Therapeutic functional electrical stimulation in hemiplegic cerebral palsy

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ABSTRACT

Objective: Background and purpose cerebral palsy is a chronic non-progressive disorder of early onset primary effects of cerebral palsy include muscle spasm or tightness, involuntary movements, abnormal gait patterns, abnormal sensation and perception. Neuromuscular electrical stimulation can be effective means of managing increased muscle tone, of facilitating voluntary motor control, and of improving gait pattern. The purpose of this study was to evaluate the effect of therapeutic electrical stimulation on gait patterns in children with hemiplegic cerebral palsy and to investigate to which extent the increased muscle tone will be decreased after electrical stimulation.

Methods: Twenty two children with hemiplegic cerebral palsy, their ages ranging from 5 to 9 years were involved in the study. They were divided into 2 equal groups; experimental and control group. The experimental group continued with their current physiotherapy regime plus surface electrical stimulation of the anterior tibial muscle of the hemiplegic leg for one hour per day for 12 weeks. While the control group continued with their current physiotherapy regime with no change. All children of the study were evaluated before and after 12 weeks of treatment. Items of evaluation were gait patterns by method of foot print and the degree of spasticity through the ratio Hofman/Myogenic ratio.

Results: The results showed a significant improvement in gait patterns of children who received electrical stimulation as well a significant reduction of spastic muscle tone through the reduction of Hofman/Myogenic ratio. While the control group did not show any significant change.

Conclusion: The results of this study indicated that, with careful supervision, electrical stimulation can be used as an adjunct therapy for the improvement of gait patterns in children with cerebral palsy with the associated benefit of improved active movement and muscle power.

Keywords: Cerebral palsy, electrical stimulation.

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The term cerebral palsy (CP) defines an umberella term covering a group of non-progressive, but often changing, motor impairments syndromes secondary to lesions or anomalies of the brain arising in the early stages of its (the brain's) development.[1] Various methods have been used to manage children with CP; physiotherapy, occupational therapy, splints and orthoses, and surgery are used to prevent and to correct deformities. Drugs have been used to reduce spasticity. Different types of physiotherapy have been developed and used; one of these methods is functional electrical stimulation. Neuromuscular electrical stimulation (NEMS) has been used to improve range of motion (ROM) in absence of contractures, temporarily reduce excessive spasticity (hyperreflexia),[2] facilitate motor control and muscle reeducation[3] and assist in gait training.[4] Leyendecker, 1975 studied 20 children with CP whose mean age was just over 10 years. There was no description of the neuromuscular electrical stimulation treatment method or measurement, including which muscles were stimulated or whether

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the children were required to be active. At the beginning of the study, the 10 children who received NEMS with neuro developmental treatment (NDT) progressed faster then the 10 children who received only NDT. At the end of the study, however, the 2 groups were equal.[5]

Alwater and colleagues used electromyography (EMG)-driven NMES with 10 children with CP, aged from 5.5 to 16 years, the children received EMG-driven NMES to either the wrist extensors or ankle dorsiflexors and a total body NDT exercise program 3 times per week for 8 weeks. The children needed to actively contract and the fully relax their muscles. The results showed an improvement in general motor function.[6] Labord, 1986 applied electrical stimulation to the quadriceps muscles of children with CP, reporting an improvement in muscle power in all patients and improved gait patterns in the more severely affected children.[7]

Carmick, 1993[8] described the application of electrical (at 35 pulses per second) to various muscle groups for variable lengths of time to children with CP. The results indicated that there was improvement in locomotor efficiency, measured by physiological cost index and improving in gait pattern measured by foot print method. The present study is an attempt to evaluate the effect of surface electrical stimulation of anterior tibial muscles of children with hemiplegic cerebral palsy on gait patterns.

Method.

Subjects. Twenty-two children (14 boys and 8 girls) with hemiplegic cerebral palsy, their ages ranging from 5-9 years were involved in the study. All of them free from contractures and mental retardation. There were 12 cases with right sided and 9 cases with left sided hemiplegia. Children with severe frequent epilepsy were excluded for safety reasons and because of the possibility of changes in the childs' physical performance. The study sample was divided into 2 equal groups; control and experimental group. The control group continued with their current physiotherapy regime with no change, while the experimental group continued with their current physiotherapy regime plus electrical stimulation of the anterior tibial muscle of the hemiplegic leg for one hour a day for 12 weeks.

