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Original Article

Role of Electromyographic Feedback Stimulation after Achilles Tendon Lengthening in Spastic Hemiplegic Cerebral Palsy

Heba A. Bahey El-Deen[1], Hala Ibrahim Kassem[2], Khaled Ahmed Olama[3], Alaa NoureldeenKora[4]

[1]Associate Professor of Physical Therapy, Faculty of Applied Medical Sciences, AlJouf University, KSA, [2]Dean of the Faculty of Physical Therapy, Delta University, [3]Professor and Chairperson of Department of Paediatric Physical Therapy, Cairo University, [4]Clinical Instructor in the Paediatrics Outpatient Clinic, Faculty of Physical Therapy, Cairo University

ABSTRACT

Shortening in Achilles tendon is one of the most common complications in spastic hemiplegic cerebral palsy. The present study was conducted to determine the effect of Electromyographic feedback stimulation during two weeks immobilization period after tendo-Achilles lengthening in children with spastic hemiplegic cerebral palsy. Thirty children with spastic hemiplegic cerebral palsy, ranges from seven to nine years in age (x` 8.2430±0.863yr.), represented the sample of the study. They were selected from different hospitals in Cairo, Egypt. The peak torque of ankle dorsiflexors and ankle excursion were measured via using MERAC isokinetic system and electro-gonimeter respectively. The subjects were divided randomly into two groups, Group A (control) received Electromyographic feedback stimulation after removal of plaster cast for two weeks daily in addition to designed physical therapy program, while Group B (study) received Electromyographic feedback stimulation during immobilization period (two weeks) in addition to the same program of Group A. Evaluation for each child of the two groups was conducted immediately after removal of plaster cast and then after two weeks. The results of this study revealed significant improvement in peak torque of ankle dorsiflexors and ankle excursion in favour of group B; also, a significant difference was observed in the results of the two groups immediately after removal of the cast in favour of group B. Improvement occurred in the measuring variables of groups b may be attributed to the effect of Electromyographic feedback stimulation during immobilization which resulted in strengthening in the anterior tibial muscles group which helped in maintain the obtained range of ankle dorsiflexion and preventing the recurrence of tendo-Achilles shortening.

Keywords: Cerebral palsy, EMG feedback, Tendo-achillis lengthening

INTRODUCTION

The limb muscles of the child with hemiplegia must perform a range of functions to accommodate the changing mechanical demands associated with movement in their natural environment. Even during steady –speed locomotion, certain muscles may be expected to function differently from others. In part, this is likely to be related to differences in their muscle – tendon architecture; for example, the shortening of Achilles tendon which may be occurred due to muscle imbalance in spastic hemiplegic cerebral palsy (Belli, Kyröläinen & Komi, 2002). In spastic hemiplegia, loss of recruitment of agonist contraction, or reduced output paresis, play a major role in impairment of muscle function (Bohannon & Smith, 1987), which leads to change in passive properties or shortening of Achilles tendon muscles (Hastings et al., 2000).

Equines deformity is a common finding in children with spastic hemiplegic cerebral palsy and may be treated by Achilles tendon lengthening (Lee, Lin & Wapner,

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Address for correspondence:
Alaa Noureldeen Kora, Clinical Instructor in the Paediatrics Outpatient Clinic, Faculty of Physical Therapy, Cairo University, E-mail: alaan.kora@gmail.com

1996). Tendo-Achilles lengthening also affects ankle performance, presumably because of the acute change in length –tension relationships of gastrocnemius and soleus muscles (Kaufman & Shaughnessy, 2000; Shaw et al., 1997; Delp, Statler & Carroll, 1995).

A reduction in ankle muscle performance following Tendo-Achilles lengthening could be especially problematic for children with hemiplegic cerebral palsy because typically ankle muscle performance is already compromised in this population (Salsich, Brown & Mueller, 2000). Both dorsi- flexor peak torque and passive torque have been reported to be reduced in children with hemiplegic cerebral palsy (Mueller, Minor, Schaaf, Strube & Sahrmann, 1995). A further reduction in ankle muscle performance from tendo-Achilles lengthening procedure could have a substantially negative impact on the walking ability of children with hemiplegia who also have loss of protective sensation (Salsich & Mueller, 1997).

