Selective Effects of Electro-Motor Stimulation in Hemiplegic Cerebral Palsied Children

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ABSTRACT

This study aimed at investigating the effects of different physical therapy modalities on muscle strength of the ipsi-lateral and contra-lateral limb muscles in hemiplegic cerebral palsy (CP) children. Thirty hemiplegic CP children, ranging in age from 6 to 9 years were selected and divided randomly into two groups of equal number, study and control, each comprised 15 patients. A program of strengthening exercises for the quadriceps muscles of the sound limb was administered to the patients of both groups, while those of the study group only received electro-motor stimulation (EMS) for the same group of muscles in addition. Treatment of both groups continued for 12 successive weeks, 3 sessions weekly. Quadriceps muscle strength of both sides was evaluated using the MIRAC device, in addition to thigh circumference measurement before and after the suggested period of treatment. Results at the end of this study revealed a significant increase in the peak torque values of the quadriceps muscle of both limbs, in addition to a significant increase in girth measurement of both thighs of the study group only. According to the results of this study, it can be concluded that EMS combined with remedial strengthening exercises may help in increasing muscle strength of both the treated and the untreated limbs among the hemiplegic CP children.

Key words: *Cerebral palsy – Hemiplegia – Electrical stimulation.*

INTRODUCTION

Cerebral palsy (CP) is the term used to refer to a non-progressive group of brain disorders resulting from a lesion or developmental abnormality in fetal life or early infancy. These disorders are characterized by poor control of movement, adaptive length changes in muscles and, in some cases, skeletal deformities. The common classification according to the perceived clinical signs is spastic, athetoid, hypotonic, ataxic and mixed type. Cerebral palsy is classified according to the distribution of motor involvement into quadriplegia, hemiplegia and diplegia[1].

Treatment of the child with cerebral palsy must be individualized, based on his / her specific problems, age, degree of involvement, intelligence, associated problems and family involvement. Treatment goals should be modified due to changes in the presenting problems. For example, an infant with hemiplegia may initially present with hypotonicity in the upper extremity and by the age of six months present with hypertonicity once he begins to move against gravity. The goal therefore changes from increasing tone in the involved upper extremity to decreasing tone in the involved upper extremity. Physical therapy management should be coordinated with all other medical and educational disciplines involved with the child. Treatment should be integrated with the goals and methods of occupational and speech therapy, orthopedic management, educational and home management[3].

Historically, electro-motor stimulation (EMS) has been used for decades to treat a variety of musculo-skeletal and neuro-muscular problems. Uses of electrical stimulation range from increasing volitional control through motor and sensory stimulation to inhibit spasticity. Burridge et al.,[2] utilized short-width pulse stimulation to increase torque output of the ankle dorsiflexors and reciprocally decrease spastic reflexes in the planter flexors. This leads to improvement of gait pattern in the concerned patients. They added that recent technology has enhanced the application of electrical stimulation because modern stimulation units are small, portable and easy to use.

In the rehabilitation setting, electrical stimulation has been used by physical therapists to reeducate muscle action, retard muscle atrophy and enhance muscle performance. In the treatment of weak muscle, it is frequently used as an adjunct to voluntary resisted exercises to improve muscle function[6].

Electro-motor stimulation has been used in the treatment of various disorders of the motor system. Its effectiveness was studied in a variety of cases including cerebral palsy, dystonia and spinal cord injury patients. The level stimulated, the pattern and polarity of the applied field and the frequency of stimulation are critical to achieve satisfactory therapeutic results, so they must be individualized in each patient[17].

Aim of the work

The purpose of this study was to determine whether an endurance-training program, lasting approximately 12 weeks would increase muscle strength of both ipsi-lateral and contra-lateral limb muscles in hemiplegic cerebral palsy children.

