# FUNCTIONAL ELECTRICAL THERAPY (FET) FOR PROMOTION OF MOTOR RECOVERY IN A PATIENT WITH ACUTE STROKE: CASE REPORT

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## ABSTRACT

**Background and Purpose:** To determine the efficacy of a Functional Electrical Therapy (FET) protocol administered to a patient with acute stroke.
**Case description:** A 73-year-old right handed women who had infarct in deep white cerebral mass from left side with acute mild hemiparesis. Intervention included thirty minutes of FET 5 times a week for 2 weeks (5 hours in total ) in addition to conventional physiotherapy.
**Outcome Measures:** The Modified Ashworth Scale (MAS), the Upper Extremity Function Test (UEFT), Motor Activity Log (MAL), the Brunnstrom µs 6 stages, the Functional Independence Measure (FIM).
**Discussion:** The patient exhibited extraordinary improvement on the UEFT, and substantial increase in MAL scores. Her active range of motion (ROM) of proximal muscles increased, although electrical stimulation was applied to distal muscles only. 2-weeks of FET may be efficacious for improving function and use of the affected arms of acute stroke patients.
**Outline:** Functional Electrical Therapy for effective brain training with instantaneous upper arm functionality as a result of maximized afferent input from simultaneous preserved volitional and external assistance by FES.
**Key words:** electrical stimulation, Therapy, Cerebrovascular accident, Acute, Exercise, Rehabilitation.

## ÖZET

**Amaç:** Akut inmeli bir hastada Fonksiyonel Elektrik Tedavisinin etkinliğini belirlemek.
**Olgu tanımı:** Sol serebral beyaz cevherde enfarkti ve akut hafif sol hemiparezisi olan 73 yaşında sağ elini kullanan bir bayan. Tedavide alışılmış fizyoterapiye ek olarak günde 30 dakika, haftada 5 kez, iki hafta boyunca (toplam 5 saat) FET uygulandı. Sonuç değerlendirimi: Modifiye Ashwort Skalası (MAS), Üst Ekstremite Fonksiyon Testi (UEFT), Motor Aktivite Logu (MAL), Brunnstrom 6'lı Skalası, Fonksiyonel Bağımsızlık Ölçeği (FIM).
**Tartışma:** Hasta UEFT de alışılmışın üzerinde, MAL skorunda belirgin bir gelişme gösterdi. Elektirik stimulasyonu sadece distal kaslara uygulanmış olmasına karşın proksimal kasların aktif hareket açıklığı arttı. İki haftalık FET tedavisi akut inmeli hastalarda fonksiyonu geliştirmede etkili olarak etkilenen kolun da kullanımını arttırmış olabilir.
**Sonuç:** Fonksiyonel Elektrik Tedavisi afferent inputları arttırarak eş zamanlı korunmuş istemli ve dış yardım ile etkin bir beyin eğitimi sonucu üst kol fonksiyonelliğini arttırır.
**Anahtar kelimeler:** Elektrik stimulasyonu. Tedavi, Serebrovasküler Olay, Akut, Egzersiz, Rehabilitasyon.

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# INTRODUCTION

## Stroke and functional movement

After stroke, humans are frequently not capable of performing simple tasks. This impairment leads to hemiplegia that limits normal eating, drinking, personal hygiene and many other activities of daily living (ADL) that have been normal before the stroke. Humans, after stroke, want to become independent again, in the easiest, simplest, and fastest way. This is why regaining arm/hand function is important in rehabilitation after stroke.

Following a stroke, the motor disability is due to several specific impairments, the impact each varying between patients: muscle weakness and spasticity which limit the voluntary range of movement, a loss of interjoint co-ordination and pathological movement synergies and incorrect timing of components within movement sequences of an action. These impairments contribute to alterations in the trajectories of goal directed movements. Patients may develop alternative grasping strategies.