Electromyographic feedback stimulation is one of the physiotherapeutic modalities which can be used to modulate muscle tone disturbance and increase the muscle performance (Kim, Cho, Kim & Lee, 2016)

The purpose of this article is to investigate the effect of electromyographic feedback stimulation after Tendo-Achilles lengthening in spastic hemiplegic cerebral palsy on ankle dorsiflexion peak torque and ankle excursion.

SUBJECTS, INSTRUMENTATION AND PROCEDURES

Subjects

Thirty children with spastic hemiplegic cerebral palsy, selected from both sexes (13 males and 17 females), ranging in age 7 to 9 years (mean= 8.243 ±0.863 yr) represented the sample of this study. Ten of them were right sided, while twenty were left sided affection. They were operated by tendon-Achilles lengthening with no other disorders. They were selected from different hospitals in Cairo. They were divided randomly into two groups of equal number, each include 15 subjects. Evaluation of each child of the two groups was conducted immediately after removal of plaster cast and then after two weeks. Each group of patients received a specific treatment protocol.

Instrumentation:

A) For evaluation

1. MERAC isokinetic system was used for measuring the peak torque of ankle dorsiflexors. The system provides training via applying different modes of muscle exercises. It includes bench, dynamometer provided with a computer system, for testing, recording and printing the results. It provides advanced information about strength, exercises and fatigue. The computer also allows the therapist to control speed, torque and time of every exercise in different directions. The data provided by this system are valid and reliable, due to the presence of stable bench for proper position and dynamometer, proper joint isolation and gravity calibration.
2. Electrogoniometer for measuring ankle excursion. It consisting of a potentiometer fixed at the pivot point of the two arms (Fixed and movable). The potentiometer is connected to a digital millimeter to record the degree of angular displacement. The device is maintained in position via straps, connected to its both arms.

B) For treatment

1. Electromyographic feedback electrical stimulator:
   Automove AM 706 (biometer international A.S.) which includes one cable with three Electromyographic electrodes and two stimulating electrodes. The cable was connected to the automove machine via special blug.
2. Tumble Forms (Mats, wedges, Rolls and balls) from Preston©, for the application of the exercises program.

Procedures:

A) For evaluation
   Double blind evaluation of each child in the two groups was conducted in a warm, well lighted and quit room, immediately after removal of plaster cast and after two weeks of the removal of the cast using MERAC system to measure ankle dorsiflexors peak torque and the electrogoniometer to measure ankle excursion.
   1. Measuring ankle dorsiflexors peak torque:
      Using the MERAC system, from sitting position with the knees flexed at the edge of the machine bench. The pelvic, trunk and

the thigh of the tested limb were stabilized by straps to ensure isolation and to prevent substitution. The child's back was completely supported on the back support of the bench. The anatomical axis of rotation of the ankle joint was aligned with rotational axis of the dynamometer and the lateral aspect of the leg was placed in parallel alignment with the lever arm of the dynamometer. Subjects were then asked to perform two trials of ankle dorsiflexion without resistance, to be accommodated with system. Then, three trials using the maximum power of ankle dorsiflexion were conducted from full planter flexion. The mean of three trials was then calculated.

2. Ankle excursion:
   From sitting position on the bed with both hips and knees in right angles, the fixed arm of the electrogoniometer was placed parallel to the lateral aspect of the leg. The fulcrum just below the lateral malleoli and the movable arm was placed parallel to the longitudinal axis of the fifth metatarsal. The arms of the goniometer were maintained in this position via straps. Each child was then asked to move his/her ankle from full planter flexion to the maximum available range of dorsiflexion, and reached range of motion was recorded.

B) For treatment
   The thirty children with spastic hemiplegic cerebral palsy representing the sample of this study were divided randomly into two groups of equal numbers (A and B). Group A (Control) received the Electromyographic feedback stimulation after removal of plaster cast for two weeks daily in addition to a designed exercises program, which continued for one hour daily including Neurodevelopmental technique, positioning with special attention to the unaffected side. Group (B) (Study) received the Electromyographic feedback stimulation during the immobilization period (two weeks) through windows in the cast, in addition to the same treatment program as Group A. The Electromyographic feedback stimulation was applied on the middle of the anterior tibial group for picking up the weak signal, coming to these muscles. The signals were propagated inside the machine (Automove AM 706) and feedback as electrical stimulation via two stimulating electrodes. The treatment session of Electromyographic feedback stimulation was applied for two hours/day for each child.

