Medicina Sportiva (2012), vol VIII, no 3, 1934- 1940
Romanian Sports Medicine Society

Effects of electrical stimulation in the management of the cerebral palsy upper limb spastic syndrome

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Abstract. This study objective was to investigate the efficiency of the electrical stimulation (ES) applied to antagonists muscle in upper extremity in addition to standard rehabilitation in children with cerebral palsy, and if ES decrease the spasticity and/or increases muscle strength more effectively than standard rehabilitation. ES combined with kinetic therapy is more effective than kinetic therapy for spastic limbs of children with cerebral palsy. Evidence suggests that the ES treatment on extensor muscles of affected wrist and elbow improves the spasticity, possibly through decreased co-activation of the flexors.
Key words: *electrical stimulation, upper extremity, cerebral palsy.*

Introduction

Electrical stimulation therapies (TES, FES or NMES) use very low levels of electrical current to trigger muscle contraction. Significant malfunction of upper limb in cerebral palsy (CP) requires modern therapeutic approaches, based on function rehabilitation. Positive results emerging from recent studies regarding electrical stimulation are encouraging. One of the electrical stimulation (ES) advantages is spasticity modulation more than its total cancelling, offering the possibility to use the remaining muscular tonus for a correct movement. This method is non-invasive and can be applied localized unlike the oral medication which interact with entire muscle system on the patient body.

In clinical practice, before the recommendation for ES therapy is mandatory a deep scientific knowledge of her indications, efficiency, optimal mode of stimulation to ease the motor rehabilitation of upper limb. Improvement in active wrist movement and performance of timed object manipulation tasks may be maintained after the stimulation protocol is ended (1).

Therapeutically ES has some characteristics: a) the aim of stimulation is to induce a strong muscular contraction by stimulation of alfa motor nerves, b) can be used to decrease muscular atrophy due to non-utilisation in muscles with an poor/lack of nerve stimulation, c) supports the neuromuscular function by increasing the contraction force, and d) electrical stimulation induces a higher muscle fatigue than physiological contraction Repetitive ES can be an efficient therapy for children with cerebral palsy. Therapeutically potential of ES has a peripheral target and a central one also.

In periphery, ES actions by: increasing muscle force (1), decreasing spasticity of antagonist muscle (2), decreasing spasticity of stimulated muscle (3), decreasing of co-contraction (4), modification of soft tissue allowing increasing the joint amplitude movement (5).

At the central level, ES increases the grade of reorganization in the motor area of the brain due to the well-known effect of neural plasticity (6-13). It’s often unclear the efficiency by the both mechanisms.

According to the theory of motor learning, the activity has to be repetitive, focused on the aim and to the limit of performance (14-17).

The concept of neuroplasticity has recently attracted mainstream attention and focus [18], and researchers have shown that the adult brain is able to adapt and can be submitted to change and researchers have proven that the adult brain is in fact able to adapt and change. The brain's ability to reorganise itself by forming new neural connections throughout life is now well-documented and highlighted in a recent article OF Wittenberg "...from a theoretical standpoint there should be more plasticity in the fetal and infant brain than in the adult brain, while the mechanisms for activity-dependent plasticity should apply across brain ages" [19].

According to Bertoli et al. [20] successful functioning in gross motor performance requires two key factors: a correct centrally generated plan as well as the simultaneous activation and interaction between several muscle groups with proper timing, intensity and accuracy. Given that ES can drive muscle groups in specific activation patterns, provide strengthening exercise as well as retrain coordination, it presents as an attractive modality option that can also be customised to the needs of a particular individual [20] and can be used in the upper limb rehabilitation management from CP patient.

The main objective of this study was the evaluation and comparing of effects after applied ES in the rehabilitation treatment of upper limb spasticity at the CP diagnosed child, starting from the principle that the ES added to a conventional treatment of classical kinetotherapy will have a positive superior impact on upper limb functional parameters.

Materials and methods

The research protocol was applied at the Neuromotor Rehabilitation Centres for the child with disability from Craiova - DGASPC Dolj. Before they were enrolled in the study we obtain the signature of an informed consent from the parents by which they agree the participation of the study and they agree with the publication of research results.