Functional movements typically used in ADL belong to the group of goal-directed movements executed with coordinated activity of the body, arm, and hand. The functional movement depends on several elements: the activity that should be accomplished, the position of the object with respect to the hand and the body, and the shape and size of the object. The input leading to the movement is the voluntary decision, the visual information on the position of the object, and the proprioceptive information about the geometry and kinematics of the arm/hand. The sensory feedback associated with the performance of the activities assists learning process of the brain. During relearning, functional feedback should be as close as possible to those in "normal" movement. Further, this functional sensory feedback should be optimized both, in intensity and in duration and should not be limited to short clinical training sessions.

## Stroke management

Most clinical studies [1-10] agree that the common denominator for successful therapy in stroke survivors is to induce concentrated, repetitive functional practice of the affected limb as soon as possible after the onset of impairment avoiding the development of a "no-use" pattern [11]. Page [12] suggested that the nature of post-stroke motor therapy should be altered and made task-specific while still remaining within the typical treatment time (30 to 45 minutes daily). This alteration would lead to better recovery compared with the improvement induced by traditional rehabilitative approaches. Additional to conventional management of upper extremity (UE) motor impairment following stroke includes new training methods: Constraint-Induced (CI) movement therapy (e.g. [13]), robot-based therapy (e.g. [14]), and various electrical stimulation techniques (e.g. [1-4, 6, 7]). Many studies [12, 15-21] suggested that CI therapy; robot or electrical therapies are promoting the recovery when applied to the affected arm. Furthermore, the reduction of the compensatory use of the less affected arm (e.g. [22]) or of the trunk (e.g. [23]) also improves the function of the UE. Current neurorehabilitation strategies for cerebrovascular accidents (CVA) are based on the increased knowledge of brain plasticity (e.g. [24]) and re-organizational capacity (e.g. [25]) of the motor control networks.

## Functional Electrical Therapy (FET)

Functional Electrical Therapy (FET) aims to promote recovery of the paretic arm in a post-stroke hemiplegic patient [26, 27]. This method of training motor function as soon as possible after stroke is a combination of functional exercise and electrical therapy. FET protocol comprises voluntary movement of the paretic arm in synchrony with electrically assisted hand functions in order to perform typical daily activities. This method follows a through literature search, and original clinical studies that analysed the recovery of reach and grasp [26, 27]. The suggestion is based on evidences that cortical plasticity can be promoted by intensive exercise and electrical stimulation. Clinical findings from reach and grasp studies in individuals with moderate post-stroke disability suggested that FET therapy, performed in the acute phase, after a few weeks greatly promoted long-term recovery; yet that the same dose in chronic subjects was much less effective [26]. The same treatment in acute hemiplegic individuals with major disability promoted recovery; yet, the follow-up evaluation suggested only marginal differences between the treated and control subjects [27].

Functional tasks (i.e., ADL) are assisted by electrical stimulation of only distal muscles. It enables acute stroke patients to grasp during the period when they are not capable of doing it on their own; hence, preventing the disuse pattern. This added ability to grasp motivates the user to activate hemiplegic arm by the proximal muscles. The use of the affected arm enhances the awareness about being able to fulfill functional needs, further promoting active extremity use. The functional sensory information generated by FET was hypothesized to result in intensive functional brain training of the activities performed. Data from our previous randomized studies [26, 27] indicated that both, the functional support and maximized sensory feedback to the central nervous system, make FET very effective in regaining functions.

### Functional electrical stimulation for therapy in clinical settings

FET intervention requires extensive interaction between the patient and a trained therapist. This is why it is very important to show its effectiveness, should it be accepted as a standard in rehabilitation facilities.

In clinical settings, a device to be applicable for such intervention must be relatively inexpensive, ease to operate, and compact. One assistive device, potential to be used with functional electrical stimulation for therapy is ActiGrip CS[1] [26]. This device uses 4 channels of pre-programmed electrical stimulation to provide functional grasp and release of object at instances free of choice by the user.

This case report describes a 2-week training program using electrical stimulation in conjunction with conventional therapies in a patient with acute stroke. Our aim was to build evidence about efficacy of FET measured as an impact of an extra therapists' time to improvement of both, functional independence and UE function [28].