RESULTS

In this study, the effect of the Electromyographic feedback stimulation after tendo-Achilles lengthening on the ankle dorsiflexors peak torque and ankle excursion was investigated. The raw data of the two groups were statistically analyzed to determine the mean value and standard deviation. The student t-test was then utilized to determine the significance of treatment procedures applied in each group.

1) Ankle dorsiflexors peak torque:
   Table 1 and Figure 1 shows significant improvement in the mean values of peak torque of ankle dorsiflexors (N/M) after two weeks of removal of the cast in the two groups when compared to their result immediately after removal of the cast (after two weeks of immobilization period). The

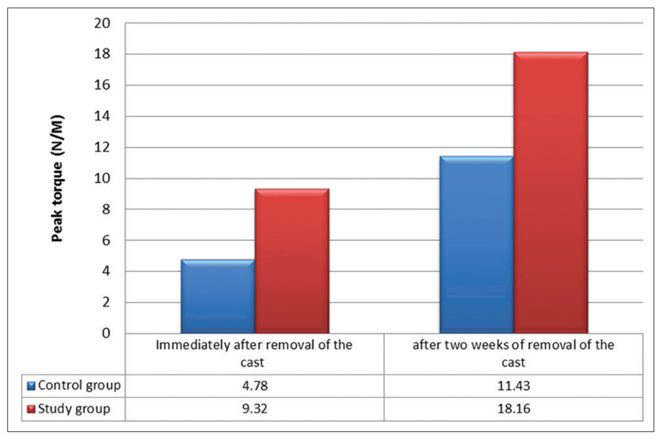

Figure 1: Illustrating the Mean values (N/M) of peak torque of ankle dorsiflexors for control and study groups immediately and after two weeks from cast removal

Table 1: Mean values of peak torque of ankle dorsiflexors (N/M) for both control and study groups immediately and after two weeks from cast removal

	Control group		Study group	
	After cast removal	After 2 weeks of cast removal	After cast removal	After 2 weeks of cast removal
$\bar{X}$ ± SD	4.78±2.16	11.73±4.83	9.32±3.17	18.16±2.13
t-test	3.652		5.723	
P	<0.001		<0.0001	
Sig.	Significant		Significant	

$\bar{X}$: Mean SD : Standard deviation P: Level of significance Sig.: Significance

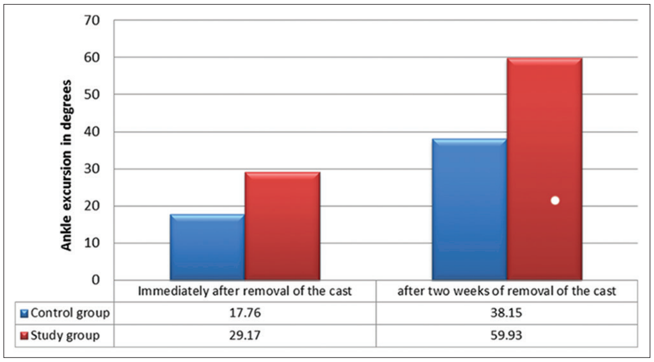

Figure 2: Illustrating the mean values (degrees) of ankle excursion for control and study groups immediately and after two weeks from cast removal

Table 2: Mean values of ankle excursion (degrees) for control and study groups immediately and after two weeks from cast removal

	Control group		Study group	
	After cast removal	After 2 weeks of cast removal	After cast removal	After 2 weeks of cast removal
X̄± SD	17.76±3.52	38.15±4.89	29.17±4.39	59.93±4.87
t-test	6.724		7.637	
P	<0.0001		<0.0001	
Sig.	Significant		Significant	

X̄: Mean SD : Standard deviation P: Level of significance Sig.: Significance

mean values of peak torque of ankle dorsiflexors in the control group immediately after removal of the cast were 4.78±2.16 N/M and 11.43±4.83 N/M after two weeks of cast removed ($p<0.001$), while the mean values of peak torque of ankle dorsiflexors in the study group immediately after removal of the cast were 9.32±3.17N/M and 18.16±2.13 N/M after two weeks of removal of the cast ($p<0.001$)

As shows in Table 2 and Figure 2, there was significant improvement of peak torque of ankle dorsiflexors which was denoted by significant increase in the mean value immediately after removal of the cast when comparing the two groups in favour of the study group. The mean value of peak torque of ankle dorsiflexors immediately after removal of the cast for control group was 4.78 ± 2.16 N/M and 9.32 ± 3.17 N/M for study group ($p<0.001$)

