The Use of Sensory-Level Electrical Stimulation in Ambulant Child with Cerebral Palsy

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ABSTRACT

Background and purpose: *The motor function of children with cerebral palsy depends on the interaction of spastic agonist muscles, and antagonist, which are atrophic due to inactivity. The purpose of this study was to investigate the effect of electrical stimulation with sensory-level on range of motion and gait pattern in children with spastic cerebral palsy.* ***Subjects and Method:*** *Subjects were fifteen children with spastic diplegic cerebral palsy were participated in the study. Inclusion criteria were mild to moderate spastic diplegic CP, age 4-9 years, failure to achieve progress using usual physical therapy program, limited active dorsiflexion, No previous surgery in ankle, have the ability to cooperate during physical therapy sessions. Using battery powered unit electrical stimulator. The tibialis anterior muscle was stimulated for thirty minutes during the physical therapy program, five/week, for eight weeks.* ***Measurements:*** *All children were assessed before and after intervention by measuring range of motion of ankle joint and gait pattern. Results. The results revealed a significant increase in active and passive dorsiflexion as well as improvement of step length, stride length and foot angle.* ***Discussion:*** *The results of the present study supports the claim that sensory-level electrical stimulation have specific effect, which are not directly comparable with those of physical therapy.*

INTRODUCTION

The motor function of children with cerebral palsy (CP) depends on the interaction of spastic agonist muscles, and antagonist, which are atrophic due to inactivity[7].

Neuromuscular electrical stimulation (NMES) is transcutaneous application of electrical current to innervated, superficial muscle to stimulate muscle fibers, augment muscle contractions, increase range of motion (ROM), and enhance sensory awareness[1,2]. The broad term NMES involves the external control of innervated yet paretic or paralytic muscles by electrical stimulation (ES) of the corresponding intact peripheral nerves. In general, NMES has been applied so that the motor threshold is exceeded (high intensity) for a short period (15-60 minutes)[1].

When the specific goals of therapy entail functional and purposeful movements, the specialized term functional ES (FES) is applied. FES therefore is a subset within the more broadly defined term NMES[1].

Threshold ES (TES) differs from NMES by being administered at sensory level (low intensity) for a longer period (overnight for eight to 12 hours).

TES was first used in children by Pape et al.,[14] who developed a program for treatment of disuse muscle atrophy in newborn infants who were ventilator dependent. Later, they used a similar protocol for children with CP.

In 1993, Carmic[4] reported on the clinical use of NMES in children with CP. She used ES as an add-on therapy so that it first gave a tapping sensation and sensory input without causing a fused contraction. When this sensation was tolerated by the child, the setting was increased to give fused muscle contractions. She analyzed the functional differences that occurred after the application of NMES to the lower extremities of three boys, aged 1.6, 6.7, and 10 years. The youngest child displays an immediate improvement in his ability to walk and run symmetrically. The two older boys demonstrated a significant increase in locomotor efficiency. One boy's physiological Cost Index improved fourfold, whereas that of the other boy improved twofold[4].

The effect of electrically stimulating the anterior tibialis muscles of children with hemiplegic CP was studied by Hazlewood et al.,[11]. Ten children received NMES, applied daily for an hour for 35 days by their parents at home. Ten children acted as controls. During the stimulation the intensity was set to cause dorsiflexion and the children had no scheduled exercises. The children were assessed prior to the treatment, and the outcome was assessed between six and 12 weeks later (mean = nine weeks). There was a significant increase in the passive range of dorsiflexion of the children receiving ES. There was also a significant increase in the power of the anterior tibialis muscle in the stimulation group. The power was estimated using the Medical research Council grades of muscle power[11].

Comeaux et al.,[6] used gait analysis in 14 children with CP to study NMES given for 1 minute to the gastrocnemius or gastrocnemius and tibialis anterior muscles of children during scheduled gait and/or functional activity. The children received no other physical therapy during this study. Each period was four weeks, including pre and post treatment periods. Stimulation treatments, gastrocnemius only or gastrocnemius and tibialis anterior, improved heel strike dorsiflexion.

