Effect of Neuromuscular Electrical Stimulation on Foot Pressure Distribution in Congenital Clubfoot

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Abstract: Conservative treatment of clubfoot is well accepted and has been reported to result in better correction ranging from as low as 50 % to as high as 90%. This study was an attempt to evaluate the effect of neuromuscular electrical stimulation on foot pressure distribution in congenital clubfoot. **Methods:** Thirty children with congenital clubfoot were participated in this study, their age ranged from 2.5 to 3.5 years matched with 20 healthy pediatric subjects. They were randomized divided into two equal groups; Study group received electrical stimulation for 12 weeks (frequency of 40 Hz, pulse width 330 ms and intensity was set where a visible movement of the foot was achieved and the sensation did not cause any distress to the infant), and control group didn't receive any stimulation. Foot pressure distribution was measured using foot scan for all children pre and post treatment. **Results:** There was a statistically significant difference in maximum foot pressure between study and control group after electrical stimulation application (p< 0.001). By contrast maximum foot pressures were not completely recovered in the study group compared with their matched healthy controls after 12 weeks. **Conclusion:** Neuromuscular electrical stimulation may have the potential to maintain or improve evertor muscle activity and foot pressure distribution in children with clubfoot.

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1- Introduction

Clubfoot or talipes equinovarus is one of the most frequent congenital deformities of the foot. It is seen in approximately 1/1000 live births and the incidence rises to 1/20 if there is a genetic predisposition. The main deformities in this condition are : a) inversion and adduction of the forefoot, b) inversion of the heel and c) equines fixation of the foot in plantar flexion of the ankle and subtalar joints[1]. The deformity can cause parental anxiety at birth and if left untreated may cause major lifestyle difficulties for the affected patient in the future. The condition is developmental rather than embryonic in origin, although its exact etiology and pathogenesis remains largely unknown with a variety of studies showing input from genetic,environmental and anatomical factors [2].

Assessment is particularly important in the planning and evaluation of treatment of any musculoskeletal condition and can assist the prediction of prognosis [3.] Plantar pressure and foot-print studies offer the opportunity to record quantitative data, which is not only objective but also reproducible, an ideal combination suited to the evaluation of the clubfoot deformity [4]. Historically, the treatment of clubfoot deformity was primarily surgical [5,6]. More recently, it has been reported that these operative treatments involving extensive soft tissue releases do not always produce satisfactory long term clinical results [7,8]. In addition, gait disturbances such as knee hyperextension, ankle stiffness, and decreased gastrocnemius-soleus power and strength have been documented [9]. As a consequence of these clinical and functional results, there has been a renewed interest in the non-operative treatment of clubfoot deformity [8].

Conservative treatment of clubfoot is well accepted and has been reported to result in better correction ranging from as low as 50 % to as high as 90% [10] .The Ponseti method is now considered to be the first choice treatment for idiopathic clubfoot. It is a non-operative procedure which utilizes the fibroelastic properties of the infant foot and ankle's connective tissues [11]. This involves 4 – 6 weeks of long leg (toe-to-groin) plaster casts, changed weekly by gentle manipulation of the foot between casts to gradually correct the deformity [12]. Neuromuscular electrical stimulation (NMES) is the electrical stimulation of skeletal muscle through a motor or sensory nerves applied at an intensity sufficient to cause a muscle to contract [13]. There is only one report in the literature regarding the use of NMES to increase the range of motion (ROM) to correct foot deformity in the treatment of congenital talipes equinovarus. Although limited in terms of the number of patients (two children and one adult) and information on stimulation parameters, the study suggested this approach had potential to improve ROM, muscle balance, foot position and gait, and called for further work to address this concept of treatment [14].

The aim of this study was to investigate the effect of NMES on foot pressure distribution in infants with clubfoot deformity, and to give preliminary data on its potential to increase or maintain ROM and facilitate the peroneal muscle activity, following the initial correction achieved with the Ponseti method. If this proves to be a practicable approach, it could be an important adjunct to treatment in preventing recurrence of deformity and reducing operative procedures after walking age.

