

Analysis of postural control after the application of functional electrical stimulation in stroke patients

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ABSTRACT

Strokes cause the main neurological impairments in adults around the world. They can result in neuromotor and cognitive deficits. Among the neuromotor deficits there is spasticity; this affects the planning of movements and posture control. The postural control system is essential for functional independence in daily life activities and is, therefore, one of the main goals to achieve in rehabilitation programs. These programs have various therapeutic elements aimed at providing stimulus to the individual, which help them control their movements and stance more efficiently. Among these techniques is neuromuscular electrical stimulation, which contributes to decreasing spasticity and other benefits. When used for functional tasks it is called Functional Electrical Stimulation (FES). **Objective:** The purpose of this study was to verify the response of the postural control in two individuals with hemiparesis by stroke after the application of the FES over a short period time. **Method:** The experimental protocol had four phases. A: pre-FES; B: Immediately after the application of FES; C: 45 minutes after the application of FES; D: 90 minutes after application of FES. In each phase, the participants were positioned on a force platform and made three attempts to do the chosen task: touching the fingertip-to-floor test. **Results:** The software Matlab 7.0 provided the variable center-of-pressure velocities along the mediolateral (Vmx) and anteroposterior (Vmy) axes. In this way it was possible to see that, even when the participants showed a reduction in Vmx and Vmy, it was by less than 1%. **Conclusion:** This may indicate postural regulatory activity similar to before the application of FES, and even less postural regulatory activity when the center-of-pressure velocities were greater at the start, even 90 minutes after the application of FES.

Keywords: Stroke, Postural Balance, Electric Stimulation Therapy

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INTRODUCTION

Strokes are the world's number one neurological condition afflicting adults. They give rise to significant traumas for individuals as well as their families.¹

In a stroke, an upper motor neuron lesion is commonly seen, which triggers motor disorders, mainly, owing to spasticity, a form of hypertonia, characterized by an increase in the tonic stretching reflexes that depend on the speed of the movement.²

Under conditions of spasticity, the motor repertoire for control of movement and posture is altered,² which leads to a reduction in functional capacity making numerous basic activities of the daily life impossible.³

Considering post-stroke motor conditions, especially the alterations due to spasticity and its consequences, the importance of the individual reacquiring postural control is obvious—in other words, of controlling the position of one's body in space, and thereby resuming daily life activities independently with functionality and safety.⁴

Thus, considering all the alterations seen after a stroke, especially in postural control, we can see the importance of implementing a rehabilitation program that can enable the individual to achieve functional independence. This program must be based on the individual's needs and abilities, which must be analyzed within a complex interaction between neuromotor and cognitive deficits, and also the influence of the social milieu. In order to make it possible to reach the goals of rehabilitation, various techniques are used, including kinesiotherapy, the application of botulinum toxin, and neuromuscular electrical stimulation.⁵

Neuromuscular electrical stimulation uses electrical impulses in the peripheral nervous system to generate action potentials. These contribute to reciprocal inhibition; in other words, they inhibit antagonist muscle action during agonist muscle contractions. Therefore, in the case of strokes, they promote the inhibition of the spastic musculature in favor of agonist contractions. When used for functional tasks it is known internationally as Functional Electrical Stimulation (FES).⁶

In view of the reciprocal inhibition caused by FES and based on studies like Alfieri,⁷ it was observed, subjectively, a reduction in spasticity after the application of FES.

OBJECTIVE

The objective of this study was to verify the postural control response of individuals with hemiparesis due to stroke after the application of FES in a short period of time.

METHOD

Two patients were invited to participate in this experiment who were in a Light Hemiparesis model rehabilitation program at the Institute of Physical Medicine and Rehabilitation at the Clinics Hospital of the University of São Paulo School of Medicine (IMREA/HC-FMUSP), at the Lapa Station and Clinics Units. The study was developed at the Movement Laboratory of the *Vila Mariana* Unit.