TES was used by Pape et al.,[14] who applied sub-sensory TES overnight for six months to six patients with mild CP and noted a statistically significant improvement of function. At follow-up, after the children had been without TES for six months, there was a uniform decrease in scores. In a randomized study of children with CP who had undergone selective posterior lumbosacral rhizotomy more than a year later, Steinbok et al.,[18] using low-intensity overnight TES, demonstrated improvement in the Gross Motor Function Measure score. A contradictory result was obtained by Dali et al.,[7] who, in a randomized, double blind, placebo-controlled study of 57 children with CP (age range, five to 18 years), failed to show an significant effects using TES for 12 months.

In a randomized, crossover study over 24 months Sommerfelt et al.,[17] evaluated the effect of TES applied to the antagonists of the spastic leg muscles in 12 children (age range, five to 12 years) with spastic diplegia and were unable to show any significant effect of TES on motor or ambulatory function.

In athletes, NMES has been shown to increase muscular strength[10,12] and therefore it could be speculated that stimulation of this kind as an adjunct to physical therapy in children with CP would enhance the options for new active movements[2,4,9].

The aim of the present study was to investigate the effect of threshold electrical stimulation as an adjacent to physical therapy program in child with spastic CP.

SUBJECTS AND METHODS

Subjects

Fifteen children with spastic diplegic CP (9 boys and 6 girls) were participated in the study and they meet the following inclusion criteria:

- Mild to moderate spastic diplegic.
- Age 4-9 years.

- Failure to make substantial progress using standard PT.
- Limited active dorsiflexion.
- No previous surgery with ankle.
- Have the ability to cooperate during physical therapy session.

Informed consent was obtained from their parents.

Ethical approval for the study was granted by the Ethics committee at pediatric unit in King Abdul-Aziz Hospital, King Saud University.

Electrical stimulation

Small battery powered unit (Birtcher Model 135) producing a symmetrical biphasic waves was used as a neuromuscular ES. The battery-powered stimulator has two channels that allow two different muscles. To be stimulated at the same time. The small size of the portable device allows the child to move freely, self-adhering electrodes were placed o the clean skin. The active electrode was placed on the probable motor unit of the tibialis anterior and the other electrode was placed on the same muscle distal to the active electrode. The child was given the time to feel, adjust to and accept the sensation.

ES was described to child & parents as being like the ticklers, and children were told that they would feel a tickling sensation but no pain.

At the beginning of the therapy, stimulation was given at a frequency of 10-20 Hz, which produced a tickling sensation and sensory input but no muscle contraction. The aim of ES is to increase the sensory awareness and muscle response.

The current required to achieve this was varied from child to child (4-20 mA). The pulse duration was fixed at 300 ىs (set by the device). On-off time were set at one second on, followed by one second off.

The basic therapy for the children was physical therapy based on neurodevelopmental treatment (NDT) in addition to TES (20 min), 5 sessions/week for 8 weeks.

Assessment

All children were assessed before and after TES intervention by the following measures;

I. Active and passive range of motion of ankle joint.

II. Gait analysis by foot print.

I. Range of Motion (ROM)

With the child lying in the supine position with hip and knee flexed (90°), active and passive dorsiflexion and plantarflexion of the ankle were measured using standard goniometer, keep the child in the same position but with extended hip and knee. These measurements were repeated. The mid position of (90°) the ankle was used as a baseline with the goniometer at zero.

II. Gait evaluation

The gait pattern for the children were assessed through foot print method; three major gait parameters were chosen to be measured and analyzed.

1- Step length: The distance from heel strike of one foot to heel trike on the next successive step of the opposite foot.
2- Step width is the transverse linear distance between points on two successive feet.
3- Foot angle; It refers the amount of toe out or toe in of each foot.

For each step, along axis was draw between the heel center and the base of the second toe. A line intersecting was draw between the heel center and the base of the second 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° mark on the protractor.