## METHOD

### Instruments

Assessment included a comprehensive interview and administration of the Brunnstrom's stages [29], the Functional Independence Measure (FIM) [30], the Modified Ashworth Scale (MAS) [31], the Upper Extremity Function Test (UEFT) [32, 33], the Motor Activity Log (MAL) [34], and active Range of Motion (ROM).

The MAL, UEFT, and MAS are used as outcome measures in studies of FET [26, 27]. The MAL is a semi-structured interview that examines how much and how well an individual uses the more affected arm outside of a laboratory or clinical setting. It gives a measure how patients use their affected limb for activities of daily living (ADLs) in the home. Tasks include classic ADLs, such as brushing teeth, drinking from can, and eating with a fork or spoon. In the MAL interview, patient is asked to rate by him/herself how much and how well he/she has used the affected arm during the past week. On the amount scale, individuals are asked to rate the amount of use, during selected daily tasks, of their more affected arm. On the how-well scale, the individual assesses the effectiveness of the affected arm when performing the selected tasks. For both interviews the 6-point scale ranges from 0 to 5.

The UEFT is an eleven-item instrument (Fig. 1) consisting of timed performances that quantifies UE movement ability in people with mild to moderate stro-

Upper Extremity Function Test

1) combing hair;
2) using a fork;
3) picking up a VHS format video tape;
4) picking up a 0.3-liter can;
5) picking up a 0.33-liter bottle;
6) writing with a pen;
7) using the telephone receiver;
8) brushing teeth;
9) pouring from a one-litter juice box;
10) drinking from a 0.25-liter mug; and
11) handling finger-food

**Figure 1.** Test battery consists of 11 objects that are commonly used in activities of daily living. The same objects were used for FET sessions. During test, patient is asked to functionally use each of 11 objects in stereotyped manner, as many times as he/she can in a 2 minutes interval. Each trial is valued with “success”, “failure” or “not tested”.

[1] *ActiGrip CS is a CE approved four-channel electronic stimulator manufactured by Neurodan A/S, Aalborg, Denmark, 2004.*

ke. The UEFT objectively assesses a person's ability to use the hemiparetic arm in functional activities. Tasks require participation from proximal to distal joint movements and gross to fine motor skills combining all joint movements in functional tasks. Eleven tasks are performed in a self-paced manner. Task components include objects of different sizes, shapes and masses. Scoring criteria are based on the amount, speed, and quality of participation by the hemiparetic arm in performing the task components. The performance of the tasks is graded as Success, Failure and Non Tested. Each task was repeated as many times as patient could perform in 120 seconds. Only successful trials were counted. For this study, the UEFT was administered and videotaped. The therapist who was not involved with this study, according to the videotaped record, assigned scores (Fig. 1).

Functional movement is partitioned into four consecutive phases (RC, M, P, RT) during which hand moves between hand post, object post and task post. Arm voluntary activity starts at movement onset. Ends of phases are assigned with Ti (i=1-4). Open/grasp/hold hand functions are assisted with electrical stimulation of hand extensor and flexor muscles triggered by the first TG1 (grasp synergy), while the next TG2 triggers open/release/relax hand functions (release synergy) assisted with electrical stimulation of extensor muscles only. Both triggers are voluntarily synchronized accordingly to phases of functional task being performed: TG1 closely after the hand approached the object post, and TG just after the hand approached object post again. User decides when to press the trigger button. Note that the stimulation is ON between TG1 and closely after TG2.

We included three more tests: Brunnstrom's 6 stages of post-CVA motor recovery test, FIM and active ROM, as standard tests in Medical Military Academy hospital. The FIM, a measure of independence in basic ADLs, is the most widely used rehabilitation outcome measure. Fugl-Meyer assessment motor component [35] is derived from Brunnstrom's 6 stages of post-CVA motor recovery test. Active ROM serves as an immediate measure of movement gain.

## Case Description

Recruitment of patient: Patient was recruited from the Neurology Department, Medical Military Academy hospital.