Symptoms of the participants

The participants have a medical diagnosis of chronic stroke (more than one year post-lesion). They show grade 2 spasticity in the lower limbs according to the modified Ashworth scale;⁸ a degree of muscular dorsiflexion strength ≥ 3 on the Kendall⁹ strength scale, and are independently ambulatory. The subjects were called participant 1 (p1) and participant 2 (p2).

Experimental Protocol

The equipment used was a system of force plates (AMTI, OR6-7-1000) (Figure 1). A *Kroman* model *Quadrikron KC 170* electrostimulator was used to apply the FES (Figure 2).

Initially, the experimental protocol consisted in mapping the motor point that was done the day before the data collection, which was divided into four phases which were named A (pre-FES), B (immediately after application of FES), C (45 minutes after FES), and D (90 minutes after FES).

In all the phases the subjects performed the fingertip-to-floor test, which consisted in making a movement of anterior flexion of the trunk with the upper members in front

of the body.¹⁰ This task was chosen to create a motor perturbation (Figure 1).

The test began and ended with a sonic stimulus supplied by the laboratory system; the subject maintained the task's ending position, with the trunk in anterior flexion, for fifteen seconds. This task was repeated three times, giving a one-minute rest between each attempt.

Two 5-cm electrodes were used to apply FES at a frequency of 20 Hz, a pulse width of 300 μ s, an up-ramp of 2 sec, a down-ramp of 2 sec, a contraction time of 6 sec, a rest time of 12 sec, and enough intensity to provoke a minimal dorsiflexion contraction of the ankle, without any articular movement. The subjects remained seated during the application of FES, keeping the hip, knee, and ankle joints at approximately 90°. The application time was 40 minutes (Figure 2).

Data analysis

The raw PC data from the on the X-coordinate in the anteroposterior direction (*PCx*) and the Y-coordinate in the mediolateral direction (*PCy*) during the 15-second interval was obtained by the Software *EVArT* at an acquisition frequency of 1,000 Hz and exported to Microsoft Excel®, wherein the first five seconds were eliminated in order to analyze only the posture of maximum anterior flexion of the trunk the participants reached in the task. Within Microsoft Excel® the data was down-sampled to a frequency of 100 Hz.

Next, the software Matlab 7.0 supplied the variables for average Velocity of the PC in the mediolateral direction (*Vmx*) and the anteroposterior direction (*Vmy*). Regarding the position of the PC, the data obtained from the plate was transmitted to the computer by signals submitted to a second-order low-pass filter, critically damped, at a frequency of 1,050 Hz.

For each variable of *Vmx* and *Vmy* an average was taken of the three attempts at each phase (A, B, C, and D).

RESULTS

Vmx and *Vmy* for p1

The *Vmx* in steps A, B, C, and D were, respectively, 3.24 cm/s (± 0.42), 2.66 cm/s (± 0.20), 3.19 cm/s (± 0.29), and 3.22 (± 0.41).



Figure 1. Fingertip-to-floor test

From this we see that from step A to step B there was a reduction of 17.90% in the V_{mx} followed by an increase of 16.61% in step C, by comparison, and another slight increase from steps C to D of 0.93%. When analyzing V_{mx} from step A to D, it is evident that there is a slight reduction of 0.62%.

In steps A, B, C, and D the V_{my} was respectively 3.76 cm/s (± 0.46), 3.14 cm/s (± 0.44), 4.16 cm/s (± 0.46), and 4.07 cm/s (± 0.67). From step A to B there was a reduction of 16.49% in the V_{my} , followed by an increase of 24.52% from B to C. In step D, the V_{my} shows a small reduction of 2.16%,

however it still shows a 7.62% increase when compared to step A.