According to Ogg, 1963 only the following tools were needed; a strip of white smooth paper, a small chair, corn plaster, a colored powder, adhesive plaster, tap measure scaled in centimeters and protractor. There are steps for recording the child's gait pattern.

RESULTS

Range of Motion:

Table (1): Comparison of mean values of ankle range of motion active and passive pre and post.

	Pre	Post
Passive dorsiflexion with knee flex	22.4 ± 6	28.3 ± 4.2
Passive dorsiflexion with knee extended	18.7 ± 5.9	23.2 ± 4.1
Active dorsiflexion with knee flex	8.7 ±5.4	16 ± 7.7
Active dorsiflexion with knee extended	1.9 ±3.2	8.7 ± 8.0

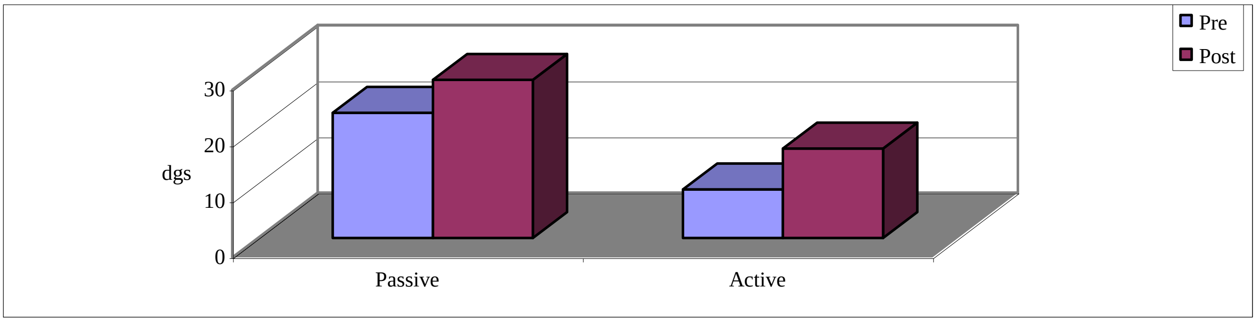

Fig. (1): Range of motion with knee flexed.

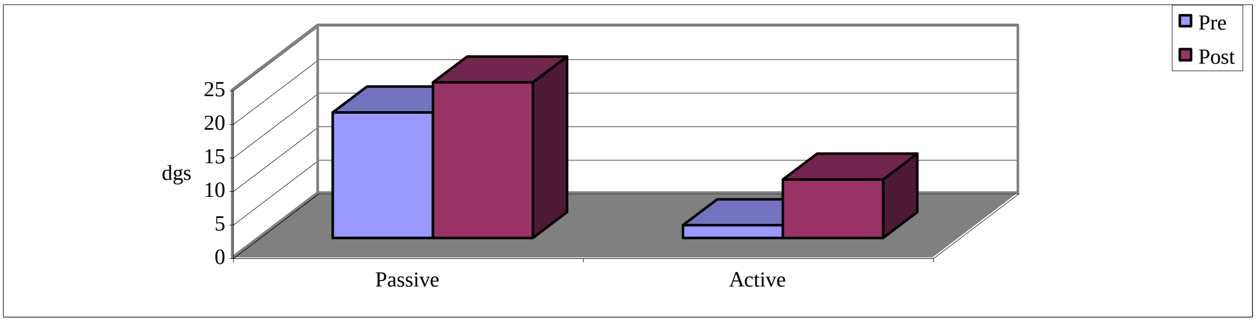

Fig. (2): Range of motion with knee extended.

Gait assessment:

Table (2): Comparison of gait parameters pre and post.

