Can the EMG-FES interface contribute to the rehabilitation of acute post-stroke? An update

Jessika Mehret Fiusa

Emerson Carraro

ABSTRACT

Surface electromyography (EMG) is a technique for identifying and processing data on the neural activation of skeletal striated muscle (WONG *et.al.*, 2017). Surface electrodes (Ag/AgCl) are used to detect the action of the motor neuron when it reaches the muscle fiber, even if there is not enough force to move the joint during contraction, as in a patient with hemiparesis after a stroke (FANG *et.al*., 2019). Functional electrical stimulation (FES) is one of the resources used in the treatment after stroke, allowing the activation of the lower motor neuron and consequently of the innervated musculature, through electrical stimuli (LUCAS *et.al.*, 2018). Its most common application is performed through surface electrodes in the regions near the innervation of the muscle (PARK, 2017).

Keywords: Electromyography, EMG-FES, Skeletal striated muscle.

1 INTRODUCTION

Surface electromyography (EMG) is a technique for identifying and processing data on the neural activation of skeletal striated muscle (WONG *et.al.*, 2017). Surface electrodes (Ag/AgCl) are used to detect the action of the motor neuron when it reaches the muscle fiber, even if there is not enough force to move the joint during contraction, as in a patient with hemiparesis after a stroke (FANG *et.al*., 2019). Functional electrical stimulation (FES) is one of the resources used in the treatment after stroke, allowing the activation of the lower motor neuron and consequently of the innervated musculature, through electrical stimuli (LUCAS *et.al.*, 2018). Its most common application is performed through surface electrodes in the regions near the innervation of the muscle (PARK, 2017).

FES has been shown to be a technique capable of stimulating neuroplasticity (CRAVEN *et.al.*, 2017). Its operation has two phases, being the time on (*on*) that consists of the activation period, and the time off (*off*) being the rest time for the patient, where the FES remains off. The off time should be at least 2 times the time on, so that there is no rapid muscle fatigue. The values of on/off time are added to calculate the total time of electrical activation (PINHEIRO *et.al.*, 2018).

In order to mimic a voluntary motor activity, the EMG-FES interface detects and activates the selected neuromuscular apparatus, for example, the contraction of the hand so that a quadriplegic picks up a glass (ZHOU *et.al.*, 2018). This resource is able to assist the neuroplasticity of patients who have motor sequelae such as spinal cord injury and stroke through tactile, visual and proprioceptive biofeedback (LI, 2017).

2 GOAL

In view of the need for an update on the EMG-FES interface so that it can be inserted in the motor rehabilitation of patients with stroke sequelae, the objective of the present study is to seek the main parameters used in the interface and its effectiveness in this clinical practice.

3 METHODOLOGY

The search was performed in the databases Google Scholar, PubMed, Scielo, Lilacs, Medline, PeDro and Bireme with the keywords **a)** *EMG-FES interface*; **b)** *Functional Electrical Stimulation AND Electromyography*; **c)** *EMG-FES system*; **d)** *EMG trigger FES*; **e)** *EMG-FES AND stroke*, on articles published between 2017 and 2019. Articles from journals and congresses were selected, and those that were not CVA or EMG-FES interface were excluded, as well as abstracts, experimental studies and expanded abstracts.

4 DEVELOPMENT

According to the aforementioned keywords, 923 articles were found. Duplications with a different theme from the one proposed were excluded and 21 were selected. After the readings, 10 articles were used for this review and 11 were removed because they did not conform to the study theme.

Figure 2. Descriptive analysis of the results obtained by the authors regarding the intervention with the EMG-FES interface in the post-stroke period. EMG-FES: electromyography-functional electrical stimulation; Stroke: stroke; n: number of participants / sample; MMSE: mini-mental state examination; X-ray: X-ray; VAS: visual analog scale; ROM: range of motion; MRI: magnetic resonance imaging; MMSS: upper limbs.