V_{mx} and V_{my} for p2

The V_{mx} in steps A, B, C, and D was, respectively, 2.64 cm/s (± 0.20), 2.72 cm/s (± 0.25), 3.02 cm/s (± 0.21), and 2.84 cm/s (± 0.23). A slight increase of 2.94% can be seen in V_{mx} from step A to step B, and the pattern continues with an increase of 9.93% from step B to C. And although there is a reduction in V_{mx} of 5.96% from C to D, even with this reduction, the V_{mx} in step D remains greater than step A by 7.04%.

In steps A, B, C, and D the V_{my} was respectively, 3.36 cm/s (± 0.10), 3.31 cm/s (± 0.45), 3.54 cm/s (± 0.28), and 3.34 cm/s (± 0.41). From this we see that from step A to step B there was a slight reduction of 1.49% in the V_{my} . However, from B to C there was an increase of 6.50%. From C to D the V_{my} goes back down, having a reduction of 5.65%. When comparing step D with step A, a slight reduction in V_{my} of 0.59% is visible.

DISCUSSION

Analysis of the studied variables demonstrates that the two participants show similar postural behavior.

The V_m of the PC can be interpreted as the variable that best portrays the individual's conditions in relation to postural control—in other words, the quantity of regulatory activity necessary to attain the desired stability.^{11,12}

Regarding the present study, p1 showed a diminution of V_{mx} and V_{my} (Figures 3 and 4), but only in step B, immediately after the application of FES, but that increased in the following steps stabilizing in step D at the end, with V_{mx} and V_{my} very close to that at the outset, the condition previous to the FES. P2 showed only a small reduction in V_{mx} and V_{my} (Figures 5 and 6) in step B with an increase in step C and, at the end in step D, stabilizing close to step A. Interestingly enough, the V_{mx} of p2, contrary to the V_{my} , showed an increase in step B, a behavior they maintained in step C and then, in step D, it diminished to levels close to the beginning in step A. We therefore observe that, even with the variations noted between steps, in the end, 90 minutes after the application of FES, both p1 and p2 remained with their V_{mx} and V_{my} (Figures 3, 4, 5, and 6) close to the initial readings, before the application of FES.

Consequently, if the V_m of the PC can indicate the level of regulatory activity required for postural control, the subjects in the present study, in step D at the end of the experiment, showed a reduction of less than 1% in V_{mx} and V_{my} , which may indicate a postural regulatory activity similar to before the FES, and even less postural regulatory activity, when the V_m of the PC was greater than initially.

