Effectiveness of dorsum hand splint with electrical stimulation on hand functions in stroke patients
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ABSTRACT
Background: Upper extremity spasticity is a common clinical outcome following stroke and may be seriously debilitating condition. Regaining functions in the upper extremities is often more difficult than in lower extremities, which can seriously affect the progress of rehabilitation. Mainly, the hand and wrist synergistic spasticity limits rehabilitation outcomes and physical function. Therefore, rehabilitation process appears to be a challenge in stroke patients, mainly with upper limb synergistic spasticity
Objectives: The aim of this study is to evaluate the effectiveness of the electrical stimulation and the dorsum hand splint to reduce hand flexion spastic synergy and to enhance the functional activity of paretic hand.
Methods and Materials – Sixty patients with hand flexion synergistic spasticity selected for this study. They randomly assigned into two groups. One group received NMES as well as hand functions activities and asked to wear a dorsum splint for 2x3/day hours for 12 weeks. The second group received traditional physical therapy, which include active assistive range of motion and hand activities. Subjects in both groups evaluated before and after 12 weeks of treatment using Wolf Motor Function Test and active ROM for the wrist and fingers.
Results: The mean value for seven factors of Wolf Motor Functional Test evaluated in both groups. There was significant difference p<0.05 in t test for the pre and posttest in both groups. Comparison between the means of the posttest in the experimental and control group, using ANCOVA test showed significant difference between groups with p<0.05 in all factors except for index finger ROM and reach to table.
Conclusions: Author concluded that using dorsum hand splint and NMES could be helpful to reduce flexion synergistic spasticity of the stroke hand and improve hand functional activities.
Keywords: Dorsum hand splint, stroke, rehabilitation, neuromuscular stimulation, grasp reflex, neuroplasticity
INTRODUCTION

Stroke is the leading cause of long-term disability and hemiparesis is the most common impairment in stroke\(^1\),\(^2\). Longitudinal studies of recovery after stroke suggest that upper extremity spastic rehabilitation appears to be a challenge for stroke survivors to regain functional improvement\(^3\),\(^4\),\(^5\). One of the main clinical outcome for stroke patients is the hand and fingers flexion spastic synergy. So the disability of the affected arm leads to a disuse atrophy, which limits rehabilitation outcomes and functional improvement\(^2\).

In the other hand, muscle synergies moves body segments in abnormal pattern in stroke. This type of spastic synergy is a common complication of several neurological conditions such as spinal cord injury, traumatic brain injury, cerebral palsy, and in more prominent in stroke patients\(^3\),\(^4\). It is characterized by a reduction in joint mobility and increase in resistance to passive joint movement\(^4\). Spastic synergy is due to neural and non-neural factors, including spasticity and structural changes in hand soft tissues\(^4\),\(^5\). One of the causes of this complication is the reappearance of primitive reflexes; in addition to Babinski reflex, grasp reflex appears strongly in stroke patients\(^3\),\(^4\). This reflex is characterize by hypertonic property in flexor muscles of the paretic hand, which cause fingers and wrist spastic flexion contracture. Grasp reflex is stimulated by touching or brushing the palm of the affected hand\(^3\),\(^4\),\(^5\),\(^6\). This flexion synergistic spastic hand posture can result in deformities, joint pain, and skin breakdown along with restrict activity of daily living. To achieve hand functional level, it is necessary to inhibit this synergistic flexion spasticity of wrist and muscles of the fingers. This requires avoiding any stimulation of the grasp reflex\(^7\),\(^8\). However, in order to prevent contractures, therapists are often prescribed stroke patients to wear wrist and hand palmer (volar) splints for stroke patients\(^9\). The problem with the palmar splint is that it is stimulating the grasp reflex when it touches the palm of the paretic hand\(^5\),\(^7\),\(^8\),\(^9\),\(^10\). We think to prevent or reduce wrist and fingers contracture, but it is in reality, stimulate the primitive reflex and decelerates the motor learning to reach efficient motor control in various hand movements. Therefore, this type of splint is not beneficial to stretch the spastic hand, and may results in wrist and hand muscle disuse atrophy and deforming synergy\(^10\). The recovery of the motor activities of the hand take place slowly for long time through facilitation process related to neuroplasticity in the damaged brain area\(^11\). Neuroplasticity allows the neurons in the brain to compensate for injury and to adjust their activities in response to new situations or repeated functional activities. This requires stroke patient to receive physical therapy and functional activities for long period\(^10\),\(^11\),\(^12\).