The prospective, non-experimental study was conducted between January 2009 and march 2011, on 37 children diagnosed with CP, the spastic form, with bilateral or unilateral central neuro-motor impairments of the upper limb, ages between 7 and 14 years old at the beginning of the study.

The subjects were randomised in 2 groups: GES, the 18 patients group that receive ES associated with kinetic treatment and the 19 patient witness group, GK, that receive only classic kinetic treatment.

Inclusion criteria for the GES group: the children's diagnosed with the spastic form of CP (hemiparesis/tetraparesis), with a dynamic spasticity of the upper limb, without surgical orthopaedic intervention or botulin injection in the last year.

Inclusion criteria in the GK group*:* children's with CP but with epilepsy history, or that did not follow all the complex therapy session or did follow other rehabilitation programs (at the parents request in other centres, or locations), but the children were present at the periodic evaluations.

The ES therapy associated with the physical therapy for GES and the physical therapy applied isolated for GK was applied 4 times a week for 6 month (ideally 100 sessions). The evaluation was realised before the application of the treatment – T0 moment, after 3 month from the beginning of the therapy – T1 moment and at the end of the study, after 6 month of therapy – T2 moment.

For the two groups of children we applied a kinetic program based on stretching and joint mobility exercises, and the GES group receive in addition ES for the shoulder abductors, hand and elbow extensors. The kinetic program was compose by passive manual stretching for the elbow and hand flection muscles based on the passive motion movement (PROM), exercises described by Kisner and Colby [21] with maintaining the position for 60 seconds, repeated 5 times, with a total duration of 5 minutes stretching. The exercises facilitated the basic functional movement patterns of the hand and upper limb that include reaching an object, catching, transportation/holding and releasing and hand complex manipulation exercises, bilateral use of hands. We also included exercises FNP and caring the body weight on the hands we support from sitting and sitting laterally on the mattress.

ES was realised with BTL-5000 (BTL 5825 SL) apparatus. The parameters of the stimulation were currents of low frequency, monophasic rectangular pulse trains 1ms impulses, 50 Hz frequency, with 5s stimulation and 10s pause (modulate impulses) monophasic rectangular pulse trains. We used electrodes with 6x4 cm dimensions applied on the spastic agonist muscles, for 10 minutes length session, 20 sessions/month (4 sessions/week).

Spasticity evaluation with the Ashworth modified scale – MAS [22] was realised manually, by a passive movement of upper limb joint, on the complete movement amplitude. The validity of MAS was demonstrated by multiple studies [23, 24]. The spasticity quantification of the involved muscles for the child with CP was realised for the pectoralis major, biceps brachial, flexor carpi ulnaris, pronator quadratus/teres. To establish with certitude the score we repeat the movement for 3 times.

Reflex evaluation. At the neurologic examination all the children were tested for the ***osteotendinous*** reflectivity, until the clonus apparition that is a characteristic of the studied infirmity. We test the biceps reflex using the *osteo-tendinous reflex scale* [25].

Results

Between January 2009 and March 2011 we selected and evaluated 37 CP subjects, that we randomize in two groups, 19 in the witness group – GK and 18 in the experimental group that receive ES and classic kinetotherapy – GES.

There were no clinic relevant differences between the two groups at the beginning of the study T0 (table I).