2. Materials and Methods

Thirty children of both sexes were participated in this study, their age ranged from two and a half to three and half years selected from Abo El-Rish Hospital ,Cairo University Hospitals.Twenty age and sex matched healthy pediatric subjects were assessed similarly to serve as matched healthy controls.They were randomized divided into two equal groups; Study group received electrical stimulation for 12 weeks, and control group didn't receive any stimulation.

The inclusion criteria were:

Diagnosis of idiopathic clubfoot, have been enrolled in a program of serial manipulation and casting treatment using the Ponseti method, parent's motivated to carry out programs, and tolerance of the stimulator as assessed during the first stimulation session. The deformity was mild to moderate degree. All children had the ability to walk independently.

Exclusion criteria were:

Previous use of stimulants, earlier treatment or surgery, and other neurological conditions causing any movement disorder or spasticity. Clubfoot associated with myelocele, meningomyelocele, arthrogryposis multiplex congenital, and other neuromuscular causes were excluded, to avoid the effect of neuromuscular imbalance on treatment results.Children who had auditory, visual,heart and respiratory defects. Severe abnormalities of the foot. Written informed consent was obtained from the parents for all participants. Accordingly, the parents of each potential participant were contacted by a researcher who gave a further oral explanation, and answered any questions, if necessary. This study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University.

Foot pressure distribution measurement:

Foot scan using the plate system : From Rs scan international, the components of the system which was being used to measure the plantar pressure include: The pressure sensor platform , A computer for data acquisition, storage and retrieval, for analysis , A monitor for displaying data and various software packages to allow the physical therapist to provide the plantar surface of the foot into numerous regions to permit the analysis of data.

The pressure plate containing sensors (pressure gauges), which convert the mechanical pressure of the foot into electrical signals routed to the computer system. The software provides the calculations for the pressure values according to the pressure imposed on the plate. Also it uses specified color to display the pressures acting on the plantar surface of the foot in various preset colors the red and purple colors denoted graphically the highest pressure, while the green, blue and black colors represented the lowest pressure values. The area calculated refers to the amount of surface contact between the plantar surface of the foot and the sensor. The measurement will be done in the preset scanning direction denoted by the manufacturer. The measurement had been obtained during dynamic situation, this technique requires that the patient walk across the walkway about nine meter length while the data had been collected from a single foot contact over the sensor platform. The measured variable will represent a maximum pressure (p-max) under the three anatomical regions of the foot: The forefoot , including the medial forefoot (big toe and first metatarsal) and lateral forefoot (small toe and fifth metatarsal), The mid foot (medial and lateral) The heal regions (medial and lateral).

Instrument Preparation:

The child's personal data (name, shoe size, weight and height) have been collected and then stored on the computer in their specific folder. The data had been added in the assessment sheet. The system had been calibrated, then had been activated and ready to record the pressure when the child had been asked to walk over the pressure plate.

Technique of measurement:

The reliability of measurement required at least three from five trials steps. Calibration of the instrument needs the child to stand over the platform with his feet then by single foot . Each child had been asked to walk for nine meters as normally as possible with normal free velocity and step over the pressure platform (in its middle) by a single foot. In some cases the use of foot prints to guide the child was necessary as the child can't understand how to step over the platform by single foot contact. After completion of the trials , the measurement was saved for analysis. The analysis had been initiated by locating the second metatarsal head then the foot area was divided into six zones this procedure had been repeated using the same steps. The calculations of the maximum pressure under the selected areas of the foot, the forefoot including the medial fore foot (big toe and first metatarsal), lateral forefoot (small toe and fifth metatarsal), the mid foot (medial and lateral) and the heal regions (medial and lateral) had been measured. The data had been normalized by body weight to be expressed as a percent of the body weight.

Electrical stimulation application:

The stimulation was applied to the evertor muscles of the foot. The aim was to achieve a muscular contraction sufficient to produce an active movement of the foot into eversion, with or without dorsiflexion, as eversion is the key movement. The Microstim MS2V2 exercise stimulator (Odstock Medical Limited, Salisbury NHS Trust, Sallsbury, UK) was used. It has an ON: OFF cycle of 14 : 14 s, with a 2 s ramp at the beginning and end of each burst of stimulation. A frequency of 40 Hz was used, and pulse width was fixed at 330 ms. The stimulation intensity was set where a visible movement of the foot was achieved and the sensation did not cause any distress to the infant. Parents were instructed to use the stimulation for a total of 30 min a day, at a time convenient to them, and which did not interfere with the boots and bars regime, for example, before the child's bath[14].