	Jeon, 2017	Bae, 2017	Schauer, 2017	Camona, 2018	Zhou, 2018
Tema do estudo	Dor e funcionalidade	EMG-FES com 2 sensores de aferencia sensorial	3 tipos de técnicas associadas à FES para feedback	Eficácia da EMG-FES	Órtese robótica híbrida controlada por EMG-FES e com exoesqueleto para suspensão de MMSS
Estágio AVE	Agudo	Crônico			Agudo
Segmento corporal	Membro superior afetado	Tornozelo	Tornozelo		Ombro
Sequela	Hemiparéticos	Hemiplégicos			
n	20	18			7
MEEM (pontos)	21				>20
Avaliação	RX ombro, EMG, dor (EVA), Fugl-Meyer	Reflexo H, EMG, Ashworth, equilíbrio			Index, caixa e blocos, atividades funcionais
Protocolo tratamento	30', 5x/sem, 4 sem	20', 5x/sem, 4 sem	10 anos		30', 27 sessões
Grupos (experimental/ controle)	EMG-FES/FES	EMG-FES/FES			
Resultados	Amostra melhor que controle pela EMG e EVA. Sem resultados Fugl-Meyer	Amostra foi melhor que controle	Houve recrutamento de unidades motoras	Potencial reabilitação ativa no AVE	O sistema pareceu eficaz
	Ambrosini, 2019	**Park, 2019**	**Raghavendra, 2017**	**Wilkins, 2017**	**Zhou, 2018 IEEE**
Tema do estudo	EMG-FES associado a imagética	EMG no membro sadio e FES no membro doente	EMG-FES no braço em pós AVE	EMG-FES no braço em pós AVE	EMG-FES para reabilitação de mão em pós AVE em malha fechada
Estágio AVE	Crônico			Crônico	
Segmento corporal	Mão	Mão	Mão	Braço	Mão
Sequela				Hemiparéticos	
n	68	1	1		
MEEM (pontos)	>24				
Avaliação	Ashworth, caixa e blocos, Fugl-Meyer, index, Barthel			Fugl-Meyer, caixa e blocos, ADM ativa, RNM funcional	
Protocolo tratamento	30', 5x/sem, 6 sem			20-30 repetições, 3x/sem, 7 sem	
Grupos (experimental/ controle)	Com/sem imagética				
Resultados	Não houve diferença entre os grupos, mas ambos obtiveram melhora	Eficaz no desenvolvimento do movimento da mão	Eficaz no desenvolvimento do movimento da mão	Reorganização cortical com crescimento neuronal ipsilateral a lesão e redução da atividade contralateral	Potencial reabilitação ativa no AVE

Based on the findings in the literature (Figure 2), it is observed that in most cases EMG-FES was the technique chosen so that the post-stroke patient can actively obtain neuroplasticity. Two studies compared the EMG-FES interface with the treatment of FES alone. The first study (JEON, 2017) tested in hemiparetic individuals, in the acute phase of stroke for the treatment of MMSS, and the second (BAE, 2017) applied in hemiplegic subjects in the chronic phase, for LLLL. Both authors performed a similar treatment protocol, the only difference being the time of each session (20' x 30'). Their results revealed that the EMG-FES group provided pain reduction, increased functionality, improved balance control and reduced spasticity.

The inquiry about the structural effects at the cortical level of treatment with the EMG-FES interface was the subject of study for Wilkins (2017) (11). He used the interface for upper limb rehabilitation in chronic, hemiparetic post-stroke patients. His evaluation included functional magnetic resonance imaging in the cortex. After a 7-week treatment protocol, they were able to observe a cortical reorganization. There was neuronal growth ipsilateral to the lesion and reduction of contralateral neuronal activity, demonstrating structural changes with the active rehabilitation provided by EMG-FES. Another protocol proposed in a 2017 study (SCHAUER, 2017) also evaluated neuronal activity after treatment with 3 FES-associated techniques for *feedback.* After 10 years of study, it can be concluded that the association of functional electrical stimulation with electromyography promoted the recruitment of motor units at the peripheral level.

Other studies have associated EMG-FES with other techniques, such as imagery and *biofeedback* through a healthy limb. The first study (PARK, 2019) randomized two groups, with group (a) only EMG-FES and group (b) EMG-FES with imagery. Their treatment protocol was 6 weeks for both groups in post-stroke in the chronic phase. The experiment showed that there was no statistical difference between groups (a) and (b), however, both groups obtained improvement in hand movement. The second study (RAGHAVENDRA, 2017) applied EMG-FES in post-stroke to improve hand functionality in a case report. The individual in question presented hemiplegia and, in order to achieve movement capture with EMG, the researchers applied it to the healthy arm, while FES stimulated the hemiplegic limb. It was observed that this alternative was effective in the development of hand movement, suggesting further studies with a larger number of participants.