Table I. Characteristic and the initial parameters for the research groups

Characteristics T0	GES (n =18)	GK (n = 19)
Sex (girl/boy), *n*	8/10	7/12
Age (years) *Average ±SD (min-max)*	10.66 ± 2.25 (7 - 14)	11.2 ± 2.01 (7.8 – 13.7)
Topography of the spasticity, *n* Right hemiplegia / left hemiplegia /quadriplegic	5/5/8	7/4/8
ROT biceps brachialis *Average ±SD (CI 95%)*	3.28 ± 0.57 (3.01 : 3.54)	3.31 ± 0.58 (3.05 : 3.57)
Ashworth Score for the pectoral major spasticity *Average ±SD (CI 95%)*	2.72 ± 0.46 (2.50 : 2.93)	2.63 ± 0.5 (2.40 : 2.85)
Ashworth Score for the biceps brachial spasticity *Average ±SD (CI 95%)*	2.61 ± 0.60 (2.33 : 2.89)	2.58 ± 0.51 (2.35 : 2.80)
Ashworth Score for the flexor carpi ulnaris spasticity *Average ±SD (CI 95%)*	2.67 ± 0.48 (2.44 : 2.89)	2.68 ± 0.47 (2.46 : 2.90)
Ashworth Score for the pronator teres spasticity *Average ±SD (CI 95%)*	2.56 ± 0.51 (2.32 : 2.79)	2.63 ± 0.49 (2.40 : 2.85)

The median score for the biceps brachial reflex for GES was de 3.28 (CI 95% 3.01 : 3.54) at the T0 moment of the evaluation, and 17 (CI 95%, 2.84 : 3.49) after 3 months and 2.94 (CI 95%, 2.69 : 3.2) at T2 at the end of the therapy with ES (figure. 1).

The media of the biceps reflex score for the GK group had a value of 3.31 (CI 95%, 3.05 : 3.57) at T0, 3.10 (CI 95%, 2.85 : 3.36) after 3 months and a value of 3.05 (CI 95%, 2.81 : 3.29) at the end of the study T2.

We didn't notice significant differences between the two groups at the moment T0, T1, T2 (p>0.5 la TTEST).

It is however noted a further decrease of biceps reflex average score for the GES group at the T2 moment compared with T0 (- 0.33 points) then related with GK (difference between T2 and T0 was - 0.26 point). For the GES group that receive also the ES, after the 6 month period we noticed a slight decrease of the median score for the biceps reflex when we compare the final and initial moment of evaluation, but it is not a meaningful value for the statistic point of view, p=0.07.

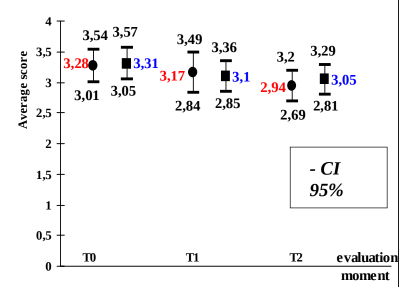

Figure 1. Average score of bicipital reflex and CI 95% for the researched groups

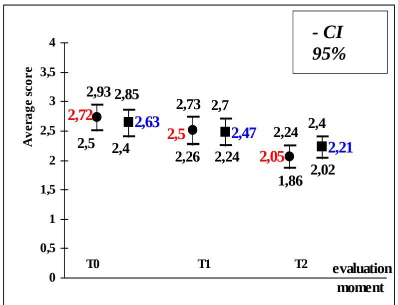

Figure 2. Average Ashworth score for pectoralis major and CI 95% for the researched groups

During all the three moments of the evaluations, the median score for the adductor scapula-humeral joint spasticity score (pectoralis major) did not revealed significant differences for the impact of the ES program applied for a 6 month period for the CP patients in the GES group comparing with the witness group (fig.2). No matter of applied therapy type (classical physiotherapy or with ES added for a 6 month period), we noticed at the end of the study a significant reduction of spasticity for the pectoral major muscle for the both research groups: *the average reduction T2-T0 for GES was – 0.67 points (CI 95%, -0.44 : -0.89), p<0.05, in the GK case the average reduction T2-T0 was – 0.37 points(CI 95%, -0.14 : -0.59), p<0.05.*

The analyse of the rehabilitation program regarding the impact on the spasticity of brachial biceps muscle for the two studied groups revealed a significant difference at the T0 and T1 evaluations between the two groups GES 2.61 (CI 95% 2.33 : 2.89) comparing with GK value of 2.58 (CI 95% 2.35 : 2.80) at the initial moment T0 (TTEST *a:b=0.43, NS*). After 3 month of therapy T1 (TTEST *a:b=0.43, NS*), GES value was 2.39 (CI 95% 2.10 :2.67) comparatively with GK value of 2.42 (CI 95% 2.19 : 2.65) (fig.3).