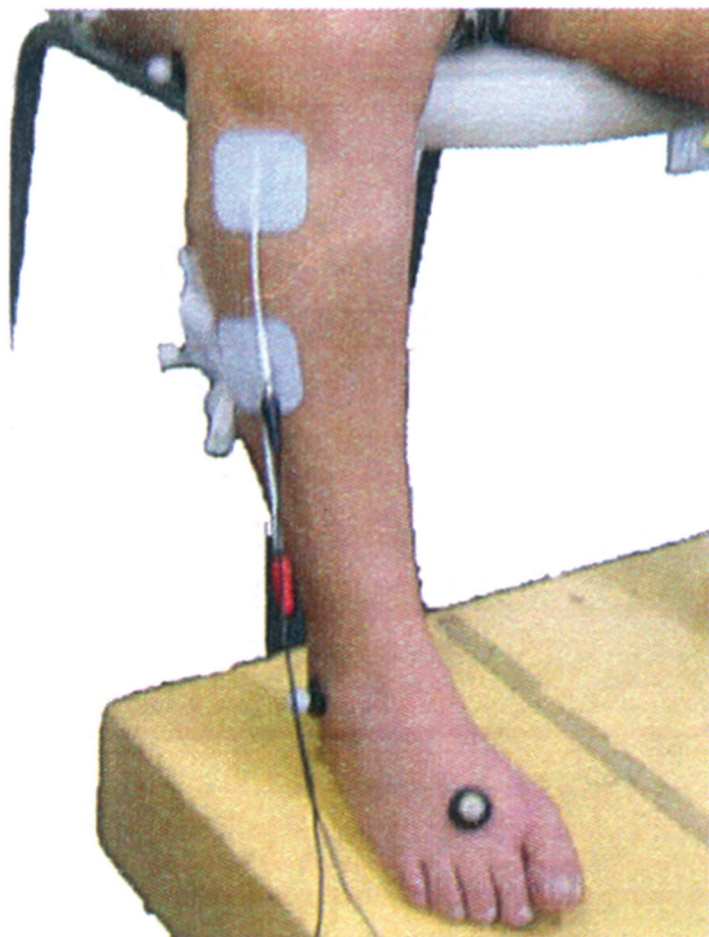
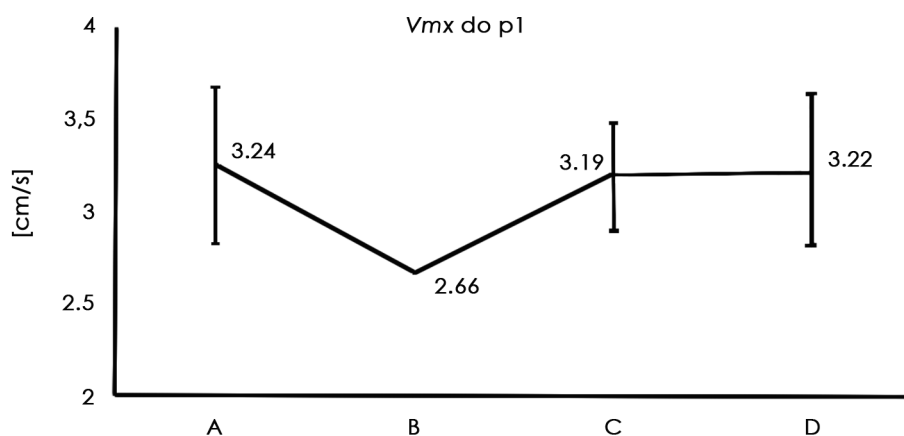


Figure 2. Subject during the application of electrostimulation



A: Pre-FES; B: Immediately after FES; C: 45 minutes after FES; D: 90 minutes after FES

Figure 3. Vmx in steps A, B, C, and D.

Therefore, by the interpretation of the variables V_{mx} and V_{my} and regarding the postural adjustments used at the beginning and end of the experiment, the postural control behavior of p1 and p2 was similar before and after the application of the FES.

Such findings might be related to the type of protocol used, since in the present study only one FES session was done while the majority of the protocols are done three to five times a week for one to five months.^{13,14,15}

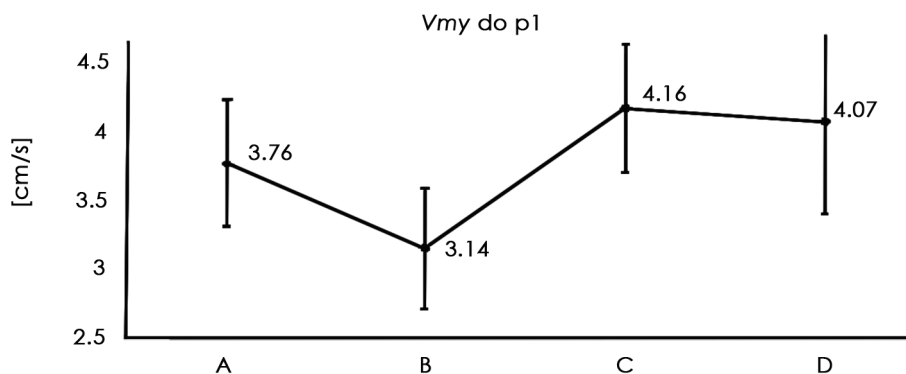
In this way, in such a short time as with only one application of FES, there probably was not enough time to observe the formation of new neuromotor engrams, and, hence any improvement of postural control as the findings of the present study indicate. However, as for other benefits that FES could bestow such as a reduction in spasticity, Alfieri⁷ observed such a diminution within an hour of the application of FES.