Inclusion/exclusion criteria: The inclusion criteria for this trial were as in other clinical trials with FET: 1) between two weeks and six months following first CVA ever caused by ischemia or hemorrhagia that was confirmed by magnetic resonance imaging (MRI) or computer tomography (CT), 2) age above 18, 3) able to give informed consent, and 4)being able to understand how to apply electrical stimulation for controlling the grasp, and 5) able to voluntarily extend the paretic wrist more than 10 degrees, and extend the Proximal Inter Phalangeal (PIP) and Meta Carpo Phalangeal (MCP) joints of the thumb and minimum of two other digits more than 10 degrees against gravity. The following exclusion criteria were applied: 1) dependent on care for activities of daily living prior to stroke, 2) severe medical condition in any arm and hand that precludes participation in the study, 3) previous injury, disease, or contracture affecting paretic or non-paretic arm or hand, 4) electrical life support devices (e.g. cardiac pacemaker ).

Patient: The patient was 73-year-old right handed woman whose CT scan indicated an infarct in deep white cerebral mass from left side with size of 1x2cm. EEG mappings showed light unspecific alternate result with suffering of entire let hemisphere. She suffered a stroke 22 days before she was enrolled in this study. The stroke resulted in acute mild right hemiparesis. She reported heart disease, hypertension and denied other brain illnesses before her stroke. The participant had received standard medicament treatment at first days after stroke and after stabilization of her condition she started inpatient rehabilitation program. She reported light assistance with most ADLs, especially dressing, negotiating stairs, solving problems and memory. A medical and then therapist evaluation revealed that the participant was medically stable. At screening, she was able to extend PIP and MCP of index finger, also could adducted thumb and could actively extend/flex her wrist for 35°/45°. She had 120° of active elbow flexion and was able to fully extend her elbow. The patient could actively abduct her shoulder 80°, flex for 75° and extend for 35°. She ambulated independently without an assistive device, but sometimes for long walking she needs presence of another person. There were no significant visual or cognitive deficits.

Intervention: FET was added to already scheduled program of conventional physiotherapy, which included range of motion or flexibility exercises, combined patterns of motion and functional patterns. Flexibility exercises was combined with stretching by following the slow dynamic movement with static stretch held for 10 to 30 seconds and also using manual assistance

**Tablo-I**

Brunnstrom's and Modified Ashworth Scale (MAS) grades before and after Functional Electrical Therapy (FET)

| Test | Pre-test | Post-test | Absolute change | Percentage of change |
|---|---|---|---|---|
| Brunnstrom's | 5 | 6 | 1 | 20 |
| MAS | 0 | 0 | 0 | 0 |

MAS 6 grade scale: 0,1,1+, 2,3,4
Brunnstrom's 6 grades scale: 1-6

of physical therapist. Combined patterns of motion consisted of diagonal patterns similar to proprioceptive neuromuscular facilitation patterns.

All training and evaluation took place at Rehabilitation Facility of Medical Military Academy in Belgrade. Each FET, as well as of physiotherapy session, lasted for 30 minutes. The patient did not complete previously scheduled therapy of 3-weeks treatment because she was discharged after 2-weeks from the hospital. She participated to 10 sessions during 2 weeks.

The local ethics committees approved the experimental procedure for the FET in conformity with the Declaration of Helsinki. Patient signed informed consent.

During FET sessions, exercise was assisted with a four channel electronic stimulator that controlled the opening, grasping, and releasing functions my mimicking natural movement. The pattern and timing of the stimulation were programmed to mimic the slowed down normal-like prehension, grasp, and release phases of the grasp, typical for normal hand palmar, lateral and precision grasps.

