Doi: 10.11606/issn.2317-0190.v14i2a102794

ARTIGO ORIGINAL

Efeitos da estimulação elétrica funcional (FES) sobre o padrão de marcha de um paciente hemiparético

Effect of Functional Electrical Stimulation (FES) about the gait standard of a hemiparetic patient

Rodrigo Costa Schuster[1], Cíntia Ribeiro de Sant[2], Vania Dalbosco[2]

RESUMO

A doença vascular cerebral resulta da restrição da irrigação sangüínea ao cérebro, gerando lesões celulares e disfunções neurológicas, sejam referentes às funções motora, sensorial e cognitiva da percepção ou da linguagem. A disfunção motora é um dos problemas freqüentemente encontrado no acidente vascular cerebral, que refletirá em uma marcha cujos parâmetros mensuráveis, tais como, velocidade, cadência, simetrias, tempo e comprimento de passo e passada, serão deficitárias. Essas alterações não são apenas devido à fraqueza muscular, mas também a anormalidades complexas no controle motor. Este estudo propôs-se a verificar os efeitos da estimulação elétrica funcional (FES), quantificando força e tônus muscular, amplitude de movimento, parâmetros espaços-temporais da marcha e a pressão plantar antes e após intervenção, em um paciente hemiparético, utilizando a corrente do tipo FES no músculo tibial anterior por 30 min, com largura de pulso de 250 µs, freqüência de 50 Hz, Ton 06s e Toff 12s, num período de 45 dias, três vezes por semana, totalizando 20 sessões. A eletroestimulação foi considerada segura e efetiva no tratamento da atrofia de desuso, além de útil na manutenção da amplitude de movimento, na reeducação muscular evidenciada pela melhora dos parâmetros de marcha e da força muscular.

PALAVRAS-CHAVE

acidente cerebrovascular, estimulação elétrica, hemiparesia, marcha, fisioterapia

ABSTRACT

The cerebral vascular illness results of the restriction of the sanguine irrigation to the brain, generating cellular injuries and neurological lack of function, they are referring to the motor function, sensorial, cognitive, of the perception or the language. The motor disfunction is one of the problems frequently found in the stroke, this will reflect in a gait, whose measurable parameters, such as: speed, cadence, symmetries, time and length of step and passing, they will suffer deficit alterations. This study was considered to verify it the effect of the Functional Electrical Stimulation (FES) quantifying muscular force and vigor, amplitude of movement, secular parameters space of the headway and the plantar pressure before and after intervention in a hemiparetic patient using the chain of the type FES in the previous tibial muscle for 30 min, with width of pulse of 250 µs, frequency of 50 Hz, Ton 06s and Toff 12s in a period of 45 days, three times per week, totalizing 20 sessions. The eletroestimulation was considered insurance and effective in the treatment of the atrophy of disuse, beyond being useful in the maintenance of the amplitude of movement, in the muscular re-education evidenced by the improvement of the parameters of gait and the muscular force.

KEYWORDS

cerebrovascular accident, electric stimulation, paresis, gait, physical therapy

1 Fisioterapeuta, especialista em Ciências Morfofisiológicas: Anatomia/UDESC, mestrando em Ciências Médicas/UFRGS, professor do curso de Fisioterapia da Universidade de Passo Fundo – UPF
2 Fisioterapeuta graduada pela UPF

ENDEREÇO PARA CORRESPONDÊNCIA
Faculdade de Educação Física e Fisioterapia da Universidade de Passo Fundo
Campus I - Km 171 - BR 285 - Bairro São José, Caixa Postal 611
Passo Fundo - RS - CEP 99001-970

Recebido em 26 de Junho de 2006, aceito em 28 de Março de 2007.

INTRODUCTION

The World Health Organization (WHO) definition for stroke is "rapidly developing signs of focal (or global) disturbance of cerebral function, leading to death or lasting longer than 24 hours, with no apparent cause other than vascular"[1].

The main cause of impairment in adults, the stroke brings functional consequences of the primary neurological deficits which, usually, predispose the stroke survivors to a sedentary lifestyle, with individual limitations for activities of daily living (ADL) and decreased cardiac reserve[2].

The clinical picture in the stroke can be divided into acute – due to muscular weakness or hypotonia, confusion and incontinence[3] - and chronic – due to flexor spasticity in the upper limbs and extensor spasticity in the lower limbs[4].

The spasticity is characterized by the difficulty in passively moving a joint, due to the intense contraction of the muscles that usually move it and by the tendency to the immediate return to the original position when the imposed force ceases[5].

