Immediate Effects of Dermatomal Electrical Stimulation on Task-Oriented Movements in Patients with Chronic Hemiplegia

YOUNG KIM¹, CHUNG-HWI YI², YOUNG-HEE LEE³, HYE-SEON JEON², YIJUNG CHUNG⁴

¹ Department of Physical Therapy, Graduate School, Sahmyook University
² Department of Physical Therapy, College of Health Science, Yonsei University
³ Department of Rehabilitation Medicine, Yonsei University Wonju College of Medicine
⁴ Department of Physical Therapy, College of Health and Welfare, Sahmyook University: Hwarangro 815, Seoul, Republic of Korea. TEL: +82 2-3399-1630, FAX: +82 2-3399-1638, E-mail: yijung36@syu.ac.kr

Abstract. [Purpose] This study was conducted to find out the immediate effects of dermatomal stimulation combined with functional tasks of the hand, and to determine whether it could be used as a modality for functional task training for chronic hemiplegic patients. [Subjects] Ten stroke patients with spasticity of the paretic finger flexors greater than or equal to G1 on the Modified Ashworth Scale (MAS), a Manual Muscle Testing (MMT) score greater than or equal to poor², Brunnstrom stage higher or equal to stage 3, and stroke onset more than 12 months ago were recruited. [Methods] Subjects performed three given tasks (Box and Block test, Velcro pegboard, and stacking cones) in a random sequence with and without dermatomal electrical stimulation, which was applied to the C8 dermatome. Each task was repeated 6 times. [Results] The immediate effects of applying task-oriented movements combined with dermatomal electrical stimulation resulted in a significant improvement in hand function. [Conclusion] Electrical stimulation of the dermatomes combined with task-oriented movements has the potential to improve the hand functions of chronic hemiplegic patients.

Key words: Dermatomal electrical stimulation, Stroke, Task-oriented

INTRODUCTION

Cerebrovascular accidents (CVAs) have long been a worldwide leading cause of motor disabilities; a flexor synergy typically develops in the upper extremity during recovery³. Of all stroke-induced impairments, arm hemiparesis may be the most disabling since it affects the ability to perform activities of daily living (ADL), and control of wrist and finger extensors is a challenging aspect of upper-extremity recovery⁴.

One common approach to augment hand functions of stroke patients is applying functional electric stimulation (FES) to the paretic muscles, using it as an exercise program. However, many research results have shown that the functional gains were modest and of limited duration, and intensive agonist activation can increase spasticity in the hemiparetic hand⁵. Bogey and Hornby stated that no form of artificial stimulation can match natural activation for precision or fatigue resistance, and Hill-Hermann et al. reported that use of surface FES for improving ADL functions in the hemiparetic hand is suboptimal compared to the protocols encouraging task-specific, affected-limb use for motor learning, because patients are not volitionally activating their muscles, which ultimately limits the motor relearning effects⁶, ⁷. One of the approaches used to treat spastic post-stroke patients is low-intensity transcutaneous electrical nerve stimulation (TENS). The results of previous clinical studies that have investigated the effects of low-intensity TENS showed decreased spasticity, reduced magnitude of stretch reflexes, and decreased electromyographic (EMG) co-contraction ratio⁸. Sonde et al. stated that previous studies have shown positive effects when FES and TENS were used to improve restoration of muscular strength after stroke, but it was difficult to prove whether the improvement was of functional benefit to the patient⁹.

Based on these findings, this study was conducted to determine whether dermatomal stimulation combined with functional tasks that are specific to hand grasp and release could be used as a modality for functional task training in chronic hemiplegic patients. The specific objective of this study was to investigate the immediate effect of dermatomal electrical stimulation, applied while performing the given functional tasks.

SUBJECTS AND METHODS

Ten stroke patients (four males) were recruited for this study. The mean age of the stroke patients was 55.0 (SD 4.94) years, the mean duration since stroke onset was 3.0...
(SD 0.86) years, and they were right-side dominant before stroke. The patients’ characteristics are presented in Tables 1 and 2. All patients met the inclusion criteria: a score of at least 24 out of 30 on the Korean Mini-Mental State Examination (K-MMSE)\(^8\), spasticity of the paretic finger flexors assessed on the Modified Ashworth Scale (MAS) greater than or equal to G1, a Manual Muscle Testing (MMT) score of paretic finger flexors greater than or equal to poor\(^7\), Brunnstrom stage higher or equal to stage 3, no history of relapse stroke, no musculoskeletal or peripheral nervous disease, and duration of longer than 12 months since stroke onset. All subjects signed informed consent before participation.

The Box and Block test\(^9\) (B&B), a velcro pegboard, and stacking cones were used for assessment, outcome measures, and functional tasks in this study. All subjects were initially tested for their ability to perform the hand function required for the intervention, moving at least one item in each task. B&B was used to evoke fine digital movement control, the velcro pegboard for relatively strong volar grip and pulling, and the stacking cones for gasping and releasing. Subjects were asked to move each type of items (blocks, pegs, and cones) from one side to the other for one minute, as many and as fast as possible. The tasks were performed in a random sequence with and without dermatomal electrical stimulation, with 1 to 2-minute breaks between each trial. Each task was repeated 6 times. Low-intensity transcutaneous electrical stimulation was delivered by FATA Vu 1.0 to decrease the flexor tone of the wrist and hand flexors. Two surface electrodes of 2 cm in diameter were placed over the C8 dermatome, one on the proximal and one on the distal area of the medial forearm, which is the cutaneous area of the wrist and hand flexors innervated corresponding to the spinal segments. For the electrical stimulation, submotoric intensity with a stimulation frequency of 100 Hz, a pulse width of 250 μs, and a biphasic rectangular waveform were used\(^7\). An accelerometer, worn on the dorsal wrist, was used to record movement acceleration while performing the cone-stacking task. The data were collected using a physiologic data acquisition system (MP150, Biopac Systems, Goleta, CA). The acceleration data (x, y, z values) were integrated by time, and velocity was calculated by Matlab program. Microsoft Excel was used to calculate the mean of Δt, the time spent to move one cone.