	Pre	Post	P- value
Step length	19.3 ± 6.4	22.6 ± 6.7	
Step width	6.7 ± 3.2	7.9 ± 3.6	< 0.05
Foot angle	4.31± 2.4	5.23 ± 2.04	

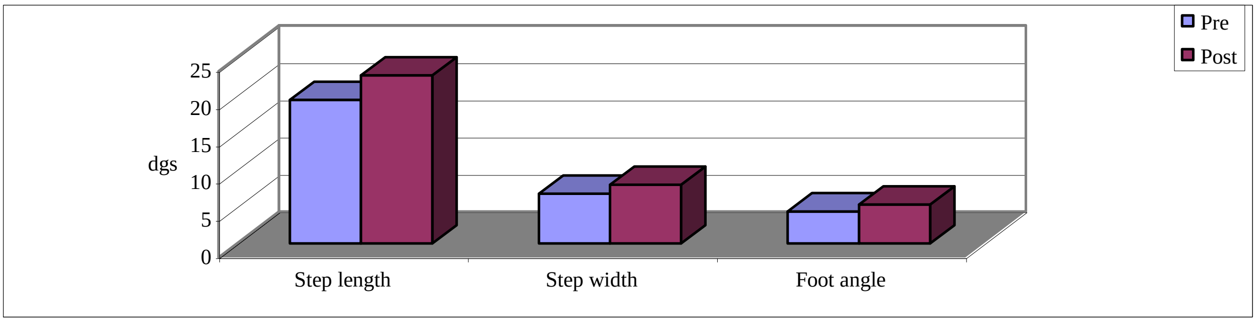

Fig. (3): Gait assessment pre and post.

DISCUSSION

The history of ES is long, going back to at least 1775[1]. However, in children, different ES techniques have been used more extensively during the past few decades and especially in children with CP. ES treatment in general has been applied either during a physical therapy session[2,4,5] or by parents at home during free activity[6,11], or over night[14,18]. The potential advantage of ES is that it can enhance sensory input, thereby increasing the child awareness of muscle function. The positive effect of ES may be mediated through activation of the muscle fibers or through activation of cutaneous and muscle afferent pathways that modulate excitability levels of interneurons and ل motor neurons[1,15]. In a number of studies using TES, the stimulation was used at the sensory or sub sensory level and was applied overnight during sleep[7,14,16,17]. The reported results have been very contradictory, perhaps reflecting subtle but important differences in the protocols[3].

Generally, NMES is administrated so that muscle contraction is elicited. The main underlying muscle impairment in equines gait in children with CP usually is the spasticity of the triceps surae muscle. Therefore, the weak antagonist muscles, the ankle dorsiflexors, usually have been the target of neuromuscular ES in children with spastic hemiplegia or diplegia.

A report in which NMES was used for strengthening the spastic gastrocnemius in a child with spastic diplegia and showed a positive result[5]. Similarly, Comeaux et al.,[6] demonstrated an improvement in both ROM and gait patterns after NMES applied to the gastrocnemius or gastrocnemius/tibialis anterior. In both studies, the favorable results were attributed to reciprocal inhibition. Stimulating the tibialis anterior inhibits the gastrocnemius and stimulating of the gastrocnemius inhibits the tibialis anterior so that co-activation of the two muscles is diminished. In addition, NMES provides proprioceptive input and acts as a type of biofeedback[1,15].

Several authors have pointed out that the terminology in the field of neuromuscular ES has not been used consistently, and this has caused problems in interpreting and comparing results of different studies. Our study differs from all previous ones by using ES at the sensory level only.

It differs from Carmick's report[5] by not reaching muscle contraction. In comparison with the TES used by Pape et al., it should be noted that the stimulation level is similar but the duration was short (30-60 minutes). A reason for using a short treatment was derived from reported experiences with NMES[1,4,5,6], which have shown that even 10 minutes of stimulation can cause muscle fatigue. This is especially important because the muscle usually are weak in children with CP and become tired very rapidly during active practicing. Another reason for choosing this protocol was that its duration appeared to be well tolerated by the children and their families. Because this treatment was planned as an add-on therapy, it was considered advantageous to apply the stimulation simultaneously with the physical therapy. This design contributed markedly to the variability of the treatment intensity. We also found that the intensity of physical therapy tended to be higher in spastic diplegia than in hemiplegia. The evident drawback of this design is the relatively low or individually very variable frequency of stimulation sessions, but the aim of the study was not to change the children's basic physical therapy program. The on/off time usually used in NMES[2,4,6,11], has been reported to vary from four to 15 seconds/12 to 20 seconds. In our study, we chose the shorter on/off ratio (both 1 second) because the children felt that it was comfortable and easy to identify.