SUBJECTS, MATERIALS AND METHODS

Subjects

Thirty hemiplegic cerebral palsy children of both sexes, ranging in age from 6 to 9 years, selected from the Out-patient Clinic of the Faculty of Physical Therapy, Cairo University, represented the sample of this work. They were 19 males and 21 females, 24 of them were right- while 16 were left side affected. All of them had neither fixed deformities nor previous operations. The patients were divided randomly into two groups of equal number, group A (study group) and group B (control group); each comprised fifteen patients. Then, each group was exposed to a definite program of treatment for 12 successive weeks, 3 sessions per week.

Materials

- Electrical stimulator: "Medisana EMS", dual-channel electrical stimulator.
- Isokinetic device (MIRAC system).
- Tape measure.

Methods

- **For evaluation**

1. Torque evaluation

The "MERAC" isokinetic dynamometer was used to measure the peak torque value of the quadriceps muscles of both sides at angular velocity of 90 / sec. The MIRAC unit was calibrated at the beginning of each test to insure valid results. The patient was seated, with both knees flexed to 90° and inclined backward with stabilization by trunk straps to bring all parts of the quadriceps muscle into action. Each subject was instructed about the procedures in order to allow him/her to be familiar with the test protocol. Then, the patient was asked to perform three trials of knee extension and the mean was calculated. The test was carried out for both sides and the peak torque value for each side was recorded separately.

2. Girth Measurement

Using tape measure, the thigh circumference was evaluated. It was measured 10 cm above the upper end of patella.

These tests were conducted before and after the suggested period of treatment (12 weeks).

- **For treatment**

All patients received a physiotherapy program for strengthening the quadriceps muscle of the sound limb. Such a program included isometric and isotonic resisted exercises. Each session lasted 30 minutes and consisted of low-resistance, high-repetition exercises for the quadriceps muscle[7].

Patients belonging to the study group received electromotor stimulation for the quadriceps muscle of the sound limb for other 30 minutes in addition. The contraction-relaxation ratio was 1:5 (10 seconds for contraction, followed by 50 seconds for relaxation).

RESULTS

Before the start of the physical therapy program, there was no significant difference between the two groups neither in quadriceps torque nor in thigh circumference ($P > 0.05$).

As shown in table (1) and fig. (1), before treatment the mean value of the quadriceps torque of the sound limb in the study group was 27.21 ± 2.166 Nm, which increased after 12 weeks of treatment to be 27.68 ± 2.124 Nm, with a mean difference of 0.46 Nm. Concerning the control group, the mean value of the quadriceps muscle torque of the sound limb was 27.14 ± 2.099 Nm before treatment, which increased to be 27.57 ± 2.146 Nm after the suggested period of treatment, with a mean difference of 0.43 Nm. The mean difference values of the quadriceps torque in both the study and the control groups at the end of treatment were statistically significant ($P < 0.05$).

Table (1): Mean values of quadriceps torque (in Nm) of the exercised (sound) limb in both groups before and after 12 weeks of treatment.

Evaluation time	Study		Control	
	Before	After	Before	After
Mean	27.21	27.68	27.14	27.57
SD	2.166	2.124	2.099	2.146
MD	0.46		0.43	
t	2.250		2.067	
P	< 0.05 Sig.		< 0.05 Sig.	