Statistical analysis:

All data were analyzed by the SPSS software, version 16.0. Descriptive statistics of mean and standard deviation presented the children's ages, weight and height. The paired and unpaired t-test was used to compare the pre- and post-treatment values of maximum foot pressure within and between the groups. A P-value of less than 0.05 was taken as significant.

3. Results

The collected data of the current study were statistically analyzed to examine the effects of electrical stimulation on foot pressure in clubfoot. Thirty children with clubfoot and 20 age and sex matched healthy control group were studied. They were randomized divided into two equal groups; Study group received electrical stimulation for 12 weeks, and control group didn't receive any stimulation. The mean values of the age, height, weight of children with clubfoot (n=30) were represented in Table 1. They were matched for age and sex with a healthy normal group (n=20).

Table 1. Physical characteristics for children of the three groups

	Children with club foot		Healthy Children
Character	Control group	Study group	Matched group
	Mean ± SD	Mean ± SD	Mean ± SD
Age (Year)	3.28 ± 0.24	3.13 ± 0.22	3.31 ± 0.24
Male %	65%	75%	60%
Weight (Kg)	13.99 ± 0.77	13.90 ± 10.57	14.08 ± 0.73
Height (Cm)	92.8 ±.67	92.75 ± 1.38	93.12 ± 1.47
Right sided %	55%	52%	

The mean values of maximum foot pressure before treatment reported in Table 2. Maximum foot pressure at hindfoot , midfoot and forefoot for the control group before treatment were 7.03±0.22 ,6.25±0.20,4.69±0.17 respectively . Maximum foot pressure at hindfoot , midfoot and forefoot for the study group before treatment were 7.1±0.19 ,6.32±0.19,4.60±0.11 respectively. The clubfoot infants had 60 % decreased maximum foot pressure compared with healthy subjects at the beginning of the study. There were no statistically significant differences between the control and study group regarding the pre study maximum foot pressure in hindfoot, midfoot and forefoot points (P > 0.05) as shown in Table 2.

Table 2. Pre treatment mean values of maximum foot pressure % of total body weight in control and study group.

Item		Control group	Study group	P-Value	Healthy group
Maximum foot pressure of the hindfoot %	Medial Point	7.03±0.22	7.1±0.19	0.34	10.02±0.65
	Lateral Point	7.02±0.15	7.08±0.22	0.39	10.03±0.65
Maximum foot pressure of the midfoot %	Medial Point	6.25±0.20	6.32±0.19	0.37	9.97±0.64
	Lateral Point	6.88±0.29	6.92±0.23	0.62	9.84±0.66
Maximum foot pressure of the forefoot %	Medial Point	4.69±0.17	4.60±0.11	0.12	9.93±0.66
	Lateral Point	6.02±0.12	5.82±0.43	0.1	9.93±0.66

There was a significant increase in maximum foot pressure after 12 weeks in the study group. Maximum foot pressure at hindfoot , midfoot and forefoot for the study group after treatment were 8.56±0.45,8.1±0.76,7.03±0.58 respectively. Maximum foot pressure at hindfoot , midfoot and forefoot for the control group after treatment were 7.5±0.36,6.84±0.51,5.13±0.61 respectively. There were statistically significant differences between the control and study group regarding the post study maximum foot pressure in the hindfoot, midfoot and forefoot points ($P < 0.001$) as shown in Table 3.

Table 3. Post treatment mean values of maximum foot pressure % of total body weight in control and study group.

