age from 3 to 12 years, and the individual differences of mean stiffness between the no-FES and FES conditions were quite different based on their age.

## Conclusion

Electrical stimulation over the gastrocnemius-soleus muscle improve the gross motor skills in hemiparetic cerebral palsied children.

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### الملخص العربي

#### دراسة تأثير التنبيه الكهربائي على تطور الوظائف الكبيرة للأطفال المصابين بمرض الشلل النصفي التشخيصي

**الخلفية و الهدف من الدراسة :** الشلل النصفي التشخيصي هو مشكلة شائعة ومعيقة يتميز هذا المرض بالعديد من الأعراض ألا وهي التأخر في القدرة المشي والاتزان مقارنة بين الأطفال المساويين لهم في الأعمار . **الهدف من الدراسة :** يهدف هذا البحث إلى دراسة تأثير التنبيه الكهربائي على تطور الوظائف الكبيرة للأطفال المصابين بمرض الشلل النصفي التشخيصي . **طريقة البحث :** شملت الدراسة 30 طفلاً مصاباً بمرض الشلل النصفي التشخيصي تتراوح أعمارهم ما بين 3-8 أعوام وتم تقسيمهم عشوائياً إلى مجموعتين مجموعة مشاركة في التمارين ومجموعة غير مشاركة . كانت مدة البرنامج ثلاثة أشهر (ثلاث جلسات في الأسبوع) ، الجلسة لمدة 60 دقيقة تم استخدام مقياس جهاز الاتزان قبل وبعد الانتهاء وقياس PMDs من البرنامج (أي بعد ثلاثة أشهر) . **نتائج الدراسة :** أظهرت النتائج وجود تأثيرات إيجابية ذات دلالة إحصائية بين القياس قبل وبعد للمجموعة المشاركة في القدرة على استخدام الاتزان ذات دلالة إحصائية . **الاستنتاج :** استنتج من الدراسة أن هناك تأثير إيجابي للتنبيه الكهربائي على وظائف الكبيرة والقدرة الاتزان للأطفال المصابين بمرض الشلل النصفي التشخيصي .