

# Restoration of Functional Grasping in Patients with Quadriplegia

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## Abstract

*This was a randomized pilot study in which FES was applied as a therapeutic tool to help patients improve voluntary grasp and release movements. The goal of the treatment was to increase hand function, independence in activities of daily living and quality of life. In the treatment group (N=13), daily FES was applied to stimulate weak and non-functional muscles in a sequence of movements to coordinate a hand grasp for manipulating everyday objects. In the control group (N=9), patients received conventional occupational therapy of equal intensity to the treatment group. The following tests were used to measure change: Rehabilitation Engineering Laboratory Hand Function Test, Functional Independence Measure, Spinal Cord Independence Measure and a Qualitative Interview. Preliminary results suggest: 1) the proposed treatment has a positive impact on voluntary hand grasp when used in combination with occupational therapy; 2) greater improvement was expected with incomplete participants, but was also seen with our patients with complete injuries; 3) stimulation programs need to be adjusted by an occupational therapist regularly; and 4) patients report improved voluntary hand function, greater independence and quality of life as a result of the neuroprosthesis treatment.*

## 1. INTRODUCTION

In recent years, several neuroprostheses have been developed as therapeutic systems for people with hemiplegia and quadriplegia [1]. A recent study has shown that neuroprostheses can cause greater recovery of function in hemiplegia due to stroke than conventional approaches to therapy [2]. This paper is a continuation of our study originally presented at IFESS 2003. We are examining the carryover effect of using a neuroprosthesis for grasping function in a clinical setting. It was anticipated

that the application of daily FES training, in addition to regular occupational therapy (OT) and physiotherapy would facilitate the restoration of motor function in the wrist and/or fingers and subsequently increase a person's level of independence in daily activities. We were also trying to determine how best to apply FES in order to restore hand function. It is our hope that improvement in voluntary function of the hand can be facilitated through increasing strength and range of motion, increasing confidence in using the hand successfully in daily activities, and ultimately, to increase independence in daily activities.

## 2. METHODS

### 2.1. Subjects

So far, 22 patients with incomplete or complete motor quadriplegia, ranging from C4 to C7 have participated in this study. All participants were inpatients at a rehabilitation center, and each received regular occupational therapy and physiotherapy as prescribed by clinical staff. All subjects were recruited into the study within seven months of their date of injury. At admission to the study, participants had muscle strength of grade 2 or less in the wrist or fingers indicating significant functional impairment.

Subjects were randomly divided into two groups: Group A (treatment) – patients that were trained with the neuroprosthesis; or Group B (control) – patients received standard occupational therapy and physiotherapy without FES. To date 13 patients have been assigned to each group.

### 2.2. Neuroprosthesis

The Compex Motion electric stimulator provided the hardware platform for the neuroprosthesis for grasping [3]. This FES system is programmable and has four channels for surface stimulation. The specific stimulation protocol was individualized to each patient to best facilitate grasping function. Stimulation events were triggered by a push button, which the participant controlled. The

FES program evolved during the treatment and was adjusted according to the participant's progress such that the neuroprosthesis carried out the movements that he or she could not voluntarily perform.

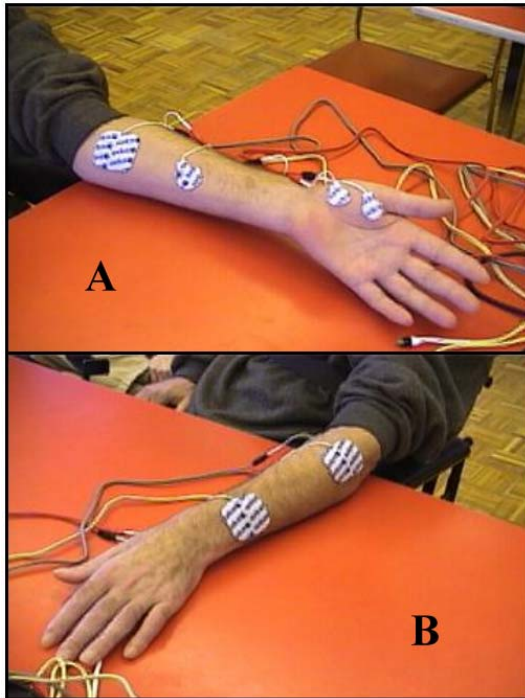


Figure 1 – Electrode arrangement. A) *Flexor digitorum* for palmar grasp and *flexor pollicis brevis* for pinch grasp; B) *Extensor digitorum* and wrist extensors for release of grasp.

## 2.1. Stimulation Protocols

Under the supervision of trained OT the FES program was carried out in two phases: the strengthening phase and the training phase. The strengthening phase was required initially for subjects who demonstrated very weak and non-functional initial responses to stimulation. Once a sufficient response was achieved, as demonstrated by increased strength and active range of motion while using the neuroprosthesis, participants entered the training phase. During training, the participant practiced functional activities using the neuroprosthesis, using the grasp and release pattern to manipulate a variety of everyday objects such as books, a toothbrush and a badminton racket. Various objects were grasped and released 30 to 50 times during each treatment session, which would last up to 60 minutes. Participants had one session per day, five days per week. During the intervention period the therapist adjusted the placement of electrodes and guided the hand movements in

order to optimize functional, efficient and normal movement patterns.