Item		Control group	Study group	P-Value
Maximum foot pressure of the hindfoot %	Medial Point	7.5±0.36	8.56±0.45	< 0.001
	Lateral Point	7.58±0.34	8.62±0.35	< 0.001
Maximum foot pressure of the midfoot %	Medial Point	6.84±0.51	8.1±0.76	< 0.001
	Lateral Point	6.74±0.41	8.06±0.67	< 0.001
Maximum foot pressure of the forefoot %	Medial Point	5.13±0.61	7.03±0.58	< 0.001
	Lateral Point	6.54±0.35	8.06±0.62	< 0.001

Finally; there was statistically significant improvement in maximum foot pressure were observed in the study group after 12 weeks of treatment. By contrast maximum foot pressures were not completely recovered in the study group compared with their matched healthy controls after 12 weeks as shown in Figure 1.

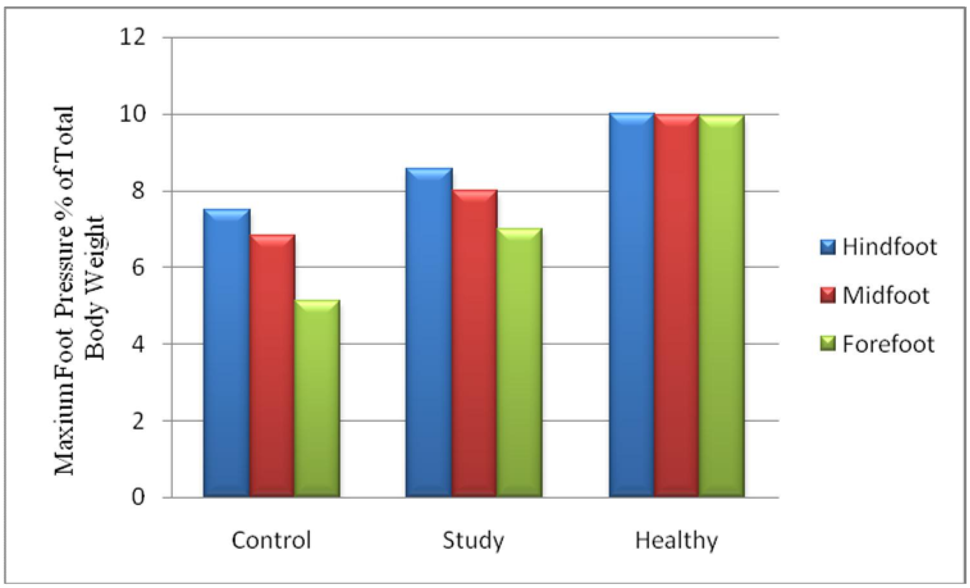

Figure 1. Post treatment mean values of maximum foot pressure % of total body weight.

4. Discussion

The results of this study identified a statistically significant effect of electrical stimulation on foot pressure distribution in infants with clubfoot after 12 weeks of treatment. There is only one report in the literature regarding the use of electrical stimulation in the treatment of congenital clubfoot[14] .

Congenital clubfoot must be differentiated from postural and structural or secondary type of clubfoot. The postural clubfoot has the clinical appearance of congenital clubfoot, but it can become fully correctable to normal anatomic position at birth, or shortly thereafter following a period of manipulative strapping. The patient should be thoroughly examined to exclude features of paralytic clubfoot including multiple congenital malformations [15].

Interestingly, children with unilateral clubfoot had the same degree of motor problems as children with both feet involved, although children with bilateral clubfeet had a significantly poorer clubfoot outcome. This indicates that other factors besides foot function play a role in these children's motor abilities. Ball skill problems were significantly more common than expected in this sample, though no high demands are made on the standing ability of the child during these ball tasks.

Plantar pressure distribution was accepted as a good tool for an assessment of normal and abnormal foot posture, because it provides a useful information to diagnose foot deformities. The high plantar foot pressure is an important risk factor for the development of foot, which has been associated with callus, foot deformities, reduced plantar tissue thickness, and limited joint mobility. The reduction of peak plantar pressure on the forefoot during walking has become a primary focus of the prevention and treatment of this condition [16].

