FUNCTIONAL ELECTRICAL THERAPY (FET) FOR IMPROVING THE REACHING AND GRASPING IN HEMIPLEGICS

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Abstract
The hypothesis is that subjects will show significantly greater improvement in real world outcomes shortly after the sub-acute stroke period assigned to three weeks of Functional Electrical Therapy (FET) than control subjects left with the traditional therapy. Functional electrical therapy was applied for three weeks using a Belgrade reaching/grasping system, that is a four-channel of surface electrical stimulation and synergistic control [8]. Eight subjects were randomly assigned to FET and control groups. After three weeks the FET group showed better functioning measured by Upper Extremity Function Test (UEFT) than controls: 55.4% – FET, 44.5% – control. The FET group shows much better co-ordination measured as the tracking of geometric shapes on the digitizing board. Although substantial difference in functioning exists among the study participants, they could all better use their paretic arm after FET. The results relate to the assessment immediately after the therapy: long-term follow-up is needed.

Introduction
Neurorehabilitation comprises methods and technology for maximizing the efficiency of preserved neuro-muscular structures in a human with sensory-motor impairment. Maximizing function relates to developing of new sensory-motor mechanisms that benefit from the preserved, yet unused systems. The primary objective of the neurorehabilitation is to promote and develop processes underlying sensory-motor systems and change the dynamics of “learning” by providing the substrate that would not be available under normal circumstance [7].

Electrical stimulation of sensory-motor systems contributes to the facilitation of voluntary movement, strengthening of atrophied muscles, change of the muscle length and bulk, change of the muscle type and function, interaction between agonist and antagonist muscles, increasing the range of movement, and the moderation of spasticity [1-6].

Methods

Subjects. This study presents the results after the first group of six male and two female subjects finished the three-week long FET (Table I). The cerebro-vascular infarction (CVI) caused the contralateral weakness, sensory loss, diminished shoulder/elbow/hand co-ordination, and somewhat disturbed spatial perception. Motor and sensory losses are greatest in the hand.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Time of CVI</th>
<th>Ashworth</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>62</td>
<td>11.2000</td>
<td>1+</td>
<td>Hemi. l. sin.</td>
</tr>
<tr>
<td>B</td>
<td>61</td>
<td>12.2000</td>
<td>1+</td>
<td>Hemi. l. sin.</td>
</tr>
<tr>
<td>E</td>
<td>62</td>
<td>11.2000</td>
<td>1+</td>
<td>Hemi. l. dex.</td>
</tr>
</tbody>
</table>

Table I: Subjects were randomly assigned to FET group (A to D) and controls (E to H). All subjects use medications against high blood pressure, anticoagulants, and spasticity reduction. Ashworth scale was used as the measure of spasticity. CVI stands for cerebro-vascular infarction.

Volunteer candidates for study participation received general medical and physical therapy examinations. The neuropsychological assessment was performed in order to determine which individuals have cognitive deficits that could negatively affect their ability to follow directions appropriately on the motor evaluation tests employed in the project. The subjects were characterized as high or low functioning prior to inclusion in the study upon their active range of motion capability at the wrist and fingers.

The determinations were made with the subject sitting, the forearm resting on a supported surface, and the forearm in pronation. The hand was hanging over the edge of the supporting surface (e.g., the arm of a chair) to allow for maximum wrist flexion with gravity. The subjects were identified as belonging to a Higher Functioning Group (HFG) if they were able to actively extend the paretic wrist further than 20 degrees and...
actively extend the MP and IP joints of all digits at least 10 degrees (i.e., the upper cut-off of the lower functioning group). The subjects were assigned to a Lower Functioning Group (LFG) if they were able to actively extend the paretic wrist at least 10 degrees and actively extend the MP and IP joints of the thumb and at least two additional digits 10 degrees. The study included seven subjects from the HFG subjects, and one subject form the LFG (subject F). Table I summarizes the status of the study participants.