Important differences were noticed in the evaluations of the spasticity of elbow flexors for the moment T2 with a the value of 2 (CI 95% 1.78: 2.22) for the GES comparing with the value 2.26 (CI 95% 2.05: 2.47) for the GK after 6 month of therapy (*p<0.05*), the decrease of the spasticity for the brachial biceps was clearly higher for the children with ES therapy included. Whatever the applied therapy type (classic kinetotherapy or kinetotherapy and ES for a 6 month period of time), we noticed a significant decrease of the spasticity for the brachial muscle for the both research group: the median score decrease at T2-T0 for GES with – 0.61 points (CI 95%, -0.33 : -0.89), p=0.001, the median reduction at T2-T0 for GK was 0.32 points (CI 95%, -0.10 : -0.53), p<0.05.

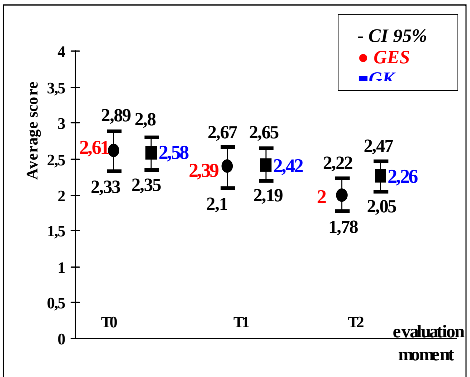

Figure 3. Average Ashworth score for the brachial biceps muscle and researched groupsCI95%

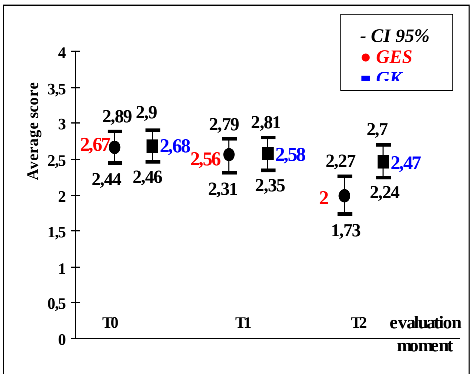

Figure 4. Average Ashworth score for the carp ulnar flexor and researched groups 95%

At the initial moment of evaluation and after 3 months of therapy T1, it didn't exist significant differences between the groups regarding the Ashworth medium score for the spasticity of the carp ulnar flexor (GES:GK la T0 p>0.05, la T1 p>0.05).

After 6 month of differentiated therapy we noticed a significant decrease of the average spasticity for the ulnar flexor for the children that received ES: for GES a value of 2 (CI 95% 1.73 : 2.27) comparing with the value of 2.47 (CI 95% 2.24 : 2.70) for the GK (GES:GK for T2 p=0.006) (fig.4).

Whatever was the type of the applied therapy (classical therapy or ES added for a period of 6 month), at the end of rehabilitation period that we studied, we noticed a decrease of spasticity for the carp ulnar flexor for the both research group, but only significant in the case of *GES: the medium reduction T2-T0 for the GES was 0.67 points (CI 95%, -0.44 : -0.89), p<0.05; the medium reduction* T2-T0 for GK was 0.21 points (CI 95%, -0.14 : -0.59), p>0.05, with significant implication for the rehabilitation of the hand biomechanics and function for the child with CP. Our study did not revealed major differences between the median values of the spasticity for the pronator teres (fig.5) in all the three evaluations for the two researched groups: for T0 GES had an average value of 2.56 (CI 95% 2.32 : 2.79) comparing with GK average of 2.63 (CI 95% 2.40 : 2.85), GES:GK for T0 p>0.05; at T1 GES has a media of 2.28 (CI 95% 2.06 :2.49) comparing with GK 2.47 (CI 95% 2.24 : 2.70) (GES:GK la T1 p>0.05);

for the T2 media for GES was 2.06 (CI 95% 1.80 : 2.30) comparing with median for GK 2.36 (CI 95% 2.09 : 2.63), GES:GK at T2 p=0.05.