It is noticed that over time the studies with the EMG-FES interface have expanded, but there are still many doubts about the technique and its legitimacy. Researchers focus their study on the body segments with the greatest recovery difficulties after a brain injury and present potentially effective results. Research conducted in 2019 associated EMG-FES with robotic orthosis for upper limb and exoskeleton for arm support in acute post-stroke (AMBROSINI *et.al.*, 2019). Another study applied the interface with a closed-loop system for hand opening (ZHOU, 2018). A third study used EMG-FES to improve wrist and finger function in chronic hemiparetics (CAMPONA, 2018). These studies obtained results in common, inferring that the EMG-FES interface has a good potential for active rehabilitation in stroke.

Table 2. Configurations used for acquisition, application and processing of electromyography and functional electrical stimulation data.

		Jeon, 2017	Bae, 2017	Schauer, 2017	Camona, 2018	Zhou, 2018	Ambrosini, 2019	Park, 2019	Raghavendra, 2017	Wilkins, 2017	Zhou, 2018 IEEE
FEZ											
	f (Hz)				50	50	25			50	
	p (µs)		250		300	200-400	300			300	
	i (mA)		30-70			30-60		15-30			
	t (s)				3					3	
EMG											
	F (kHz)	1.5	1				4		2		1
	pb (Hz)	60-450	20-500		30-300						
	pba (Hz)								90		20
	pa (Hz)								10		50
	rf (Hz)								50		50
Processes chin		RMS	RMS	RMS or peak-to-peak by the difference in value and filter	RMS or peak-to-peak by the difference in the estimated value	RMS					RMS

FES: functional electrical stimulation; EMG: electromyography; f: frequency; p: pulse width; I: intensity; t: time; F: acquisition frequency; PB: bandpass filter; PBA: low-pass filter; Pa: high-pass filter; RF: band-reject filter; RMS: root *mean square*.

Regarding the configurations most used by the researchers (Table 2), we have in the FES the most used frequency of 50 Hz, described in studies for treatment in the post-chronic stroke of the upper limbs (7,11,17), pulse width of 300 µs for both acute and chronic post-stroke of the upper limb (7,11,15,17), intensity ranging from 30 – 70 mA being lower intensities in the upper limbs and higher in the lower limbs in the chronic patient (7,10,13), time *on of* 3 seconds, described only in two studies of MMSS, in the chronic phase of the disease (11,17).

For EMG, the authors used, in their majority, acquisition frequency of 1 kHz for both acute and chronic phase of stroke in lower and upper limbs (9,10,16). The filters varied according to the environment in which the treatment was applied, type of muscle and goal to be achieved (band-pass filter (9,10,12), low-pass, high-pass and band-reject (14,16)).

The data processing used in all studies (which were cited) was through the temporal domain of frequencies (RMS), with variations in those studies that performed more detailed evaluations, being them the count of the recruitment of motor units and evaluation of motor function and stereognosy (12,17).

5 FINAL CONSIDERATIONS

Based on this literature review, it can be understood that the use of the EMG-FES interface in post-stroke patients has been carried out in order to obtain a new form of rehabilitation, active, facilitating, as opposed to the techniques usually used in clinical practice. Their results have suggested several benefits in relation to the speed of treatment and neural restructuring at the cortical and peripheral levels.

Regarding the equipment, there is still no consensus on the issue of standardized configurations, since each study seeks a specific objective. However, in general, researchers have used in FES the frequency of 50 Hz, pulse width of 300 μs, intensity between 30 – 70 mA and time *on* of 3 seconds. To capture the signal with EMG, an acquisition frequency of 1 kHz and filters have been used according to the environment to be applied. For data processing, all authors used the temporal domain of frequency (*root mean square* - RMS).

From the results observed, it is noted that the use of the EMG-FES interface has provided benefits to patients who have suffered stroke, both in the acute phase, avoiding spasticity and atrophy, and in the chronic phase, generating cortical reorganization and peripheral neural reactivation. Further studies are still needed to confirm these results and adequacy of the equipment.

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