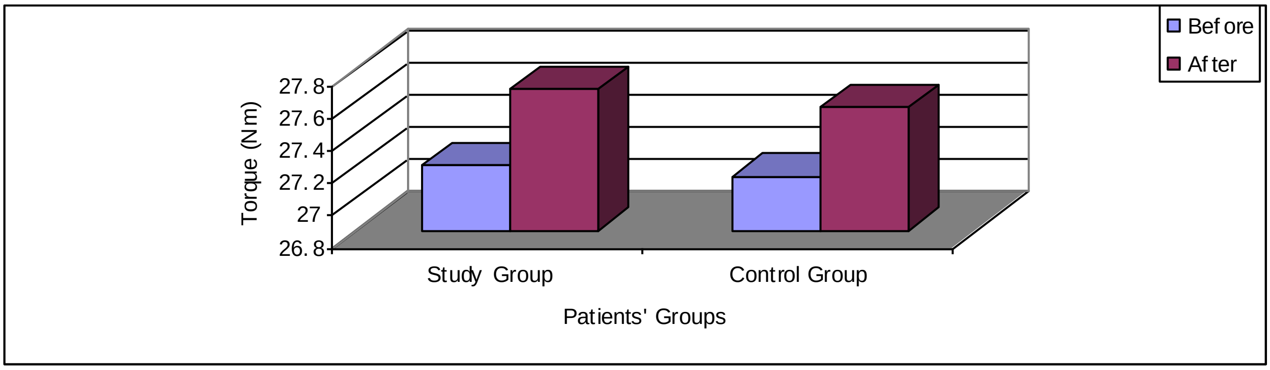

Fig. (1): Mean values of quadriceps torque (in Nm) of the exercised (sound) limb in both groups before and after 12 weeks of treatment.

Concerning the quadriceps muscle of the affected limb of the study group, the mean torque value increased from 26.28 ± 2.151 Nm before treatment to 26.58 ± 2.241 Nm after 12 weeks of the combined method of treatment, forming a mean difference of 0.30 Nm. Before treating the control group, the mean value of the quadriceps muscle torque was 26.01 ± 1.912 Nm, which increased after treatment to 26.11 ± 1.895 Nm, with a mean difference of 0.10 Nm. The mean difference values of the quadriceps torque in both groups after treatment were statistically significant ($P < 0.05$) (Table 2 and fig. 2).

Table (2): Mean values of quadriceps torque (in Nm) of the non-exercised (affected) limb in both groups before and after 12 weeks of treatment.

Evaluation time	Study		Control	
	Before	After	Before	After
Mean	26.28	26.58	26.01	26.11
SD	2.151	2.241	1.912	1.895
MD	0.30		0.10	
t	2.330		2.214	
P	< 0.05 Sig.		< 0.05 Sig.	

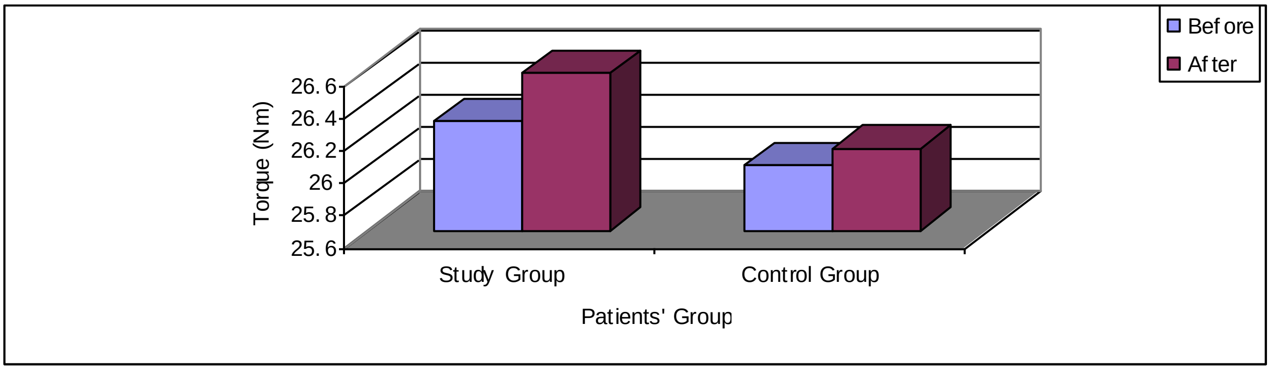

Fig. (2): Mean values of quadriceps torque (in Nm) of the non-exercised (affected) limb in both groups before and after 12 weeks of treatment.