As shown in Figure 1, surface electrodes were used to stimulate the following muscles and nerves: 1) *flexor digitorum superficialis* m. and the *flexor digitorum profundus* m.; 2) median nerve, *flexor pollicis brevis* and *opponens pollicis* m.; 3) *extensor digitorum* m.; 4) radial nerve, *extensor carpi radialis longus* and *brevis*, m. and *extensor carpi ulnaris* m. Stimulation parameters used were: 1) balanced, biphasic, current regulated electrical pulses; 2) pulse amplitude from 8 to 50mA (typical values were 17-26mA); 3) pulse width typically 250  $\mu$ s; and 4) pulse frequency from 20 to 40 Hz.

The FES intervention was highly customized so that grasping was optimized throughout the length of the program. Once the participant showed signs of recovery of voluntary extension or flexion, he or she was challenged to make an effort in producing movements previously generated by FES. Participants that normally used tenodesis received electrical stimulation to the finger extensors with minimal effect on the wrist extensors in order to preserve their tenodesis pinch. This was done by changing the position of the surface electrode to a more distal position on the forearm. During the treatment period most patients were observed to have a temporary decrease in the amount of tone visible in the hand allowing better use of tenodesis or active finger dexterity.

## 2.1. Tests

The following data was collected:

A. Administrative Data: Demographic information and medical history was collected at admission on all 22 participants.

B. Functional Assessments: Scores from the Functional Independence Measure (FIM), Spinal Cord Independence Measure (SCIM), passive and active range of motion, manual muscle testing, grip and pinch strength, Nine-hole Peg Test, Rehabilitation Engineering Laboratory Hand Function Test for FES-Assisted Grasping, and writing samples were collected at baseline and after intervention for all 22 participants.

B. Qualitative Interview: An independent assessor conducted interviews with all participants in Group A to explore their experiences with the neuroprosthesis and their perceptions of its impact on their daily function.

Differences in the quantitative variables between groups were assessed using repeated measures ANOVA. Statistical significance was accepted at  $p < 0.05$ .

### 3. RESULTS

Subjects in both groups showed significant improvements between all baseline and post-treatment measurements. There have been greater trends in Group A with respect to improved independence and hand function compared to Group B. However, the sample is still too small for statistical significance in most categories. Positive results were found in the measurement of torque applied to an instrumented cylinder ( $p = 0.048$ ).

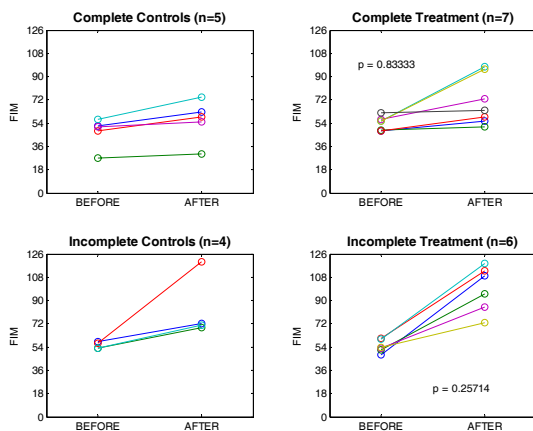


Figure 2 – FIM scores before and after intervention. P-values displayed refer to test of treatment-vs-control.

Subjects with motor complete injuries (ASIA A and B) demonstrated less improvement than other subjects. This can be seen in Figures 2 and 3. However, some subjects with complete injuries were observed using their hands spontaneously in new activities, such as eating candies or playing table tennis following sessions where they used the FES to complete these or similar tasks. All feedback from participants in the treatment group was positive and included comments on improved function, independence in ADLs and self-satisfaction.

### 4. DISCUSSION AND CONCLUSIONS

The preliminary results of this ongoing study appear promising, but currently lack the statistical power to prove that FES-assisted grasping therapy can facilitate the recovery of hand function in patients with complete and incomplete quadriplegia. The recovery in participants with incomplete SCI was notably greater than in participants with complete injuries as expected. The flexible nature of

using surface electrodes allowed us to adapt the neuroprosthesis as the patient improved.

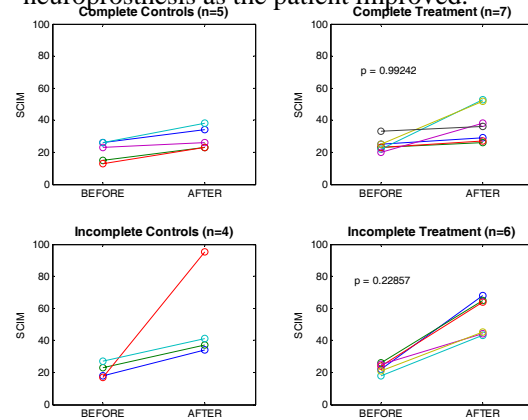


Figure 3 – SCIM scores.

We are mid-way through our study and our objective is to have 40 participants (20 receiving FES and 20 receiving regular therapy activities). We have been able to apply our observations to daily occupational therapy practice and incorporate the following observations of practice in order to maximize functional recovery: 1) individualized stimulation programs monitored and adjusted by an OT can be an effective way to facilitate improved hand function; 2) a strengthening program followed functional training increased likelihood of carryover; 3) FES is a complementary approach to therapy that can be applied for a short period of time with durable results. The durability of the carryover effect needs to be determined in future studies.

### References

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### Acknowledgements

The authors wish to acknowledge the Toronto Rehabilitation Institute, Natural Sciences and Engineering Research Council of Canada, Connaught Foundation and McAllister Foundation sponsorship of this research.