2) Ankle excursion:

As showed in Table 2 and Figure 2, there was significant improvement in the mean values of ankle excursion (degrees) after two weeks of removal of the cast in the two groups, when compared to their result immediately after removal of the cast (after two weeks of immobilization period). The mean values ankle excursion of the control group immediately after removal of the cast were 17.76±3.52 ° and 38.15±4.89 ° after two weeks of cast removed ($p<0.0001$), while the mean values ankle excursion of the study group immediately after removal of the cast were 29.17± 4.39° and 59.93±4.87 ° after two weeks of removal of the cast ($p<0.0001$)

DISCUSSION

Given that ankle dorsiflexion and its control is one of the most difficult motions to regain after Achilles tendon lengthening in spastic hemiplegic cerebral palsy and is a key precursor for walking activity, loss of this capability is a primary disabler for gait. Frequently, walking and dorsiflexion movements serve markers for therapeutic intervention (Thikey, Grealy, van Wijck, Barber & Rowe, 2012)

From this study, two lines of evidence clearly support the use of Electromyographic feedback neuromuscular electrical stimulation in the rehabilitation program with individuals after Achilles tendon lengthening in spastic hemiplegic cerebral palsy.

In respect to the results of the present study, significant difference was observed when comparing the results immediate after cast removal in the two groups in favour of group B.

On average, both control and study dorsiflex ankles and walk better after two weeks of cast removal than immediate after cast removal. This performance indicates an improvement in functional capability representing a transfer of neuromuscular stimulation to functional dorsiflexion task.

Additional support was the improved peak torque of ankle dorsiflexors which was observed after two weeks of cast removal. Once the participants voluntarily attempted to reach ankle dorsiflexion target levels and experienced successful ankle dorsiflexion assisted by potentiating of muscle contraction via electromyographic feedback muscle training, which lead to motor control improvement. This is meaningful result. The ability to dorsiflex ankle is necessary for use of the ankle in walking activities (Dobkin, Firestine, West, Saremi & Woods, 2004).

Regarding the work of Lin (2005), who investigated dorsiflexion in both involved and uninvolved limbs, he noticed that computerized recording of motor performance during ankle dorsiflexion could be helpful to detect subtle improvements in neuromuscular capability.

According to the results of this work, the significant difference in the mean values of peak torque of ankle dorsiflexors and ankle excursion immediate after cast removal between the two groups in favour of group B suggested that electromyographic feedback electrical stimulation assisted the alternative motor pathways and can be recruited and activated to assist the efferent pathway (Chang, 2007).

In the same context, significant improvement was observed in the mean values of all variables after two weeks of cast removal between control and study groups in favour of group B which is supported by Sarlegna & Sainburg, (2009) who stated that Proprioception was appeared to be critical in the transformation of the motor commands muscles.

Nevertheless, a theoretical question about the mechanism still abounds; what mechanism does the Electromyographic feedback electrical stimulation activates that could explain the improved ankle dorsiflexion as well as the increased integrated force value? Of course, a change in the paretic muscles is one part of a possible explanation. However, the restricted treatment time involved and the short training program suggested that a muscle training explanation has limitations as reviewed by Sale (1988); and a significant increase in muscle activity has been shown to occur in a two weeks time frame.

Moreover, multiple representation and redundancy in the system may underline motor recovery after spastic hemiplegic cerebral palsy. This explanation takes advantage of the functional equivalence that underlines movements. Functional equivalence refers to the capability of the motor system in achieving a movement goal through multiple routes. Interactions in sensorimotor system may achieve a retro activation of motor commands based on proprioceptive feedback activity from convergent regions (Prochazka, 1989). Thus, the basis for sensorimotor integration theory as mediating mechanism in motor recovery for post- hemiplegic cerebral palsy is appealing.

CONCLUSION

From the obtained results, it can be concluded that the use of Electromyographic feedback electrical stimulation to the anterior tibial muscle group with children with spastic hemiplegic cerebral palsy after tendo-Achilles lengthening results in significant improvements for peak torque of ankle dorsiflexors and ankle excursion. These findings suggest that Electromyographic feedback electrical stimulation is a beneficial adjunct to the rehabilitation of post operative Achilles tendon lengthening in children with hemiplegic cerebral palsy.

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