Four channels of electrical stimulation were applied via self-adhesive surface electrodes positioned over the following muscle groups: finger flexors (Flexor Digitorum Profundus m. and Flexor Digitorum Superficialis m.), finger extensors (Extensor Digitorum Communis m.), thumb extensor (Extensor Pollicis Longus m.) and the Thenar muscle group (Abductor Pollicis m. and M. Opponens). Trained therapists positioned carefully the electrodes over the innervation points in order to maximize selectivity of stimulation. Stimulation parameters were: frequency 50 pulses per second, pulse duration $T = 200\ \mu s$, and current stimulation intensity of about $I = 9$ mA for extensor and flexor muscles at the beginning of study. At the end of intervention, current stimulation intensity was reduced to 6 mA.

The overall goal during a single session was to perform as many as possible daily functions with the following objects: toothbrush, comb, telephone receiver, pen, finger-food, 0.5-liter can, 0.3-liter can, 1-liter juice box, video cassette, and coffee mug, Fig. 1. These objects were selected to force the patient to practice palmar, lateral and precision grasps. A functional use of object consisted of the following phases: reach, grasp, manipulate, apply and bring back the object to the original post, and release it.

The patient was taught to push the trigger button on the stimulator with her non-paretic hand at the appropriate time during the reaching of the paretic arm towards an object in order to initiate the "grasp" synergy. Patient also triggered the "release" synergy once she accomplished the task, or established that she was not able to perform it. Sessions were tailored according to the recovery during the two weeks of the treatment, that is, patient started with easier and progressed to more difficult tasks upon her recovery status. Activities were particularly customized to suit this patient's expectations, varying within each session. The use of comb was emphasized.

A therapist assisted and instructed the patient while she was trying to reach, grasp, and functionally use the objects during sessions. The assistance comprised of holding the object in the adequate orientation and position, if so required. Patient was instructed how to maximize the use of external control of the paretic hand.

Evaluation: The patient was assessed with the FIM, Brunnstrom's stages, MAS, ROM, UEFT, and MAL at two instances, before and after the intervention.

## RESULTS

Pre-test and post-test Brunnstrom's and MAS grades for more affected limb are shown in Table 1. The initial to this study (highest) grade MAS scale was not changed after intervention, and Brunnstrom's score improved from 5 to 6 (being the highest grade).

There was a 1 absolute or 14 percentage of change in mean value of FIM. Pre-test and post-test data are provided in Table 2. For the MAL, improvement was seen in both, amount and how well scores with increase of close to 50 percent. Pre-test and post-test data

**Tablo-II**

Mean and mean change scores on the Functional Independence Measure (FIM) and Motor Activity Log (MAL) before and after FET therapy

| test | Pre-test | post-test | Absolute change | Percentage of change |
|---|---|---|---|---|
| FIM | 6 | 7 | 1 | 14 |
| MAL amount | 2 | 3.9 | 1.9 | 49 |
| MAL how well | 2.4 | 4.5 | 2.1 | 47 |

FIM motor skills subscale: 13-91; (13 items, range each item 1-7, mean 4)
MAL amount scale: 0-55; (11 items: range each item, 0-5, mean 2,5)
MAL how well scale: 0-55; (11 items: range each item, 0-5, mean 2,5)

**Tablo-III**

Number of 11 task repetitions and mean value in 120 seconds before and after FET therapy

| Upper Extremity Function Test (#) | | | | |
|---|---|---|---|---|
| **Task** | **Pre-test** | **Post-test** | **Absolute change** | **Percentage of change** |
| comb | 4 | 9 | 5 | 125 |
| fork | 7 | 26 | 19 | 271 |
| video cassette | 6 | 14 | 8 | 133 |
| can | 6 | 20 | 14 | 233 |
| bottle | 5 | 12 | 15 | 300 |
| pencil | 3 | 20 | 9 | 300 |
| phone | 5 | 16 | 11 | 220 |
| toothbrush | 6 | 18 | 12 | 200 |
| 1 l juice box | 3 | 12 | 9 | 300 |
| cup | 2 | 14 | 12 | 600 |
| finger food | 7 | 23 | 16 | 229 |
| **mean** | 5 | 17 | 12 | 265 |

are presented in Table 2.