Among the main symptoms generated by the stroke, the hemiplegia/hemiparesis is one of the most important, a classic sign of cerebral neurovascular pathology, which is caused by ischemia or hemorrhage, involving the brain stem or hemispheres. This is the motor dysfunction in the stroke and affects the voluntary motor control on the contralateral side of the injury[6].

The physical manifestations of spasticity include pain, involuntary movements, abnormal postures, gait impairment, and increased resistance to movement. Such manifestations can lead to secondary problems, such as alteration in muscular length, culminating in the development of contractures (which are reversible with conservative treatment) and even muscular deformities, which are not reversible with conservative treatment, but only with surgical ones[7].

Gait is defined as a method of ambulation involving the use of the two legs in an alternate way, to provide support and propulsion to both, with at least one foot in contact with the ground all the time, or as a series of highly coordinated movements, in which balance is being constantly challenged and continuously recovered[8].

The gait pattern includes the ambulation velocity (cm per second) and the number of steps completed by time unit (steps per minute), also called cadence[9]. This pattern, which is usually altered after a stroke due to a number of factors, includes sensitivity, perception, mobility and motor control impairment[6].

The hemiparetic gait is common in patients with spastic hemiparesis. The upper limb flexion can be observed with extension of the lower limb in the affected hemibody. As a consequence, the lower limb cannot support the body weight completely during the stance phase, in addition to not being able to project the body forward during the swing phase, except as a whole in circumduction. This type of gait is also called "reaping gait"[10].

The Functional Electrical Stimulation (FES) is a technique used in Physical Therapy, with the main objective of attaining muscular reeducation, atrophy delay, temporary inhibition of spasticity and decreased contracture and edema[7]. This technique is designed to interfere directly on the dynamics of the sensorimotor control, reestablishing the proprioceptive feedback that is blocked in the muscular movement attempts[11].

There are several studies in literature on the use of FES to improve the functionality of hemiparetic patients, but a consensus on this therapeutic intervention is yet to be attained.

Many of the studies that have been published present positive results and some, when compared to the conventional intervention do not demonstrate efficacy improvement regarding the treatment with electrical stimulation.

The importance of an effective treatment, with a higher number of sessions within an established period of time so the patient can be discharged as soon as possible, can help optimize the number of treated patients, as the number of patients surpasses that of physical therapists[12].

OBJECTIVES

The main objective of the present study is to verify the effects of neuromuscular electrostimulation on the ankle dorsiflexors in a hemiparetic patient and evaluate the patient's gait, alterations in muscular tonus and strength, joint ROM and functionality.

METHODS

The study consisted of an intentional sample, comprising one individual that fulfilled the inclusion criteria: to be receiving physical therapy; to have had the stroke more than six months prior to the study; to be able to ambulate without support for at least 10 meters; to have a minimum of grade 03 regarding muscular strength; to accept participating in the study through the Free and Informed Consent Form. The exclusion criteria were to demonstrate cognitive deficit that would prevent the use of the technique; to present deformities in the hemiparetic limb and to present a deficit of sensitivity in the paretic lower limb, which were delimitated by the researchers.

The patient, a 54-year-old male, was recruited through the Service of Neurological Physical Therapy of the University of Passo Fundo and had had a hemorrhagic stroke two years prior to the study. The sequelae included left paresis with strength deficit in the affected LLLL and consequent gait alteration.

The physical therapy assessment (initial and final) was carried out in the Laboratory of Biomechanics of the College of Physical Education and Physical Therapy of the University of Passo Fundo; muscular strength was verified by computerized dynamometry, plantar pressure by baropodometry, muscular tonus by the Ashworth scale, ROM by goniometry of the dorsi/plantiflexors and spatial-temporal gait parameters by the podogram.

The treatment consisted in the use of neuromuscular electrostimulation through a low-frequency, biphasic FES (Functional Electrical Stimulation) current A

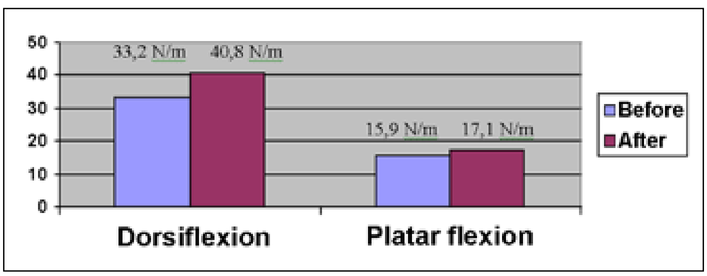
The Physiotonus Four equipment (Bioset®) was used, with an electrode on the ankle dorsiflexor muscle (anterior tibial muscle) and electrical-conducting electrodes made of rubber that measured 5cmx5cm. The treatment duration was 45 days, with three weekly sessions of 30 minutes each, with a pulse width of 250 µs, frequency of 50 Hz, T*on* 06s and T*off* 12s. The slope up of 0.2 s and down of 0.1 s were used as well as the intensity, according to the patient's tolerance, totaling 20 sessions.