As revealed in table (3) and fig. (3), the mean value of thigh circumference of the sound limb in the study group before treatment was 32.8 ± 1.373 cm. After 12 weeks of treatment, the mean value increased to be 33.2 ± 1.146 cm, which represented a mean difference of 0.4 cm. Before treatment of the control group, the mean thigh circumference of the sound limb was 31.4 ± 2.131 cm, which increased after 12 weeks of treatment with therapeutic exercises to be 31.7 ± 2.193 cm, having a mean difference of 0.3 cm. The mean difference in the thigh circumference of both the study and the control groups at the end of treatment were statistically significant ($P < 0.05$).

Table (3): Mean values of girth measurements (in cm) of the exercised (sound) limb in both groups before and after 12 weeks of treatment.

Evaluation time	Study		Control	
	Before	After	Mean	SD
Mean	32.8	33.2	31.4	31.7
SD	1.373	1.146	2.131	2.193
MD	0.4		0.3	
T	2.449		2.256	
P	< 0.05 Sig.		< 0.05 Sig.	

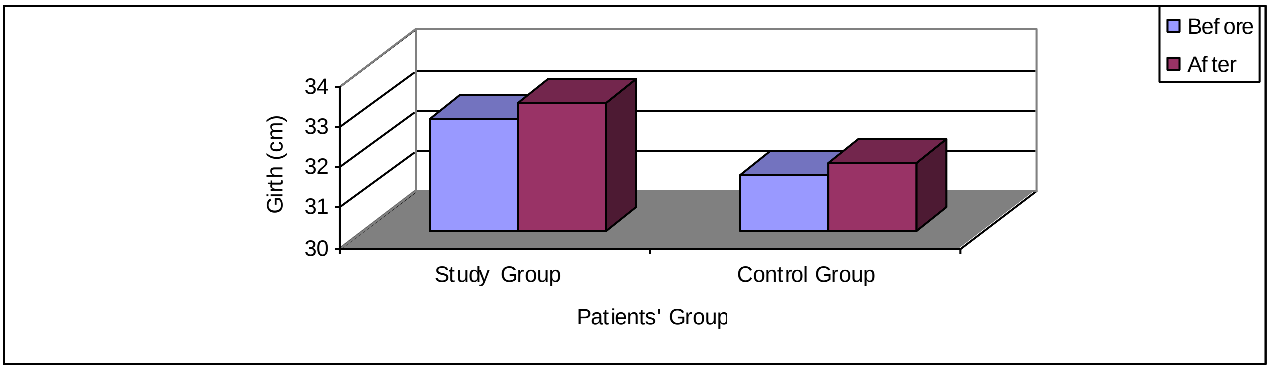

Fig. (3): Mean values of girth measurements (in cm) of the exercised (sound) limb in both groups before and after 12 weeks of treatment.

The mean thigh circumference of the affected limb in the study group increased from 31.9 ± 0.916 cm before treatment to be 32.2 ± 0.640 cm after the suggested period of treatment, forming a mean difference of 0.3 cm. Similarly, the mean value of the thigh circumference of the affected limb of the control group increased from 31.2 ± 1.207 cm before treatment, to be 31.4 ± 1.183 cm after treatment, with a mean difference of 0.2 cm. As shown in table (4) and fig. (4), the mean difference in thigh circumference of the study group at the end of treatment was statistically significant ($P < 0.05$), while the difference was not significant in the control group ($P > 0.05$).

Table (4): Mean values of girth measurements (in cm) of the non- exercised (affected) limb in both groups before and after 12 weeks of treatment.

Evaluation time	Study		Control	
	Before	After	Mean	SD
Mean	31.9	32.2	31.2	31.4
SD	0.916	0.640	1.207	1.183
MD	0.3		0.2	
t	2.256		1.382	
p	< 0.05 Sig.		> 0.05 Non-Sig.	