However, hand and fingers spastic synergy will be the most hindering factor which hold patient back from reaching his potentials in ADL. Previous studies showed improvement in neuronal activities following functional trainings through physical therapy\(^2\). It is necessary for rehabilitation process to reach
optimal results to repeat functional activities and put the body segment in the functional position for long intervals of time.  

Paretic hand usually treated in rehabilitation clinics by different stretching techniques applied manually, and using volar splints. Traditionally, therapist use tactile stimulation on the dorsum of the hand and then do manual stretch to the fingers, which allow the thumb and wrist to extend temporally. It is necessary to maintain this position for longer time to allow tendons and joint in functional position to prevent fingers contracture. This position will prepare the spastic hand for more functional activities.

From a neurophysiology point of view, the activation of the extensors muscles (agonist) to maximum contraction will stimulate the flexors muscles to relax. This will prepare the muscles tone to allow normal functional activities. Many authors have experimented with neuromuscular stimulators (NMES) to improve paretic upper extremity functions. They found that this type of current provides active exercise and/or sensory feedback to muscles that are unable to contract voluntarily, or can only contract weakly, together with other muscles.

NMES promotes blood flow to the muscles tissue, decreases fibrotic changes in the muscle, and can improve function. It also prevents or reverses disuse atrophy, provide proprioceptive feedback, improve motor control, decrease pain, and strengthen muscle tissue. Clinical use of NMES in stroke rehabilitation provides therapeutic and functional benefits. NMES leads to improve sensorimotor and functional activities of stroke patient's hand and enhances the upper motor function recovery.

To achieve recovery of hand functions, it recommended that, hand activities practiced early and repeated for long time. It is necessary for a therapeutic procedure that can help patient to do activities for longer time to achieve functional level. The aim of this study is to evaluate the effectiveness of using the electro stimulation and the dorsum hand splint in reducing hand flexion spastic synergy and how much that will effects on the prehension activity of paretic hand.

METHODS AND MATERIALS

Subjects:

Sixty stroke patients with hand flexion synergistic spasticity selected for this study based on the following.

Inclusion criteria
1. Age from 55-75 years
2. Stroke for 2-6 months
3. Hand spastic synergy

Exclusion criteria
1. Chronic stroke
2. Upper extremity fractures or injuries
3. Dementia or psychological factors

Procedures

All subjects signed informed consent form. Ethical clearance approved by the IRB in Majmaah University. Subjects randomly assigned into one of two groups. Group I (Experimental) received NMES for 20-minute functional activity training for 20 minutes and the wear the dorsum hand splint for 3 hours at morning and evening.

Group 2 (control) used traditional physical therapy include active assistive range of motion, stretching, and hand activities for 30 minutes. Both groups evaluated for Active Range of Motion (AROM) for wrist and fingers. Hand functions evaluated by using Wolf motor hand function test factors; hand to table, turn a key, hold a can, and release a can, pre and in 12 weeks post treatment
Instruments

Dorsum Hand Splint

The dorsum hand splint is made of hard plastic sheet covered with cloths. It opens at the dorsum of the wrist and hand area to allow for full wrist extension. It has an extension to cover the dorsum of the thumb, which held with a strap to keep it in abducted and extended position. At the wrist area, there is a solid pieces extended from the sides of the hand with an extension flat piece comes under the fingers to hold them up in extension position and prevent them from unwanted synergistic flexion spasticity. The volar of the hand stay free of any parts to avoid any stimulation of grasp reflex (Fig1, Fig2 and Fig 3).

Figure 1: Side view for dorsum splint show the volar side of the hand clearing the

Figure 2: Dorsum hand splint from dorsal side

Figure 3: Dorsal view of the dorsum splint shows clearance of the wrist and fingers at the dorsal side

Neuromuscular electrical stimulation (NMES): Portable, low frequency electrostimulation, with 2 channel electrodes fastened at the dorsum forearm on the extensor digitorum and supinator muscles motor point. NMES current frequency of 150-200 MH (LAICA, Viale Del Lavoro, 10-Fraz. Ponte. Italy). The size of the electrode used is 1 inch in diameter. Current intensity display on screen, and adjustable by special key for each channel. Patient is able to choose the suitable current strength per his/her tolerance as long as it produces muscles contracture.