RESULTS

Muscular strength

Figure 1 shows an increase of 22.9% in torque peak of the dorsiflexor musculature that was stimulated, which was 33.2 N/m before and 40.8 N/m after the intervention. Regarding the plantiflexor musculature, which was not stimulated, there was an increase in peak torque of 7%.

Figure 1
Peak torque at 30 °/SEC: dorsiflexors and plantiflexors



Plantar pressure

Table 1 shows the values of plantar pressure in g/cm², in the different foot regions, before and after the intervention.

At an initial analysis of the plantar pressure, a pressure increase was observed in the region of the midfoot (lateral plantar arch), characteristic of equinovarus foot of the hemiplegic individual, justified by the spasticity of the plantiflexors and intrinsic foot musculature, after the physical therapy intervention with the use of FES in the anterior tibial muscle (antagonist to the spastic one).

Table 1
Plantar pressure in the different foot regions

REGION	PRESSUE PEAK (g/cm2)	
	BEFORE	AFTER
Hindfoot	2648	3263
Midfoot	790	3476
Forefoot	1405	1525
Toes	1847	4198

A decrease in the distribution of the weight on the midfoot was also observed, with an improvement in weight distribution to all the other areas, hindfoot (calcaneous), midfoot (plantar arch and external lateral border), forefoot (metatarsal heads) and toes during the stance phase of the left foot.

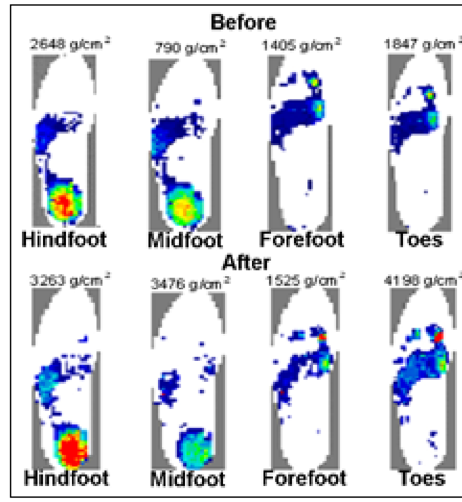


Figure 2
aPlantar pressure in the different regions of the foot.

Muscular tonus

Regarding the muscular tonus, a mild spasticity (+1) of the gastrocnemius was observed at the initial assessment according to the Modified Ashworth Scale, which was no longer present at the reassessment (0).

Range of Movement (ROM)

Table 2 shows active and passive ROM values of the ankle joint in the dorsiflexion and plantiflexion movements:

Table 2
Ankle ROM

	RIGHT		LEFT	
	BEFORE	AFTER	BEFORE	AFTER
Plantiflexion (passive)	48°	48°	40°	45°
Plantiflexion (active)	40°	40°	30°	38°
Dorsiflexion (passive)	20°	20°	12°	16°
Dorsiflexion (active)	18°	18°	8°	12°

ROM = range of movement

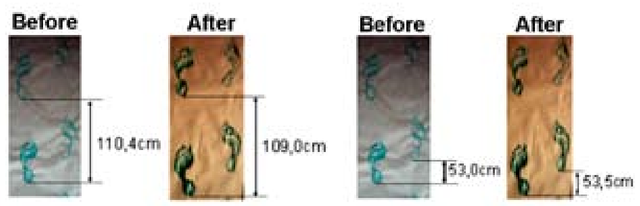
Gait

Table 3 shows the values obtained on the gait parameters (before and after the intervention); a 14% improvement in velocity can be observed, as it was 3.2 cm/sec initially and after the intervention, it was 3.7 cm/sec. As the support basis was 22.6 cm before and 20.1 cm after the intervention, a 12% improvement was observed, whereas the other parameters (step length, stride length and cadence) remained unaltered.

Therefore, regarding the treated patient, we observed an improvement in the stimulated muscle strength, which consequently results in an improvement of the ankle joint ROM and gait pattern, demonstrated by the plantar pressure and podogrammetry. There was also a decrease in the tonus of the treated musculature.