Stimulator. A dual channel battery operated electrical stimulator was used, producing alternating coupled current pulses to balance for equal charge transport in both directions. Pulse width was 300us, pulse frequensy was between 35 and 45 Hz, peake intensity was < 10 mA. Under these conditions , the stimulator was not strong enough to move the affected limb visibly.

Study Design. The stimulation was given at a frequency of 35-45 Hz , with a pulse width of 300 us pulsed 7 seconds on and 15 seconds off for one hour per day. The anterior tibial group and extensor digitorum muscles were stimulated directly via adhesive electrodes positioned over the motor points of these muscles, the inactive electrodes were positioned further down the limb. The stimulation intensity was set individually to cause dorsiflexion of the ankle to just less then the limits of passive range, the voltage required to achieve this varied from one child to another, and therefore could not be standardized. The stimulation was given 6 times per week in any convenient time of the morning from 8-12 o'clock during the 12 weeks.

Measurements. All children of the study were evaluated before and after the physiotherapy program through the following items:

A. Hofman/Myogenic ratio (H/M ratio): The M response is a compound muscle action potential generated by maximally stimulating a peripheral nerve and recording from a muscle innervated by the nerve. The H-reflex is not a direct response of muscle to stimulation of its corresponding motor nerve, but rather a reflex similar to a muscle stretch reflex bypassing muscle spindle. The H-reflex is usually elicited by delivering a submaximal stimulus to the tibial nerve in the center of the popliteal fossa, and recording from the soleus muscle. The recording electrode is placed over the soleous muscle just medial to the tibia equidistant between the stimulation point and the medial malleolus. Stimulus of long duration (0.5 - 1.0 msec) with very low intensity is the most suitable. The generated nerve action potential propagates up to the spinal cord and then, via predominantly monosynaptic reflex arc, passes down the efferent motor axon. Unlike the muscle stretch reflex, the muscle spindle is bypassed (Hugon, 1973).[9] A ratio of the maximal H-reflex and M response has been reported to assess the excitability of the motor nucleus by determining the percentage of motoneurones activated via H-reflex in comparison to direct activation of motoneurone fibers (Angles & Hoffman,1963).[10] Increased H/M ratio have been reported in the spastic phase of hemiplegia and spinal cord injury, furthermore there has been little correlation between H/M ratio and the severity of spastic hyper-reflexia (Dewaide, 1984).

B. Gait Evaluation: The gait patterns for the children were assessed through the foot print method; 3 major gait factors were chosen to be measured and analyzed. 1. Step length: The distance from heel strike of one foot to heel strike on the next successive step of the opposite foot. 2. Step width: Is the transverse linear distance between points on 2 successive feet. 3. Foot angle: It refers to the amount of toe out or toe in of each foot.

For each step, a long axis was draw between the heel center and the base of the 2nd toe. A line intersecting with the long axis was drawn perpendicular to the line of progression. Protractor placed on the perpendicular and intersecting with the long foot axis was used to determine the angle of toe out or toe in, the angle was measured as the number of degrees the foot axis varied from the 90 degrees mark on the protractor.

According to Ogg, 1963[12] only the following tools were needed; a strip of white smooth paper, a small chair, corn plaster, colored powder, adhesive plaster, tap measure scaled in centimeters and protractor. There are 7 steps for recording the child's gait pattern. 1. A strip of white, smooth surface paper 21 inches wide and 20 feet long is laid out and attached securely to the floor by adhesive plaster. 2. The patient sits on a chair placed at one end of the paper strip. 3. The patient was instructed to place his wet bare feet on the colored powder, then he was instructed to stand and walk in his usual manner to the end of paper strip. 4. While the paper is still on the floor, the heel center and the base of the 2nd toe of each subject were determined. 5. The patient's name, age and the date of the test were recorded on the paper at the starting point of walking pathway. 6. The paper strip can be removed from the floor and a table used to facilitate drawing the lines and making the necessary measurements. 7. By use of tap measure, protractor, ruler and pen, it is possible to measure and record accurately step length, step width and the angle of foot placement.

Table 1 - Comparison pre and post treatment for control and experimental groups.