Statistical Analysis

An independent- sample t test conducted to determine whether a significant difference existed in mean score of pre and post hand function of the experimental group. ANCOVA test also administer to find if there is significant difference in posttest of hand functions between experimental and control.
groups. Statistical significance was set at alpha ≤ 0.05.

SPSS 20.0 was the software used for all data analysis.

RESULTS

The aim of this study was to determine the hand functions improvement as it evaluated by Wolf hand function tool and active range of motion. A descriptive statistic was expressed as mean± SD. Experimental group had (66.4) age average, (165± 7.49) height, and (74.85± 20.12) weight. We used following statistical methods for analyzing the effectiveness of the experimental treatment protocol. Analytical comparison using t test for the pretest and posttest of seven factors of Wolf test, Hand functions, Hand to table, turn a key, hold a cane, and can release, wrist ROM, PIP ROM, DIP ROM. There was significant improvement in all factors with p ≤ 0.05 as it shows in table 1.

ANCOVA test used to evaluate the difference between the experimental and control group for the posttest in all the seven factors. The ANCOVA analysis results showed a significant difference between the mean of posttest in all seven factors except the distal phalange of the indices (DIP) and hand to table activities (results presented in table 2). The results showed improvement in active ROM of the wrist and fingers started to appear after the third week of treatment, and was very clear at the end of the study.

Table 1: shows experimental group pre and posttest in 7 factors of Wolf test of hand

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t</th>
<th>df</th>
<th>Sig</th>
<th>Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre hand to table</td>
<td>2.8389</td>
<td>0.33279</td>
<td>11.176</td>
<td>71</td>
<td>*0.00</td>
<td>0.88</td>
</tr>
<tr>
<td>Post hand to table</td>
<td>1.9722</td>
<td>0.28862</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre hold can</td>
<td>119.28</td>
<td>14.06625</td>
<td>14.16</td>
<td>17</td>
<td>*0.00</td>
<td>0.92</td>
</tr>
<tr>
<td>Post hold can</td>
<td>90.1111</td>
<td>9.63992</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre release</td>
<td>76.7222</td>
<td>9.46079</td>
<td>13.46</td>
<td>17</td>
<td>*0.00</td>
<td>0.91</td>
</tr>
<tr>
<td>Post release</td>
<td>58.0556</td>
<td>6.14982</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre wrist ROM</td>
<td>1.6667</td>
<td>1.71499</td>
<td>8.7</td>
<td>17</td>
<td>*0.00</td>
<td>0.81</td>
</tr>
<tr>
<td>Post wrist ROM</td>
<td>4.5556</td>
<td>1.14903</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre turn key</td>
<td>123.61</td>
<td>9.413</td>
<td>9.2</td>
<td>17</td>
<td>*0.00</td>
<td>0.83</td>
</tr>
<tr>
<td>Post turn key</td>
<td>104.5</td>
<td>9.88909</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre PIP ROM</td>
<td>-7.6111-</td>
<td>3.22014</td>
<td>13.76</td>
<td>17</td>
<td>*0.00</td>
<td>0.92</td>
</tr>
<tr>
<td>Post PIP ROM</td>
<td>-3.3333-</td>
<td>2.1693</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre DIP ROM</td>
<td>-3.7778-</td>
<td>2.31505</td>
<td>8.31</td>
<td>17</td>
<td>*0.00</td>
<td>0.8</td>
</tr>
<tr>
<td>Post DIP ROM</td>
<td>0.2778</td>
<td>1.44733</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant with p value <0.05, S= second,*= degrees
Table 2: Comparison between both groups posttest in all 7 factors of wolf test.