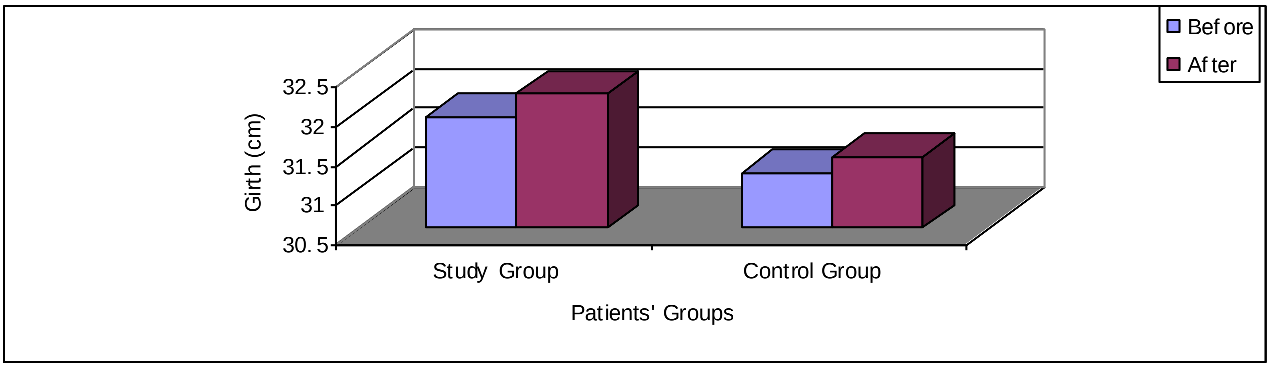

Fig. (4): Shows mean values of thigh circumference before and after treatment of both limbs, in the study and control groups.

DISCUSSION

In the present study, the electro-motor stimulation (EMS) was utilized to improve muscle efficiency of both the ipsi-lateral and contra-lateral limb muscles. The results revealed a significant increase in muscle torque of the quadriceps muscle of both treated and untreated limbs of both groups.

The results came in agreement with those of Laughman et al.,[12] who observed a significant increase in the strength of the untreated quadriceps muscle. Their patients were treated by a program of isometric exercises plus EMS for 5 weeks, 5 sessions per week.

The results also go with those of Mills and Quintana[15], who used high-resistance weight training for certain group of muscles for increasing the strength of the contra-lateral non-exercised weak group. Their findings indicated an increase in the strength of the ipsi-lateral and contra-lateral muscles, which is indicated through an increase in the number of motor unit potentials in these muscles.

The results of this piece of work were also coincident with those of Lai et al.,[11] who found significant strength improvements in the isometric strength of the untreated limb of the study group, treated by high- or low- intensity electrical stimulation. Furthermore, they added that the control group (received no EMS), had no significant changes in the muscle strength of the untreated limb.

Dubowitz[5] and Einarsson and Grimby[5] also studied the mean fiber areas for all fiber types. The observed increase in muscle size has been hypothesized that the increase in mean fiber area resulted from the greater stress placed on the muscle fibers causing the corresponding hypertrophy.

Pole et al.,[18] attributed the improvement in muscle flexibility to muscle stretching facilitated by reflex inhibition of the antagonist muscle. They announced that EMS of the anterior tibial group muscles leads to their contraction, which stretches the triceps surae muscles. Thus, synergistic co-contraction of the extensor and flexor muscle groups has therapeutic benefit, noted in gait analysis.

The effects of unilateral strength training on the strength of the trained and untrained limbs have been studied. A training group contained seven persons exercised for 6 weeks isometric leg extensions at 80 % of maximal isometric torque, on three-time per week basis. The results indicated a cross training effect on the isometric torque of the quadriceps muscle, with significant increases in torque. In both trained and untreated limbs[21].

Furthermore, the effects of exercising the non-involved side on the involved leg-muscles of stroke patients were investigated. Ten adults were instructed to perform voluntary knee extension and maximal isometric knee flexion of the non-involved side, with counter-resistance on the involved side. The results showed that isometric training of the non-involved side may be useful for facilitating the paretic muscles of both the involved and the non-involved sides[9].