The treatment goal is a foot with sufficient mobility and muscle function enabling daily activity and sport leisure without pain, stiffness or shoe problems. It should be emphasized that a clubfoot can never become "normal". Common findings are a shorter and wider foot, a thinner calf, reduced muscle strength and endurance, and restricted foot and ankle mobility [17,18]. No studies have been made on how these factors influence the child's motor performance. Generally, outcome assessments after clubfoot treatment focus on joint mobility, radiographs and registration of pain, i.e. items on body structure and body function levels according to the International Classification of Function, Disability and Health (ICF) [19]. Problems in activity and participation domains are sparsely touched. Studies on how children treated for idiopathic clubfoot cope in motor activities are rare [20].

The mechanisms by which electrical stimulation might bring about the improvements by producing muscle contraction by transcutaneous peripheral nerve stimulation. The contraction can be produced either directly, through the depolarization of motoneurons, or indirectly, through the depolarization of sensory afferents [21-23]. The stimulation recruits motor units in a specific way, which is different from physiological muscle recruitment during voluntary contraction and furthermore could be responsible for the strength gain measured after electrical stimulation training in healthy subjects.

Electrical stimulation is currently used in many forms to facilitate changes in muscle activity and performance. In clinical settings, electrical stimulation can be used for improving muscle strength, increasing range of motion, reducing edema, decreasing atrophy, healing tissue, and decreasing pain. Neuromuscular electrical stimulation (NMES), used interchangeably with electrical stimulation (ES), is typically provided at higher frequencies (20-50 Hz) expressly to produce muscle tetany and contraction that can be used for “functional "purposes and can be found in literature as early as 1964 [24].

Generally speaking, electrical stimulation does not directly stimulate skeletal muscle. Electrical stimulation is actually exciting the motor nerve going to muscle and not muscle itself. Therefore, high frequency stimulation (greater than 70 Hz) will cause neuromuscular junction failure and muscle will rapidly fatigue [25,26]. The optimum frequency is similar to the range of normal motor unit discharge frequencies generated during voluntary activity, 20-50 Hz [27]. Lower frequencies cause an unused muscle contraction [26]. One common problem is pain during stimulation.

Muscle stimulation increases the metabolic demand compared to voluntary contraction, with higher rates of inorganic phosphates and higher cell oxygen level; this phenomenon is directly related to the intensity of the induced contraction [27].

Electrical stimulation can increase the strength[28] of normally innervated muscle has increased interest in neuromuscular electrical stimulation. Electrical stimulation has been used to improve range of motion (ROM), temporarily reduce excessive spasticity (hyperreflexia) [29] facilitate motor control and muscle reeducation[30], and assist in gait training[31]. Most studies have been conducted on adult subjects; very little has been written about electrical stimulation with children.

This study has several limitations: The small number of infants might limit the generalization of the study results. The lack of follow-up for the infants in both groups might be considered another limitation of this study. Additional studies with larger group sizes, and longer intervention and follow up periods are necessary to recommend this novel addition to the current treatment methods. In conclusion, neuromuscular electrical stimulation is a novel addition to the current treatment methods in increasing the foot pressure distribution in infants with congenital clubfoot.

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References:

1. Dobbs MB, Gurnett CA. Update on clubfoot: etiology and treatment. Clin Orthop Relat Res 2009; 467:1146–53.
2. Siapkara A, Duncan R. Congenital talipes equinovarus: a review of current management. J Bone Joint Surg Br 2007;89:995–1000.

