Retraining Reaching and Grasping Functions in Hemiplegic Patients with the Chedoke McMaster Stages of Motor Recovery Scores 1 and 2

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Abstract

A neuroprosthesis that applies surface electrical stimulation technology was used to retrain hemiplegic patients with severe unilateral arm paralysis to reach and grasp. Prior to joining the program, the patients had a completely paralyzed arm, which was either flaccid stage 1 of the Chedoke McMaster Stages of Motor Recovery, or stage 2 of motor recovery. The neuroprosthesis was applied both to acute and long-term hemiplegic patients. Patients who were treated with the neuroprosthesis were compared to those patients who were administered only standard physiotherapy and occupational therapy appropriate for hemiplegic patients with unilateral upper extremity paralysis (controls). After the treatment program was completed, the patients treated with the neuroprosthesis were able to perform reaching and grasping tasks voluntarily, without any assistance. However, the majority of the control patients did not improve their arm and hand functions.

1 Introduction

In this article, an intervention is presented which has resulted in improvements in hand and arm functions in hemiplegic patients with severe arm and hand paralysis. The purpose of this study was to compare two types of therapies for upper extremity hemi-paresis: conventional physiotherapy and occupational therapy versus FES therapy. A small group of hemiplegic patients with a mean of 92 days post-stoke, whose upper extremity hemiparesis were considered stable and permanent according to the records of the head physiatrist, were administered FES therapy. A second group of patients with a mean of 26 days post-stoke and comparable clinical deficits, were provided conventional physiotherapy and occupational therapy over the same period of time. We hypothesized that the FES therapy would give rise to a greater improvement in arm and hand functions.

2 Methods

This was a randomized clinical trial with the following main characteristics: 1) the method for analyzing data was specified in the protocol before the study began; and 2) the patients were randomly assigned to control and intervention groups.

2.1 Outcome Measures

The following tests were used to measure change in motor functions following the neuroprosthetic intervention before and after the intervention.

- Neurological test: Canadian Neurological Scale [1] was used to assess neurological profile of the subjects.
- Functional tests:
  a. Functional Independence Measure (FIM) – total score [2]
  b. Barthel Index (BI) – total score [3]
  c. Chedoke McMaster Stages of Motor Recovery (CMSMR) – only a part of the total score pertaining to arm and hand functions of the hemiparetic arm [4]
  d. Fugl-Meyer Assessment (FMA) – only a part of the total score pertaining to shoulder, elbow, forearm, wrist, and hand functions of the hemiparetic arm [5]
  e. REL Hand Function Test for Functional Electrical Stimulation Assisted Grasping (REL) of the hemiparetic arm – total score [6].

2.2 Participants

The study was conducted with 13 stroke patients with severe unilateral upper extremity paralysis (hemiplegia - stages 1 or 2 of the CMSMR). The participants were recruited to the study approximately during the fourth week after they were admitted to the stroke
rehabilitation unit (acute patients), or at least 12 months after the rehabilitation was completed through an outpatient follow-up clinic (long-term patients). The subjects were randomly assigned to two groups: **Group A - the control group** which was administered only standard physiotherapy and occupational therapy; and **Group B – the treatment group** where subjects were trained with the neuroprosthesis in addition to standard physiotherapy and occupational therapy. The treated and control patients had approximately the same time allocated for arm and hand therapy.

**Group A:** Eight subjects were assigned to Group A. Five patients had strokes affecting the right hemisphere and three patients had strokes affecting the left hemisphere. Five patients were females and three were males. Their average age was 62 ± 20.3 years and they joined the program 26 days post-stroke. At admission, the patients had the following average functional test scores: 1) FIM - 59.5; 2) BI - 38.1; 3) parts of the CMSMR test pertaining to arm and hand functions of the hemiparetic arm – 3.6; 4) parts of the FMA test pertaining to shoulder, elbow, forearm, wrist, and hand functions of the hemiparetic arm – 3.1; and 5) REL test - 0, 0.3, and 0.

**Group B:** Five subjects were assigned to Group B. Three patients had strokes affecting the left hemisphere and two patients had strokes affecting the right hemisphere. One patient was female and four were males. Their average age was 57.6 ± 17.5 years. In this particular case, we had a bimodal distribution of the time post-stroke: one patient was recruited 338 days post-stroke and four patients were recruited at a mean of 30.8 days post-stroke. Overall mean was 92 days. At admission, the patients had the following average functional test scores: 1) FIM – 70.6; 2) BI - 48; 3) parts of the CMSMR test pertaining to arm and hand functions of the hemiparetic arm – 4.6; 4) parts of the FMA test pertaining to shoulder, elbow, forearm, wrist, and hand functions of the hemiparetic arm – 3.6; and 5) REL test – 2.8, 7.1, and 0.

The two groups did not differ according to their age, functional tests scores, and if subject #1 in Group B was excluded, they did not differ according to the time when they joined the program post-stroke.

