

Therapeutic Effects of Functional Electrical Stimulation

Thomas Sinkjær¹, Dejan B. Popović¹, Mirjana B. Popović^{1,2}

¹Center for Sensory Motor Interaction, Aalborg University, Denmark, ²Center for Multidisciplinary Studies, University of Belgrade, Yugoslavia

Introduction

Plasticity of the CNS has been recognized as a part of the structural and physiological substrate for recovery of function after brain injury [1]. Cortico-motor reorganization could occur as a response to: altered inputs to the cortex sensory, as an adaptation to injury of the central or peripheral nervous system or as a consequence of the motor task performed, and may be either short term or more long lasting. Dynamic remodeling processes occurring in the sensorimotor cortex of humans has been demonstrated after peripheral deafferentation [2]. Modification of the sensory representation has been shown for the fingering digits of violin players. However not for digits of the bow hand, indicating thus a long-lasting change in the sensory cortex has occurred in response to the repetitive performance of complex and highly skilled motor task [3]. Changes in the fMRI signal were found with practice of four-finger tapping exercise over a period of days and weeks to last for 4-6 weeks, whereas expansion of Transcranial Magnetic Stimulation maps persisted until the performance of the task reached plateau [4]. The question that we are answering considering the above facts is what we need to change in the rehabilitation protocols to improve outcome of functional movements after stroke by promoting neuroplasticity?

The reviews of the neurorehabilitation methods [5, 6] suggest that almost all techniques that involve increased exercise or electrical stimulation promote recovery. In order to evaluate the differences between the effects of conventional vs. enhanced therapy we introduced Functional Electrical Therapy (FET) [7]. FET is a treatment that combines electrical therapy and intensive exercise for hemiplegic patients.

Methods

Subjects. The following two evaluated: 1) acute hemiplegic subjects (more than two weeks and less than three months following first stroke ever), 2) chronic hemiplegic subjects (more than one-year post stroke). 32 subjects were randomly included in the study (mean age & SD, 61.5±7.5). The acute subjects were accepted in the study at an average 6±2 weeks after the onset of stroke, while the chronic subjects after 65±9 weeks. The inclusion criteria were: 1) stroke of ischaemic or hemorrhagic origin, confirmed by MRI or CT scan; 2) age over 18; 3) able to give informed consent; and 4) cognitive status sufficient for learning how to use FET. The exclusion criteria were: 1) dependent on care, prior to stroke, for activities of daily living, 2) severe medical condition in any arm that precludes participation in the study, 3) previous injury or disease or contracture affecting hemiplegic or non-hemiplegic arm or hand, and 4) pre-existent neurological disease or injury. All subjects had some extension of their wrist, fingers and thumb against gravity at the onset of hemiplegia (3 to 6 weeks after stroke). All subjects were able to extend the wrist and fingers more than 20 degrees against gravity, and they could extend all fingers for more than 10 degrees against gravity. The average spasticity of the subjects (modified Ashworth scale) was 2-3). Study hemiplegic subjects signed informed consent approved by the local ethics committee before entering in the study.

Treatment. All subjects received the conventional physical therapy and FET based on Bobaths methods [8]. Acute subjects were randomly assigned to control or FET group. FET is a procedure of voluntary activation of all preserved sensory-motor mechanisms of the paretic arm in synchrony with a neural prosthesis that applies four channels and surface electrodes in order to assist opening, closing, holding, and releasing of objects in a fashion similar to normal grasping. This treatment was applied in FET and chronic hemiplegic subjects for three

consecutive weeks on a daily basis. The FET sessions lasted for 30 minutes. The assignment during the session was that hemiplegic subjects functionally use various daily necessities (e.g., can, telephone receiver, comb, toothbrush, VCR tape). A functional use of an object comprised the following phases: reach, grasp, manipulate the object, bring object back to the original post, and release it. Details on the procedure are explained elsewhere [7]. Hemiplegic subjects from the control group were required to daily exercise for 30 minutes trying to accomplish the same tasks as the FET group yet without a neural prosthesis.

Outcome measures: 1) Upper Extremity Functioning Test (UEFT), 2) Drawing test and 3) structured questionnaire about the real use and satisfaction [7]. The subjects were assessed at the point of entry to the trial, after the treatment (3 weeks), and at 6, 13, 26 weeks after the beginning of the study. The statistical analysis used repeated ANOVA to compare the gains in each of the groups and differences between the groups.

Results

Figure 1 shows the results of the upper extremity test for chronic, acute control and FET groups. The linear regression trend lines are intentionally broken into two parts to point to the fact that the functional gains are changing through the evaluation period. The gains are much bigger at the beginning, and they are very dissimilar for different groups. The gains are the biggest for the acute FET. There is a statistically significant gain in acute FET subjects ($p < 0.01$, $F = 8.5$). There was a statistically significant difference between the gains in FET acute subjects compared to two other groups ($p < 0.01$, $F = 21.2$).