### RESULTS

The immediate effects of the three different task-oriented movements combined with dermatomal electrical stimulation resulted in a significant improvement. The Wilcoxon matched pairs signed-ranks test showed a significant difference in each task, between with and without electrical stimulation (p<0.05).

The finest task among the three, demanding opposition orprehension with lateral grasp, the B&B task showed a significant improvement in hand function when the two conditions of dermatomal stimulation were compared (p<0.05). The hand function improvement in the B&B task was quantified in terms of moving more blocks within a limited time. The pegs task with concurrent dermatomal stimulation also significantly improved hand function despite the relative difficulty of the task (p<0.05). The results of the cone-stacking task showed the greatest improvement in hand function among the three tasks performed in this study (p<0.05). The number of the cones moved increased with dermatomal stimulation, with less time spent transferring a cone. Hand function improved as the velocity increased (Table 3).

### DISCUSSION

The aim of this study was to test the hypothesis that task-oriented movements combined with dermatomal electrical stimulation for chronic stroke patients would induce a significant improvement in hand function. The immediate effect of dermatomal electrical stimulation while performing the given tasks significantly improved hand function. Supportive to the focus of the present study, Peckham

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Table 1. General characteristics of subjects (n=10)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Age (year)</th>
<th>Since onset (month)</th>
<th>Paretic side</th>
<th>K-MMSE(^a)</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>37</td>
<td>22</td>
<td>Rt</td>
<td>30</td>
<td>Lt. ICH(^b)</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>70</td>
<td>28</td>
<td>Lt</td>
<td>24</td>
<td>ICH &amp; inf(^b)</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>73</td>
<td>13</td>
<td>Lt</td>
<td>27</td>
<td>Ischemic inf</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>48</td>
<td>15</td>
<td>Lt</td>
<td>24</td>
<td>ICH; Rt. MCA(^d)</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>50</td>
<td>24</td>
<td>Rt</td>
<td>26</td>
<td>ICH</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>38</td>
<td>34</td>
<td>Lt</td>
<td>28</td>
<td>ICH; Rt. PCA(^e)</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>71</td>
<td>25</td>
<td>Rt</td>
<td>27</td>
<td>Lt. Chl(^f) inf</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>54</td>
<td>27</td>
<td>Rt</td>
<td>28</td>
<td>S-ICH, S-IVH(^b)</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>53</td>
<td>80</td>
<td>Lt</td>
<td>27</td>
<td>ICH</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>53</td>
<td>12</td>
<td>Lt</td>
<td>28</td>
<td>S-ICH; Rt. BG(^b)</td>
</tr>
</tbody>
</table>

\(^a\)K-MMSE : Korean Mini-Mental State Examination. \(^b\)ICH : intracerebral hemorrhage. \(^c\)inf : infarct. \(^d\)MCA : middle cerebral artery. \(^e\)PCA : posterior cerebral artery. \(^f\)Chl: cerebellar. \(^g\)S-IVH: spontaneous intraventricle hemorrhage. \(^h\)BG : basal ganglia
et al. reported that grasping and releasing are the two vital abilities of the hand for independent living. Functional hand movements include prehension with palmar grasp, prehension with lateral grasp, median palmar or lateral grasp, pinching, forearm pronation and elbow extension. The intervention of the present study was designed based on this information. The three functional tasks given to perform in this study contained all of the functional hand movements mentioned by Peckham et al. The improvement of grasp function was reflected in an ability to grasp more objects, to carry objects more safely, and to transfer objects faster; evaluating both the force and skill of functional hand movements in different aspects.

The results of this study also provided significant evidence that dermatomal electrical stimulation is effective when combined with functional hand tasks. Although many researchers studied the effects of various types of electrical stimulation in training the paretic muscles, not many of them showed improved hand functions after the electrical stimulation because most of them only triggered passive muscle contraction and contractions. Active muscle contraction by repetitive task-oriented movements is the best way to train and regain muscle functions if spasticity can be controlled. According to Schuhfried et al., submotoric electrical stimulation can be used to reduce spasticity and improve motor control through increased afferent inputs, and TENS can improve the effectiveness of task-related exercise in hemiparetic stroke patients.

Many studies have applied electrical stimulation to the paretic limb for more than 20 minutes for muscle activation. However, decreasing the amount of external electrical stimulation for more active control of the muscles may be a healthier way of recovering the muscular functions. The present study tested the effect of short-term dermatomal electrical stimulation and found out its immediate effect through reduced spasticity and improved hand functions in chronic hemiplegic patients. Additional controlled studies with a larger sample of stroke patients, along with an extended practice period will be necessary to establish the efficacy of task-oriented movements combined with dermatomal stimulation as a rehabilitation intervention.

### REFERENCES