In addition, many studies have demonstrated the benefits of associating the application of FES with conventional therapy, in which stretching and strengthening of muscles are emphasized as well as stimulation of static and dynamic balance. These works present positive results for functional activities such as gait, and consequently for the postural control system.^{14,15}

In future studies, an increased number of sessions applying FES and the association with conventional therapy can bring new results to better characterize the possible effects of FES on the postural control of this population.

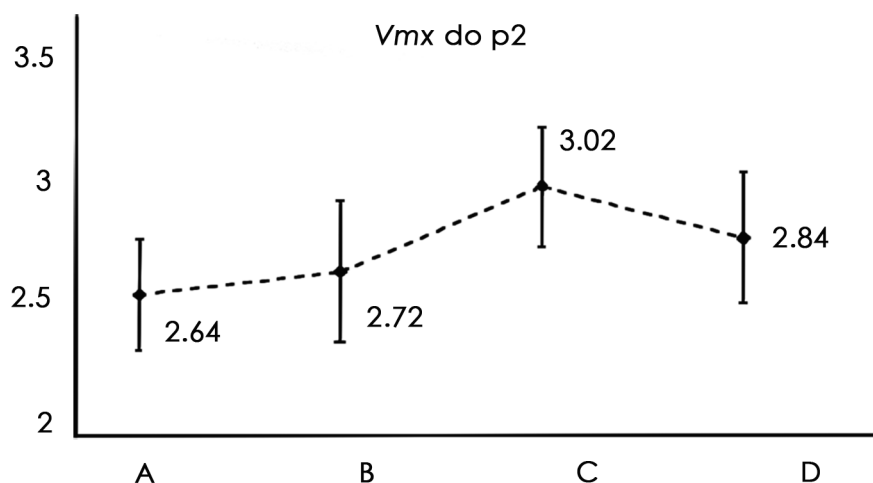
CONCLUSION

The present study observed that the short-term application of FES on stroke subjects with hemiparesis did not show more efficient responses in postural control, according to the variables analyzed. In other words, the effect of FES on postural control in a single application did not show any effect lasting more than ninety minutes from the application. Therefore, there is a need for more studies associating the protocols of FES with conventional therapy, and also with larger samples.



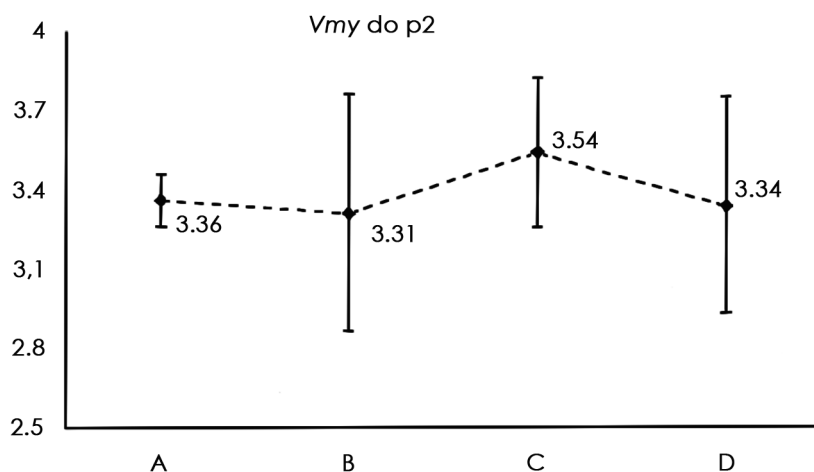
A: Pre-FES; B: Immediately after FES; C: 45 minutes after FES; D: 90 minutes after FES

Figure 4. Vmy for p1 in steps A, B, C, and D



A: Pre-FES; B: Immediately after FES; C: 45 minutes after FES; D: 90 minutes after FES