Table 3
Spatial-temporal parameters of gait

	BEFORE		AFTER	
	R	L	R	L
Step length	54,0cm	53,0cm	56,2 cm	53,5cm
Stride length	109,3cm	110,4cm	109,3 cm	109,0cm
Velocity	3,2 cm/seg.		3,7 cm/seg.	
Cadence	27passos/min		26 passos/min	
Support basis	22,6cm		20,1cm	
Cycles	7		6	



Stride and step length impression

R=right; L=left

DISCUSSION

The abnormalities of motor neuron activation thus define the voluntary tension developed by the muscle that could affect the activities of the contractile protein properties. As it is well-established in molecular biology, the process of muscle tension is the stimulus for the addition or loss of sarcomers. The key-question is whether the interruption of the central direction mechanism produces enough secondary effects in the muscle to decrease the contractile capacity. If the decreased muscular strength is an important factor in hemiparesis, then methods of muscular strength improvement should be included in the rehabilitation program. Otherwise, other strategies must be emphasized[13].

The FES could compensate this deficiency by increasing the excitability of the motor neuron, not only by the direct activation of large motor units, but also by the sensory effect produced by the electrical current on the skin[14].

It is known that FES causes the contraction of paretic muscles through the sensitive pathways, which contribute to the normalization of the basic reflex motor activities[15]. The immediate effects are: reciprocal inhibition and relaxation of the spastic muscle and sensory stimulation of the afferent pathways. The late effects act in the neuroplasticity and are able to modify the muscular viscoelastic properties[16]. Other authors concluded that the FES provides a skin feedback that alters the population of activated motor units[17].

The type II muscle fibers, also known as white fibers, present a rapid velocity of contraction, anaerobic metabolism and little resistance to fatigue, due to the fact that they are poor in hemoglobin, being in charge of the dynamic contractions with quick movements and little strength. It is possible to convert the motor units from one type to another and this plasticity is crucial for the adaptation to alterations in work or activities[18].

It is not possible to make an actual selective estimation of the different types of motor nerves and the different types of motor units (such as type I and type II fibers). Hence, we will have to observe the quality and quantity of responses obtained with the stimulation, i.e., the characteristics of the muscular contraction as the basis for such estimation, and not the selective activation of a certain fiber type[19].

The torque peak at 60°/sec presented with a deficit, which did not happen when it was tested at 30°/sec, when positive torque peak values were obtained. This can be justified by the fact that the first contractions at 30°/sec led to the fatigue of the musculature used, when rapid contraction fibers or the type II fibers, are characterized by low resistance to fatigue. Such fact is more evident in a hemiparetic patient, which can justify the deficit of the second series at 60°/sec, even when it permits a faster movement, by allowing more degrees per second of mobilization.

The hemiplegic patient develops an equinovarus foot, which is the distancing of the plantar arch from the ground, with a consequent overload of pressure between the calcaneous, forefoot (metatarsal heads) and toes[20].

There are reports in literature on the increase of pressure in the midfoot region (lateral plantar arch) as a characteristic of the equinovarus foot in the hemiplegic patient, justified by the spasticity of the plantiflexors and intrinsic foot musculature[21,22].

A study of the plantar pressure observed, in 111 male individuals with a mean age of 28.76 ± 9.88 years, the distribution called medial/central as a pattern of distribution of pressure close to a normal foot, which was similar to that observed in the present study after the physical therapy intervention through electrical stimulation[23].

The active recruiting of the antagonist muscles can act on the relaxation of the spastic muscle through the mechanism of reciprocal inhibition with the use of FES. In the reciprocal inhibition, the central prolonging of the muscle spindle afferents reaches the medullary grey matter. From there, excitatory synapses are formed with alpha-antagonist motor neurons and also with inhibitory interneurons, establishing synapses with the alpha-agonist motor neurons and the inhibition of these antagonist muscles[24].

The physical therapy promotes the improvement of the recruiting of motor units, which ensures a better performance during the motor action, resulting in the improvement of velocity, dexterity and coordination of movements, as well as other benefits such as ROM improvement and muscular tonus regulation[25].

The hemiparetic individuals usually present lower ankle joint dorsiflexion and plantiflexion range, decreased gait velocity and prolonged swing phase, when compared to healthy individuals[26]. In a study with 13 hemiparetic individuals, it was observed the improvement in active mobilization after the use of FES, with all individuals presenting some degree of mobilization, either functional or non-functional, before the intervention[27].

Another study carried out through surface electromyography showed that the dorsiflexion of hemiparetic patients that used FES improved in 100% of the patients[28].

In a study that was similar to the present one, which consisted of four individuals that received physical therapy and were simultaneously stimulated with FES, all measured gait parameters showed an increase[28].

CONCLUSION

In the present study, FES was considered safe and effective in the improvement of active and passive ROM, in muscular reeducation, in the decrease of spasticity and in a better distribution of weight on the affected side, with a consequent gait improvement. In this sense, our initial objectives were attained, showing that FES can be an important therapeutic adjuvant for hemiparetic patients.

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