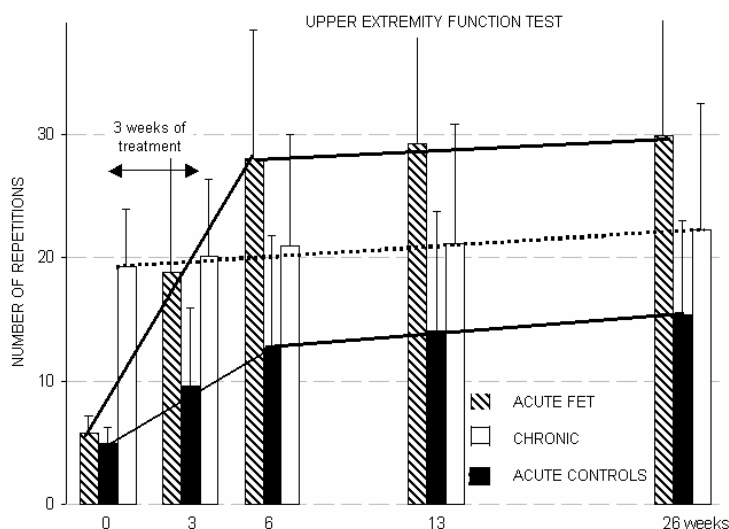


Figure 1. The Upper Extremity Function Test is a number of successful repetitions of functional tasks during two-minute intervals. 11 tasks were tested. The bars are average \pm S.D. for the whole group over all 11 tasks.

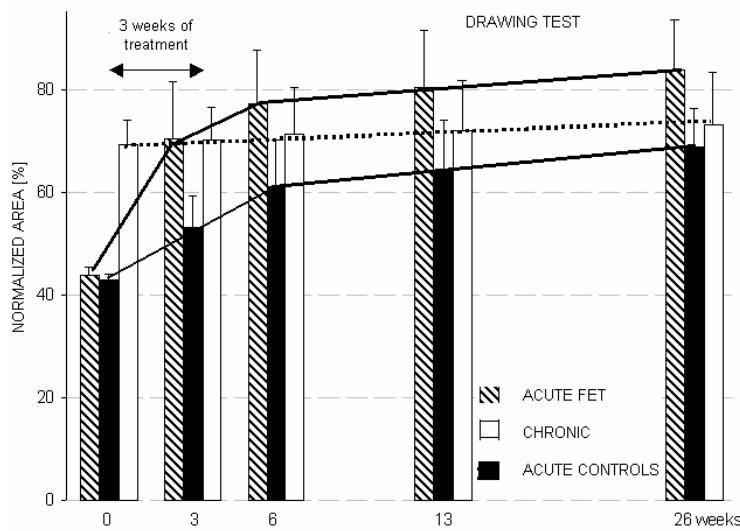


Figure 2. The drawing test shows the ability to draw a square with the side of 20cm on the digitizing board. The score expressed in percent was calculated by normalizing the area surrounded with the drawing to the nominal area of the square (400 cm²). The results were obtained from three successive drawing in clock and counter clock directions. The bars are average \pm S.D. for the whole group.

Figure 2 shows the results of the drawing test. Drawing test shows the ability to coordinate elbow and shoulder joints while making straight-line movements in four orthogonal directions in the horizontal plane. The gains in the drawing test are obvious, and very much alike the gains in the UEFT the linear regression trend lines are broken to demonstrate the variability of slopes. The gains are maximal during the treatment in the acute hemiplegic subjects. There is a statistically significant gain in acute FET subjects ($p < 0.01$, $F = 11.3$). There was a statistically significant difference between the gains in FET acute subjects compared to two other groups ($p < 0.01$, $F = 9.6$).

The gains in chronic subjects in both UEFT and drawing test are small, yet noticeable. Note that the chronic hemiplegic subjects started the study from the level being much bigger compared with the acute subjects. This was expected because these hemiplegic subjects reached plateau at about six months and their gains during this first year were due to the conventional treatment and natural recovery. The acute subjects who participated in the FET program achieved much better scores and they overcome the abilities of chronic subjects at about 6 weeks.

The gains in acute subjects cannot be attributed only to stronger muscles since the changes were dramatic in the control of non-stimulated motor systems, i.e., elbow and shoulder. The most likely answer to the question why this techniques works is that it contributes to the neuroplasticity in acute state of hemiplegia.

Conclusion

The conclusions from this presentation is that functional electrical therapy when applied in acute hemiplegic subjects with some residual wrist and fingers extension leads to faster and greater gains in functional measures that are important for normal life.

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