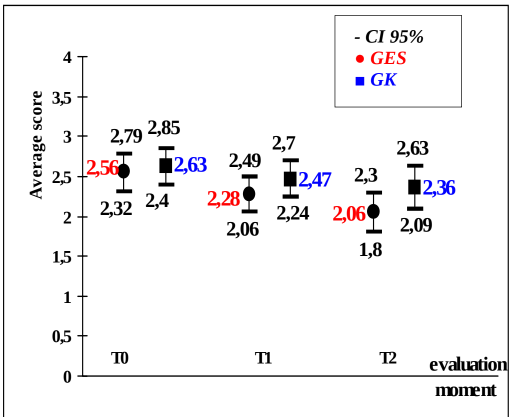

Figure 5. Average Ashworth score for the pronator teres muscle and CI95% of the studied groups

Regardless of the type of applied therapy, we found at the end of the 6 months of rehabilitation a decreasing of the spasticity for the pronator teres, more important for the children from the GES group comparing with *GK*, the median reduction T2-T0 for the GES was –0.5 points (CI 95%, -0.21 : -0.78), p<0.05 and for the case of GK was – 0.26 points (CI 95%, -0.05 : -0.47), >0.05, insignificant.

Discussions

The relationship between spasticity, contracture, and activity is complex in children with cerebral palsy [26]. The results of this study show a decrease of spasticity evaluated with MAS for the two groups of patients. But a bigger improvement was notice for the ES group. The improvement rate had a bigger variation among the subjects from the same group. The changes were significant after 3 month ES therapy and we noticed an important increase after 6 month of therapy. The amelioration rate seem to coincide with the degree of spasticity, the subjects with a lower degree of spasticity prove a better improvement.

In agreement with other studies [27, 28, 29], the results of our study proved that the ES can be an accepted therapeutic method to reduce spasticity. Electrical stimulation is used to relieve symptoms of joint stiffness and muscle tightness (spasticity) and may be most helpful for a rapidly growing child. But the effects of electrical stimulation do not last long. These therapies usually are combined with other treatments, such as physical therapy.

Also the study demonstrates that the electrotherapy and kinetic therapy are more efficient when they are applied in combination with ES therapy.

Electric stimulation of the antagonist muscle can act by a reciprocal inhibition mechanism for the agonist muscle. Few studies confirm that so called reciprocal inhibition can be decrease to the spastic patient [29,30]. The increase of the reciprocal inhibition for these children by stimulation of the antagonist muscle can be positive [30, 31]. The research activity results from the study support by Pandyan & al (1997) that report the increase of movement range of motion and decrease of the hypertonia by stimulation of the wrist extensors [32].

In the Kamper study, the rate of improvement appears to coincide with the level of impairment, as those subjects with the greatest initial wrist extension showed the best improvement at six weeks [33]. The children may have benefited strictly from renewed focus on the use of impaired hand. Finally, it is impossible to separate the impact of electrical stimulation from that of actual wrist flexion or extension for this study. While electrical stimulation repetitively excites specific peripheral nerves and sensory organs, movement of the wrist in the intended direction may also generate afferent feedback, which reinforces the activity. A controlled trial comparing the effects of electrical stimulation and mechanical assistance of wrist extension would be beneficial. This study did not investigate whether the observed improvement in wrist extension improved hand function [33].

In conclusion, electrical stimulation in addition to passive stretch had statistically significantly greater effects on spasticity and passive range of motion than passive stretching alone. However, further research is required to determine whether these effects are clinically worthwhile or could be increased with a more intensive regimen [34].

Conclusions

The results of this study are encouraging suggesting that the application of electrical stimulation associated with the kinetic treatment can modify the spasticity degree for the upper limb involved muscles. We consider that the combined therapy can be a better option in the spastic upper limb rehabilitation management, and that the studies must be extended in the future regarding ES and its effects in the rehabilitation of upper limb for the child with spastic CP, eventually on bigger groups of patients to further confirmation of our obtained results and to promote the utility of the low frequency neuromuscular electrotherapy.

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Received: 22 June 2012
Accepted: 20 August 2012