The overall aim of this study was to find out whether a low-intensity ad-on treatment of this type would yield any measurable effects, and therefore we confined our assessments to ROM and the GAS. Usually only passive ROM has been assessed, but because active ROM is functionally more important, we also measured active ROM. Probably the most gained new active muscular movements (inversion/eversion and toe flexion/extension). The fact that the new skills did not vanish during the follow-up suggests that motor learning occurred[5]. From a functional point of view, it is important that the original supporting dynamic orthosis of eight children could be replaced by less supporting ones, such as foot orthosis during the follow up period of nine months. Some of parents of the children with hemiplegia reported that their children did not need any support when cycling. When the results were analyzed and the children were split into two groups, younger or older than seven years of age, it was found that age analyzed in this way did not influence the outcome.

Based on previous studies[4,12,14], we assume that the favorable effects shown by sensory-level ES can be explained as follows: Giving ES at the sensory level helps the children to localize stimulated muscles during exercise. This in turn increases the activity of the children during the therapy sessions and when practicing by him-or herself, the muscles are not over fatigued. This interpretation is, however, clearly speculative. The lack of a control group means that no adjustment for maturation-induced possible spontaneous development could be made. Because physical therapy and sensory –level ES were used simultaneously, to definite conclusions regarding the effect of the two components separately can be drawn. Recently, McDonugh et al.,[13] presented data from study of 60 children (ages five to 16 years) with CP who were randomized into three groups to receive NMES (15 minutes 5 days per week), TES (over night 5 days per week), and physical therapy. The duration was four months, and strengthening of the quadriceps was the goal of the therapy. Assessment by Gross Motor Function Measure and lifestyle assessment questionnaire showed that TES and NMES were significantly superior to manual physical therapy. This observation supports the claim that TES or NMES have specific effects, which are not directly comparable with those of physical therapy[3,13].

Conclusions

These preliminary data show that there may be a place for sensory-level ES as an adjunct to physical therapy in children with CP because the children in our study not only attained the set goals but also acquired new muscular activities. The definite place of ES therapy in children with CP can be judged only after controlled trials combining several regimens of therapy also addressing function have been carried out.

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الملخص العربي

استخدام التنبيه الكهربي الحسي في الأطفال المصابين بالشلل الدماغي والقادرين على المشي

تهدف هذه الدراسة إلى بيان تأثير التنبيه الكهربي السطحي على المدى الحركي لمفصل القدم و على طريقة المشي للأطفال المصابين بالشلل الدماغي .

اشتملت الدراسة على 15 طفلا أعمارهم تتراوح بين 4-9 سنوات (9 أولاد و 6 بنات) كلهم قادرين على المشي و لديهم الاستعداد للتعاون مع المعالج ، لديهم قصور في المدى الحركي لمفصل القدم لم تجر لهم أية عملية جراحية في القدم من قبل .

خضعت عينة الأطفال لبرنامج علاج طبيعي يتكون من العلاج الطبيعي التقليدي الذي يعتمد أساسا على تطبيق برنامج النماء العصبي بالإضافة إلى التنبيه الكهربي الحسي لعضلات رفع القدم لمدة عشرين دقيقة أثناء برنامج العلاج بواقع خمس جلسات أسبوعيا / لمدة 8 أسابيع .

وتم تقويم البرنامج عن طريقة قياس المدى الحركي للقدم و كذلك فحص طريقة المشي قبل وبعد البرنامج و لقد أظهرت النتائج تحسنا ملحوظا في المدى الحركي للقدم مما انعكس على التحسن الملموس في طريقة المشي . الأمر الذي يشير إلى فعالية التنبيه الكهربي الحسي في تحسين حالات الأطفال ذوى الشلل الدماغى .