The pre-test and post-test scores for each item of the UEFT for more affected limb are provided in Table 3. The slected activities included: palmar (tasks 4, 5, 7 and 9), lateral (tasks 1, 2, 3, 8 and 10) and precision grasp (tasks 6 and 11). The UEFT also evaluated the ability to handle small objects (tasks 1, 2, 5, 6, 8, 10 and 11) and large objects (tasks 3, 4, 7 and 9), as well as light object (tasks 1, 2, 3, 6, 8 and 11) and heavy objects (tasks 4, 5, 7 and 9). The score used in UEFT was count of successful performances of the same task during a two-minute interval. Following the intervention, there was an extraordinary improvement in the mean number of task repetitions of 12 or 265 in percentage. The patient improved in all tasks over 100 percent; the highest improvement was for drinking from a cup (600%).

The highest motivation patient had for combing her hair with right hand. The patient showed particular motivation for one specific task - combing her hair that she barely could perform at the beginning because she did not have enough strength in her arm and; at the end she improved for this task over 100%.

Active ROM was overall improved. Data are provided in Table 4. In all joints rotations increment was higher than 5 degrees and palmar/dorsal rotation increased for 40 degrees. Note that electrical stimulation was applied to distal joints only (fingers and thumb).

## DISCUSSION

"Patients should undergo as much therapy appropriate to their needs as they are willing and able to tolerate" is one of the recommendations by Royal College of

**Tablo-IV**

Active range of movement (ROM) and its change for wrist, elbow and shoulder joints, in degrees, before and after FET therapy

| ROM [degrees] | | Pre-test | Post-test | Absolute change | Percentage of change |
|---|---|---|---|---|---|
| wrist | palm/dors | 80 | 120 | 40 | 50 |
| wrist | rad/uln | 60 | 70 | 10 | 17 |
| elbow | flex/ext | 120 | 145 | 25 | 20 |
| shoulder | add/abd | 80 | 95 | 15 | 19 |
| shoulder | flex/ext | 110 | 125 | 15 | 14 |

Physicians in National Clinical Guidelines for Stroke [36, page 3]. It was our clinical opinion for this patient that the combination of conventional therapy and FET will advance improvement [37]. We adapted FET protocol and exercise program to the individual potential of this patient to avoid risk increased hypertonia in affected muscle groups following the frequent repetition of movement in shaping and ADL practice. As MAL inteview showed, and other assessment tests measured, this combined intervention appeared to be effective in improving amount and quality of movement and transfer to the life situation. The patient overcame apparent barriers to use the more affected UE in the life situation.

The FET protocol employed with participant in this case study represents an early effort in our Institution to combine FET protocol with a conventional therapy to treat participants with stroke having reduced UE activity early after stroke.

One of the biggest challenges in applying patterned electrical stimulation, such as FET, is to provide a reliable and easy to apply interface betwen the limb and the device. New technologies are likely to introduce in the near future a full integration of wearable sensors and devices. Once fully integrated such a new technology has a high potential to increase the ease of use and to improve muscle stimulation and selectivity when FET methodology is applied.

## CONCLUSION

Intensive exercise of the hemiplegic arm in acute phase can provide earlier and greater movement of impaired arm/hand, if in parallel with exercise the grasping itself is assisted electrically. This novel paradigm of coupled volitional and electrically facilitated grasping incorporated in task-oriented exercise has been named FET. The FET combines multi-channel electrical stimulation that generates opening, grasping, and releasing functions with the exercise of the proximal muscles of the paretic arm. Stimulation pattern integrated in FET is timed to mimic the sequence of activation of hand and forearm muscles typical for able-bodied subjects. Stimulation also provides activation of afferent pathways that are timed with the activity of arm.

In this case study with a patient with mild acute stroke a conventional therapy program combined with FET appeared to improve both, functional independence and UE function, as changes in UEFT, FIM, active ROM of proximal muscles and MAL were observed. Patient was exposed to FET for thirty minutes daily for 10 days (5 hours in total). Giving that therapist time is required in full capacity at first several sessions and for the rest of sessions at initation only, this therapy protocol has a potential, particularly in motivated stroke survivors.

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