Variable	Pre	Post	Significance
Step length	Exp. 18.3 ± 6.4	21.6 ± 6.7	S
	Cont. 17.7 ± 6.6	18.02 ± 7.8	NS
Step width	Exp. 6.2 ± 3.2	8.9 ± 3.6	S
	Cont. 5.8 ± 3.1	6.1 ± 3.2	NS
Foot angle	Exp. 3.31 ± 2.4	4.53 ± 2.04	S
	Cont. 4.06 ± 1.53	4.26 ± 1.35	NS
H/M ratio	Exp. 0.57 ± 0.13	0.46 ± 0.11	S
	Cont. 0.56 ± 0.12	0.53 ± 0.24	NS

H/M = Hofman/Myogenic
S = significant, NS = not significant
Exp = Experimental, Cont = Control
Pre = Before treatment, Post = After treatment

Results.

After completion of 12 weeks of treatment for both groups, the children have been evaluated again and a student t-test was used for comparison between the measurements before and after the program of treatment for each group, the results revealed the following (Table 1) :

1. Experimental group: 1. Step length: The results showed a significant improvement, where the pre treatment mean was 18.3±6.4 and the post treatment mean was 21.6±6.7 ($p < 0.05$). 2. Step width: The results showed a significant improvement where the pre treatment mean was 6.2±3.2 and the post treatment mean was 8.9±3.6 ($p < 0.05$). 3. Foot angle: The results showed a significant improvement, where the pretreatment mean was 3.31±2.4 and the post treatment mean was 4.53±2.04 ($p < 0.05$). 4. H/M ratio: The results showed a significant reduction in H/M ratio i.e. reduction of hypertonia; where the pretreatment mean was 0.57±0.13 while the post treatment was 0.46±0.11 ($p < 0.01$).

2. Control group: 1. Step length: The results indicted that there was no significant improvement, the pre treatment mean was 17.7±6.6 and the post treatment mean was 18.02±7.8 ($p > 0.05$). 2. Step width: The results indicated that there was no significant improvement, where the pre treatment mean was 5.8±3.1 while the post treatment was 6.1±3.2 ($p > 0.05$). 3. Foot angle: The results showed a non-significant improvement, where the pre treatment mean was 4.06±1.53 while the post treatment mean was 4.26±1.35 ($p > 0.05$). 4. H/M ratio: The results showed a non-significant improvement, where the pre treatment mean was 0.56±0.12 while the post treatment mean was 0.53±0.24 ($p > 0.05$).

Discussion.

The results of the present study indicate that, with careful supervision, functional electrical stimulation can be used as an adjunct therapy for the reduction of spasticity and improvement of gait patterns in children with cerebral palsy. The effect of electrical stimulation have been found to be temporary (Labord, 1986).[7] This form of therapy might therefore be best applied on an intermittent basis as an adjunct to other forms of therapy at times of rapid growth or increasing contractures, in order to address these particular problems.

Electrical stimulation has been said to be contraindicated in the presence of contractures (Scott et al, 1990).[13] For this reason, the stimulation was set to dorsiflex the foot to just below the limit of available passive range of movement, to avoid any overpull. Using this method, there will be no adverse reactions to the stimulation, even in those children with the most severely restricted range.

The application of electrical stimulation in neuromuscular conditions should proceed with caution and continue to be carefully monitored. It is apparent that electrical stimulation can produce profound changes in muscle tissues (Salmons and Vrbova, 1969[14], Eerbeck et al, 1984[15], Pett, 1986[16], Donselaar, 1987[17]). If the electrical stimulation has been used appropriately, it will be a powerful therapeutic tool.

However, electrical stimulation for the treatment for children with CP, in view of the complex and diverse pathology associated with this condition, this requires for more clarification in terms of the desired parameters of stimulation before it is to be widely applied. Much time and effort is currently being spent on improvement of gait patterns of these children. Electrical stimulation would appear to offer a practical alternative to current methods of resolving this problem, with the associated benefit of improved active movement and muscle power. Concerns that the children might be distressed by this form of therapy were found to be unwarranted, the majority of children thoroughly enjoying the electrical stimulation.

However, much effort was spent in producing as comfortable a stimulus as possible and it is possible that the children had reduced sensory awareness in the hemiplegic limb (Hazlewood et al, 1994).[18] The children found the electrical stimulation less demanding and more exciting than the usual therapy exercise regime, and they derived pleasure from seeing the hemiplegic foot move.

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