<table>
<thead>
<tr>
<th>function</th>
<th>Groups</th>
<th>post Mean</th>
<th>SDV</th>
<th>marginal Mean</th>
<th>F</th>
<th>significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand to Table</td>
<td>exp</td>
<td>1.9722m</td>
<td>0.28862</td>
<td>1.994</td>
<td>63.037</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>2.0118m</td>
<td>0.40138</td>
<td>2.054</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold a can</td>
<td>exp</td>
<td>90.1111s</td>
<td>9.63992</td>
<td>89.344a</td>
<td>18.505</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>96.7647s</td>
<td>9.20957</td>
<td>97.577a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Releas a can</td>
<td>exp</td>
<td>58.0556s</td>
<td>6.14982</td>
<td>57.151a</td>
<td>89.828</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>67.7647s</td>
<td>7.76635</td>
<td>68.722a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist ROM</td>
<td>exp</td>
<td>4.55 *</td>
<td>1.14903</td>
<td>4.597a</td>
<td>34.533</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>3.00 *</td>
<td>1.06066</td>
<td>2.956a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn key</td>
<td>exp</td>
<td>104.5s</td>
<td>9.88909</td>
<td>1.046a</td>
<td>16.085</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>113.88s</td>
<td>12.11859</td>
<td>1.138a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIP ROM</td>
<td>exp</td>
<td>-1.333 *</td>
<td>2.1693</td>
<td>16.331</td>
<td>0.000*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>-5.0588 *</td>
<td>5.34405</td>
<td>-5.240a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIP ROM</td>
<td>exp</td>
<td>0.2778 *</td>
<td>1.44733</td>
<td>0.436a</td>
<td>7.646</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>-1.0588 *</td>
<td>2.30409</td>
<td>-1.226a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant with p value <0.05, S= second, °= degrees

DISCUSSION

Synergistic spasticity in the hand of stroke patients is a major challenge for regaining hand functional activities\(^{21}\). To break down this spasticity and regain hand functional activities clinician used many strategies. Different therapeutic approaches like virtual reality, Mish-Glove, and Constrained-hand, have been developed in the past 20 years\(^{25,26,27,28}\). In this study, we introduced the dorsum hand splint, which designed to stretch wrist and fingers without stimulating primitive reflexes (grasp reflex). In addition to the dorsum hand splint, NMES used as part of the rehabilitation protocol.\(^{22,23}\). We hypothesized that this rehabilitation protocol will enhance hand functions. The aim of NEMS used here was to stimulate the fingers extensor (agonist) muscles and inhibit the hyper-tonicity in fingers flexor muscles group (antagonist)\(^{19}\)

There was no significance difference in the mean values of tested factors at the starting (pretest) session in both groups, which reflects homogeneity among the sample. Significant improvement in hand functions appeared clear in both groups, which reflect that both used procedures; traditional physical therapy and the experimented procedure are
effective in improving hand functions in paretic hand. However, the comparison of posttest in both groups, we found that the experimental group had significant difference from the control group except for ROM of the distal digit of index finger and hand to table factors. This reflects the superiority of the use of dorsum splint along with the NMES in breaking the spastic synergy in the paretic hand.

In previous studies, authors found that repeating activities in the paretic hand of the stroke patients facilitate neuroplasticity. Stretching the flexors tendon without stimulation of the grasp reflex accompanied with activation of extensor muscles for longer time may be the reason for breaking the spastic synergy and improving the hand functions. That may explain the superiority of the dorsum splint and NMES over the traditional approach.

We noticed less improvement (none significant), when we compared posttest in both groups in hand to table activity. It is well known that, this activity requires shoulder muscles strength to be at least grade 3/5 to do shoulder flexion and abduction before extending the elbow and the wrist to reach table. The experimental group had no specific exercise for shoulder and elbow. Whereas the control group had, more exercises to upper extremity joints and that may explain the weak difference.

This experimented therapeutic approach is a new reach to handle the synergistic spasticity in the stroke hand. I did not found in the literature any study experimented a use of dorsum hand splint and NMES in treating spastic hand in the past 20 years. This approach may give a new hope for the stroke patients with hand spastic synergy.

Rehabilitation of stroke patient is a slow process, requires doing therapeutic and functional activities for long time. What we have seen in rehabilitation field that the patient and family get bored sooner than time required achieving reasonable functional improvement. The new therapeutic approach that experimented in this study, allows patient to practice therapy for longer time at home and in physical therapy setting and get faster results. In addition to the significant effects on ROM and hand functions, this approach may have positive effects on patient’s mood and psychological factors. If patients and families can see improvement faster in the patient’s activity, it will encourage them to work harder and for longer time, which may stimulate the neuroplasticity process.

**CONCLUSION:** from the results we have seen, we conclude that using dorsum hand splint and NMES can be helpful to reduce flexion synergistic spasticity of the stroke hand and the stroke hand functional activities.
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CONFLICT OF INTEREST
We, the authors of this article declare that there are no conflicts of interest

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