3. Abboud RJ. Relevant foot biomechanics. Curr Orthop 2002;16(3):165–79.
4. Herd F, Ramanathan AK, Cochrane LA, Macnicol M, Abboud RJ. Foot pressure in Clubfoot, the development of an objective assessment tool. The Foot, 2008; 18:99–105.
5. McKay DW. New concept of and approach to clubfoot treatment: section II correction of the clubfoot. J Pediatr Orthop. 1983; 3:10-21.
6. Simons GW. Complete subtalar release in club feet. Part I—a preliminary report.J Bone Joint Surg Am. 1985; 67:1044-55.
7. Kranicz J, Than P, Kustos T. Long-term results of the operative treatment of clubfoot: a representative study. Orthopedics. 1998;21:669-74.
8. Noonan KJ, Richards BS. Nonsurgical management of idiopathic clubfoot. J AmAcad Orthop Surg. 2003;11:392-402.
9. Karol LA, Concha MC, Johnston CE 2nd. Gait analysis and muscle strength in children with surgically treated clubfeet. J Pediatr Orthop. 1997; 17:790-5.
10. Ikeda, K. Conservative Treatment of Idiopathic Clubfoot. J. Pediatr. Orthop. 1992; 12: 217-223.
11. Dobbs MB,Morcuende JA, Gurnett CA, Ponseti IV. Treatment of idiopathic Clubfoot: an historical review. Iowa Orthop J 2000; 20:59–64.
12. Cooper DM, Dietz FR. Treatment of idiopathic Clubfoot. A thirty-year follow-up note. J Bone Joint Surg Am 1995; 77:1477–89.
13. Changulani M, Garg NK, Rajagopal TS, Bass A, Nayagam SM, Sampath J, Bruce CE. Treatment of idiopathic club foot using the Ponseti method. J Bone Joint Surg 2006; 88B:1385–1387.
14. Gelfer Y, Durham S, Daly K, Shitrit R, Smorgick Y and Ewins D. The effect of neuromuscular electrical stimulation on congenital talipes equinovarus following correction with the Ponseti method: a pilot study. J of Ped Ortho 2010; 19:390–395.
15. Nordin S, Aidura M, Razak S., and Faisham WI.Controversies in congenital clubfoot: Literature review.Malaysian Journal of Medical Sciences 2002: 1 (9) : 34-40.
16. Know O.Y., Mueller M.J., Walking patterns used to reduce Forefoot plantar pressure in people with diabetic neuropathies, Phys. Ther., 2001, 81, 828–835.
17. Cooper DM, Dietz FR: Treatment of idiopathic clubfoot. A thirty-year follow-up note. J Bone Joint Surg Am 1995, 77:1477-1489.
18. Dobbs MB, Nunley R, Schoenecker PL: Long-term follow-up of patients with clubfeet treated with extensive soft-tissue release. J Bone Joint Surg Am 2006, 88(5):986-996.
19. International Classification of Function, Disability and Health [http://www.who.int/classifications/icf/en/]. WHO, Geneva.
20. Buus L: Clinical examination of the treatment of children with congenital idiopathic clubfoot. Nytomforskning2000, 9:4-10.
21. Collins DF. Central contributions to contractions evoked by titanic neuromuscular electrical stimulation. Exerc Sport Sci Rev 2007;35:102–9.
22. Collins DF, Burke D, Gandevia SC. Large involuntary forces consistent with plateau-like behavior of human motoneurons. J Neurosci 2001; 21:4059–65.
23. Collins DF, Burke D, Gandevia SC. Sustained contractions produced by plateau-like behaviour in human motoneurones. J Physiol 2002; 538: 289–301.
24. Valenti F. Neuromuscular electrical stimulation in clinical practice. Acta Anaesthesiol. 1964; 15:227-45.
25. Petrofsky JS: Isometric Exercise and its clinical implications. Charles C Thomas Springfield 1982.
26. Petrofsky JS, Phillips CA, Lind AR: Interrelationships between recruitment order, muscle temperature, and endurance for static exercise and the blood pressure response in the cat.CIRC RES 1981; 48:I32-I36.
27. Petrofsky JS, Phillips CA, Sawka M, Hanpeter D,Lind AR, Stafford D: Muscle fiber recruitment and blood pressure response to isometric exercise. J Appl Physiol 1981; 50:32-37.
28. Delitto A, Snyder-Mackler L. Two theories of muscle strength augmentation using percutaneous electrical stimulation. Phys Ther. 1990; 70; 158-164.
29. Alfieri V. Electrical treatment of spasticity. Scand J Rehabil Med 1982; 14:177-182.
30. DeVahl J. Neuromuscular electrical stimulation in rehabilitation. In: Gersh MR, ed. Electrotherapy in Rehabilitation. Philadelphia, Pa:FA Davis Co; 1992:218-268.
31. Carnstam B, Larsson L, Prevec TS. Improvement of gait following functional electrical stimulation. Scand J Rehabil Med. 1977; 9:7-13.

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