### 2.3 Neuroprosthesis Hardware

The Compex Motion electric stimulator with surface stimulation electrodes, was used as a hardware platform for the neuroprosthesis for reaching and grasping. [7]

### 2.4 Stimulation Protocols

The subject was asked to execute a task with the impaired arm (e.g. reaching and grasping a pen) unassisted. The subject would then try to execute the task voluntarily. The components of the task the subject was unable to carry out him/her self were assisted with the neuroprosthesis. During the treatment, a therapist controlled/triggered the reaching and grasping functions using a push button. In the early stages of the treatment, the arm/hand tasks were performed by the neuroprosthesis alone.

As the patient improved, the neuroprosthesis assistance was reduced to the necessary minimum and eventually was removed from the treatment protocol. The participant was asked to repeat the same arm/hand task 20 to 30 times during a single treatment session. The treatment sessions lasted up to 45 minutes, 25 to 30 minutes of which were used for active treatment alone. Patients had one treatment session per day, business days only (60 to 80 treatment sessions in total).

The neuroprosthesis treatment began by training shoulder and upper arm muscles first. As soon as the patient showed signs of recovery of both the voluntary extension and flexion of the shoulder, the *extensor digitorum m.* was stimulated together with the *triceps m.* In this way, the patient was trained to extend the fingers when the elbow was fully extended. Once the patient was able to voluntarily extend or relax the fingers, the *flexor digitorum superficialis m.*, *flexor digitorum profundus m.*, *median nerve* (or *thenar m.*), and *flexor pollicis longus m.* were stimulated to generate palmar and/or pinch grasp.

### 2.5 Hypotheses

The following hypotheses were tested:

**Hypothesis 1:** On admission, Group A and Group B had the following scores equal: 1.1) REL Test - object manipulation; 1.2) REL Test - forces & torques; 1.3) REL Test - eccentric load score; 1.4) FIM; 1.5) BI; 1.6) FMA; 1.7) CMSMR.

**Hypothesis 2:** On discharge, Group A and Group B had the following scores equal: 2.1) REL Test - object manipulation; 2.2) REL Test - forces & torques; 2.3) REL Test - eccentric load score; 2.4) FIM; 2.5) BI; 2.6) FMA; 2.7) CMSMR.
Hypothesis 3: Group A had the following scores equal, on admission and discharge: 3.1) REL Test - object manipulation; 3.2) REL Test - forces & torques; 3.3) REL Test - eccentric load score; 3.4) FIM; 3.5) BI; 3.6) FMA; 3.7) CMSMR.

Hypothesis 4: Group B had the following scores equal, on admission and discharge: 4.1) REL Test - object manipulation; 4.2) REL Test - forces & torques; 4.3) REL Test - eccentric load score; 4.4) FIM; 4.5) BI; 4.6) FMA; 4.7) CMSMR.

To test Hypotheses 1 to 4, the t-test was applied to test the differences in means of two normal distributions, with unknown and unequal variances.

3 Results

Result 1: Subjects in Groups A and B were selected in random fashion, i.e. Hypothesis 1 could not be rejected. Subjects in both groups had similar arm and hand functions, and had similar abilities to perform ADL when they were assigned to the groups.

Result 2: Subjects in Group A, after the treatment was completed, only improved the FIM and BI scores; the arm and hand function scores (REL, FMA and CMSMR scores) did not improve significantly. In other words, Hypotheses 3.4, 3.5, and 3.7 were rejected with alphas 0.001 (P < 0.001), 0.005 (P = 0.0036), and 0.01 (P = 0.0079), respectively, while Hypotheses 3.1, 3.2, 3.3, and 3.6 could not be rejected.

Result 3: Subjects in Group B, after the treatment was completed, improved the FIM and BI scores. In addition, their arm and hand function assessed with the REL Test - object manipulation, FMA and CMSMR improved significantly. Also, the REL Test - forces & torques and the REL Test - eccentric load showed improvements in function; however, the significance of the changes could not be demonstrated with the given number of subjects. In other words, Hypotheses 4.1, 4.2, 4.5, and 2.7 were rejected with alphas 0.05 (P = 0.024), 0.05 (P = 0.041), 0.01 (P = 0.008), 0.005 (P = 0.0037), and 0.005 (P = 0.0025), respectively, while Hypotheses 4.3 and 4.4 could not be rejected.

Result 4: When Group A and Group B subjects were compared on discharge, subjects in Group B showed significant improvement in the arm and hand functions compared to Group A subjects, as shown with the REL Test - object manipulation, REL Test - forces & torques, FMA, BI, and CMSMR scores. Also, the FIM, and REL Test - eccentric load showed improvements in function; however, the significance of the changes could not be demonstrated with the given number of subjects. In other words, Hypotheses 2.1, 2.2, 2.5, 2.6, and 2.7 were rejected with alphas 0.05 (P = 0.024), 0.05 (P = 0.041), 0.01 (P = 0.008), 0.005 (P = 0.0037), and 0.005 (P = 0.0025), respectively, while Hypotheses 2.3 and 2.4 could not be rejected.

4 Conclusion

The statistical analysis confirmed our hypothesis that the neuroprosthesis therapy gives rise to greater improvement in arm and hand functions in subjects with severe unilateral arm paralysis, compared to traditional physiotherapy and occupational therapy alone.

References


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