Procedure. The stimulation was applied for 30 minutes, twice a day, for at least five days a week, during three consecutive weeks. The Functional Electrical Therapy (FET) was applied with the four channel stimulator and surface disposable electrodes. Two channels were used to stimulate the finger flexors and finger extensors. The cathodes were placed over the extensor digitorum communis m. and flexor digitorum profundus and superficialis muscles. The anodes of these two channels were placed above the carpal tunnel (wrist) and cover the major arm nerves. The subjects use a switch, which sequentially triggers opening and closing synergies of the hand. The stimulation intensity was set individually for each of the muscle groups by using an external potentiometer. Two remaining channels could be used for control of the elbow joint, employing the simplified synergistic control developed for the reaching neuroprostheses [8]. The tasks for all subjects were to actively reach and grasp/release different objects. The following objects were included for the exercise: juice or beer can, VCR tape, glass, telephone receiver, paper, pen, and similar objects that are used for typical daily activities. The pulse duration and the frequency were set for each subject in such a manner to minimize unpleasant sensation and pain, yet to provide active, externally assisted grasp or elbow movement. The typical values for stimulation are: frequency \( f = 50 \) pulses/second, pulse duration \( T = 300 \) \( \mu s \), stimulation current \( I = 15 – 45 \) mA. The control group was required to perform the same tasks as the FET group, yet without electrical stimulation.

Outcome measures. Evaluations are planned at the beginning, three weeks later, and every two months thereafter for 18 months. Here we present only two outcome measures: the Upper Extremity Function Test (UEFT), and the drawing of selected geometric shapes. The purpose of UEFT was to determine the differences in the performance of certain activities of daily living before and after the FET. The performance of the tasks was graded as Success (YES) and Failure (NO), and if “YES” quantified as the number of repetitions of the desired task during a two-minute interval.

The following tasks were tested: 1) combing hair; 2) using a fork; 3) picking up a VHS tape; 4) picking up a full beer can; 4) picking up a full small (pop/soda) can; 6) writing with a pen; 7) handling the telephone receiver; 8) brushing teeth; 9) pouring from a one litter juice box; 10) drinking from a mug; and 11) handling finger food (Fig. 1). The drawing at the digitizing board of selected forms (e.g., rectangle, circle, figure eighth) was used to assess the improvement in the body/arm to space co-ordination (Fig. 2).

Results

Fig. 1 shows the UEFT for FET and control group before and at the end of the three weeks of therapy. Each plot is for a single subject and shows the performance of the eleven listed tasks. Fig. 2 shows the drawings of the square at the digitizing board for the FET group. Plots illustrate the difference in co-ordination of the body/arm to external space before and after the FET for the group assigned to therapy.

Discussion/Conclusions

Fig. 1 shows an improvement in functioning of Subjects assigned to the FET group after only three weeks of therapy. A method of summarizing data (Table II) of this preliminary phase of the project was to compare \( N \), the number of tasks that subjects could not accomplish at the beginning/at the end, and
improvement index R, the ratio between the increased number of repetitions and the number of repetitions after three weeks in percent.

**Table II**: Summarized results of the UEFT for the FET group (A-D) and controls (E-H). N is the number of tasks that subjects could not accomplish at the beginning/at the end of the study. Improvement index R is the relative improvement measured by the ratio between the increased number of repetitions and the number of the repetitions at the end.

<table>
<thead>
<tr>
<th>Subject</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>N [%]</td>
<td>36</td>
<td>96</td>
<td>89</td>
<td>12</td>
<td>32</td>
<td>31</td>
<td>66</td>
<td>16</td>
</tr>
</tbody>
</table>

The increased number is a difference between the number of repetitions at the end and at the beginning of the program.

The improvement index for the whole FET group is R=55.4%, and R=45.5% for the control group. The total number of the tasks that the subjects could not accomplish are N=18/5 for the FET group, and N=7/6 for the control group.

Subject A (R=36, N=0/0) showed minor improvement; he belongs to the HFG, thus he was able to do almost all tasks without major problems. Subjects D (R=12, N=4/4) and H (R=16, N=4/4) showed marginal improvements, they have cognitive problems that compromised the therapy.

Fig. 2 shows the improvement of the reaching co-ordination. The task was to draw a square at the digitizing board. Two elements are characteristic for all subjects: they were able to draw much faster, and they followed the task template (size and straight-line movement) much better at the end of the therapy. The difference in co-ordination improvement is marginal in the control group (not shown).

All subjects from the FET group responded very enthusiastically to the therapy. Most of the large number of stroke subjects in the same rehabilitation facility who did not participated in the study are extremely interested to join the FET program.

The small size of the study sample (preliminary phase of the study) is not sufficient for the statistical analysis, yet the differences are suggesting that the FET is effective in stroke patients at early stage after the CVI.

**References**


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