The observed increase in motor unit potentials may be attributed to collateral sprouting from the survived motor units. Such an increase in motor unit potentials will lead to a simultaneous improvement in muscle tension. Moreover, increasing recruitment and firing rates of the motor units might have an effect on muscle tension[10]. It has been added that greater degree in motor unit synchronization increases the rate of tension generation per cross sectional area for a given muscle.

The results provide additional support for the cross-transfer or cross-educational effect of muscle strengthening. It has been suggested that the mechanism of cross-education consist of neural factors (motor control) that increase the maximum level of muscle activation at various levels of the nervous system[16]. Lloyd et al.,[13] added that cross-education phenomenon was also observed in the subjects, treated by electrical stimulation, even though they exerted no voluntary effort. Thus, the cross-education effect of muscle strengthening through EMS may be attributed to a mechanism similar to that of muscle strengthening through voluntary exercises. This is achieved by neural factors acting via increased facilitation or dis-inhibition at various levels of the nervous system[20].

Farmer et al.,[8] studied the effect of unilateral training on bilateral muscle strength. They concluded that the motor neuron pools of homologous right and left muscles received common synaptic input from the abnormally branched pre-synaptic axons, provided by abnormally branched cortico-spinal tract fibers. This will lead to increased bilateral muscle strength.

The results of the present study revealed an increase in the thigh circumference of the ipsi- and contra-lateral sides in both groups, which is significant in the study group only. Such difference in thigh circumference between the trained and untrained limb may be attributed to the differential responses to training in the four muscles of the quadriceps femoris muscle[14].

Conclusion

From the results of the current study, it may be concluded that the paralytic extremities in hemiplegic cerebral palsy children may benefit from endurance training programs conducted on the sound sides. It can be also concluded that EMS in addition to therapeutic exercises may result in even more increase of muscle strength, not only of the exercised limb, but also of the untreated one (cross-education effect).

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الملخص العربي

تأثيرات منتقاة للتنبيه الكهربائي للعضلات في الأطفال المصابين بالشلل المخي النصفي التشنجي

تهدف هذه الدراسة إلى معرفة تأثير وسائل العلاج الطبيعي المختلفة على عزم عضلة الفخذ ذات الأربعة رؤوس ، سواء التي طبق عليها برنامج العلاج أو مثيلتها التي على الجانب الأخر في حالات الأطفال المصابين بالشلل النصفي التشنجي . اشتملت الدراسة علي ثلاثين طفلا من المصابين بالشلل النصفي التشنجي تراوحت أعمارهم من 6 إلى 9 سنوات ، تم تقسيمهم عشوائيا إلى مجموعتين متساويين في العدد (المجموعة الضابطة والمجموعة محل البحث) ضمت كل مجموعة 15 مريضا ، تم تطبيق برنامج تمرينات علاجية على مرضي المجموعتين بهدف تقوية عضلة الفخذ ذات الأربعة رؤوس في الجانب السليم، أما المجموعة محل البحث فتم إضافة التنبيه الكهربي للعضلة ذاتها ، استمر علاج المجموعتين لمدة اثني عشرة أسبوعا متصلة، كما تم قياس عزم العضلة ذات الأربعة رؤوس في الجانبين (السليم والمصاب) باستخدام جهاز " ميراك " بالإضافة إلى قياس محيط الفخذ في الجانبين قبل وبعد فترة العلاج . أثبتت نتائج الدراسة وجود زيادة ذات دلالة إحصائية في عزم العضلة ذات الأربعة رؤوس في الجانبين في المجموعتين، بالإضافة إلى زيادة ذات دلالة إحصائية في محيط الفخذ في الجانبين بالنسبة للمجموعة محل البحث فقط، كما أثبتت وجود زيادة مماثلة ذات دلالة إحصائية بالنسبة للمجموعة محل البحث عن المجموعة الضابطة، وعليه فينصح بإضافة التنبيه الكهربائي إلى برنامج التمرينات العلاجية المتبع في علاج مثل هذه الحالات .