Figure 5. Vmx in steps A, B, C, and D



A: Pre-FES; B: Immediately after FES; C: 45 minutes after FES; D: 90 minutes after FES

Figure 6. Vmy of p2 in steps A, B, C, and D

REFERENCES

- Dam M, Tonin P, Casson S, Ermani M, Pizzolato G, laia V, et al. The effects of long-term rehabilitation therapy on poststroke hemiplegic patients. *Stroke*. 1993;24(8):1186-91. DOI: <http://dx.doi.org/10.1161/01.STR.24.8.1186>
- Ward AB. Long-term modification of spasticity. *J Rehabil Med*. 2003;(41 Suppl):60-5.
- Muren MA, Hütler M, Hooper J. Functional capacity and health-related quality of life in individuals post stroke. *Top Stroke Rehabil*. 2008;15(1):51-8. DOI: <http://dx.doi.org/10.1310/tsr1501-51>
- Benaïm C, Pérennou DA, Villy J, Rousseaux M, Pelissier JY. Validation of a standardized assessment of postural control in stroke patients: the Postural Assessment Scale for Stroke Patients (PASS). *Stroke*. 1999;30(9):1862-8. DOI: <http://dx.doi.org/10.1161/01.STR.30.9.1862>
- Mauritz KH. Gait training in hemiparetic stroke patients. *Eura Medicophys*. 2004;40(3):165-78.
- Robinson AJ, Snyder-Mackler L. *Eletrofisiologia clínica - eletroterapia e teste eletrofisiológico*. 2 ed. Porto Alegre: Artmed; 2001.
- Alfieri V. Electrical treatment of spasticity. Reflex tonic activity in hemiplegic patients and selected specific electrostimulation. *Scand J Rehabil Med*. 1982;14(4):177-82.
- Greve JMD. *Tratado de medicina de reabilitação*. São Paulo: Roca; 2007.
- Kendall FP, McCreary EK, Provance PG. *Músculos, provas e funções*. São Paulo: Manole; 1995.
- Perret C, Poiraudou S, Fermandian J, Colau MM, Benhamou MA, Revel M. Validity, reliability, and responsiveness of the fingertip-to-floor test. *Arch Phys Med Rehabil*. 2001;82(11):1566-70. DOI: <http://dx.doi.org/10.1053/apmr.2001.26064>
- Cornilleau-Pérès V, Shabana N, Droulez J, Goh JC, Lee GS, Chew PT. Measurement of the visual contribution to postural steadiness from the COP movement: methodology and reliability. *Gait Posture*. 2005;22(2):96-106. DOI: <http://dx.doi.org/10.1016/j.gaitpost.2004.07.009>
- Raymakers JA, Samson MM, Verhaar HJ. The assessment of body sway and the choice of the stability parameter(s). *Gait Posture*. 2005;21(1):48-58. DOI: <http://dx.doi.org/10.1016/j.gaitpost.2003.11.006>
- Mesci N, Ozdemir F, Kabayel DD, Tokuc B. The effects of neuromuscular electrical stimulation on clinical improvement in hemiplegic lower extremity rehabilitation in chronic stroke: a single-blind, randomised, controlled trial. *Disabil Rehabil*. 2009;31(24):2047-54. DOI: <http://dx.doi.org/10.3109/09638280902893626>
- Cheng JS, Yang YR, Cheng SJ, Lin PY, Wang RY. Effects of combining electric stimulation with active ankle dorsiflexion while standing on a rocker board: a pilot study for subjects with spastic foot after stroke. *Arch Phys Med Rehabil*. 2010;91(4):505-12. DOI: <http://dx.doi.org/10.1016/j.apmr.2009.11.022>
- Yan T, Hui-Chan CW, Li LS. Functional electrical stimulation improves motor recovery of the lower extremity and walking ability of subjects with first acute stroke: a randomized placebo-controlled trial. *Stroke*. 2005;36(1):80-5. DOI: <http://dx.doi.org/10.1161/01.STR.0000149623.24906.63>