THE EFFECT OF ELECTRICALLY-INDUCED TRUNK EXTENSION ON SEATED POSTURE AND BALANCE

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Abstract

The center of pressure (COP) was used as an indicator of seated posture and balance in three subjects with spinal cord injury. The subjects, each with implanted intramuscular electrodes in their right and left paraspinals, sat without support on a force platform and outstretched their arms while balancing themselves in the seated position. Their COP was calculated with and without electrical stimulation to the trunk extensor muscles. It was hypothesized that there would be an anterior shift in the COP with stimulation, and that the sway area of the COP would decrease. It was found that there was, in fact, an anterior shift in the COP in all subjects, but no discernable trend in the change in sway area with stimulation. These data suggest that electrical stimulation can induce a more functional posture by shifting the COP forward. Further research regarding the effects of stimulation on seated balance and bimanual workspace is ongoing.

Introduction/Background

Individuals with spinal cord injury (SCI) have diminished to no control of their trunk musculature, depending on the level of injury. As a substitute, electrodes can be used to stimulate the erector spinae (ES) muscles to induce trunk extension. Electrically-induced trunk extension may provide the means by which a person with SCI can maintain a stable, functional posture while seated in a wheelchair. An improved posture can lead to a greater range of motion of the upper extremities, which can thereby lead to an increased ability to perform bimanual tasks in a seated workspace. This can be highly beneficial at home and at work for people with a spinal injury.

The position of the center of pressure (COP) of a subject has been used to determine the amount of body sway and postural stability [1]. The COP is a two-dimensional representation of the position of the ground reaction force supporting the subject. It is influenced by the shear forces produced by body segment accelerations, so the excursions of the COP are reactions to body dynamics [2]. The path length of the COP, and sway area are common measurement parameters in monitoring postural sway [3], and the excursions of the COP are used to determine postural stability. The excursion of the COP can be determined using data from a force platform [2].

In this study, a comparison was made between the excursion of the COP of three seated subjects with SCI with and without electrical stimulation of the ES muscles. It was hypothesized that stimulation of the trunk extensors would create more erect and functional sitting postures, thereby producing a forward shift in the COP. Stimulation was also anticipated to increase stability, resulting in decreased sway area.

Methods

Three subjects with SCI participated in this study, each having two surgically implanted intramuscular electrodes [4] in the inter-vertebral foramen at either T12-L1 or L1-L2 to excite the spinal roots innervating the iliocostalis lumborum or longissimus thoracis for trunk extension. The electrodes were implanted symmetrically and bilaterally in the right and left paraspinals and connected to an implanted receiver-stimulator [5]. Table 1 details the gender, age, height, weight, level of injury, and the time post-injury and post-surgery of the subjects. The subjects were seated on a biomechanics force platform (AMTI, Inc.) mounted on a bench adjusted to keep the hips, knees and ankles at approximately 90° of flexion. To prevent external support, the bench did not have armrests or a backrest. The subjects sat facing the positive x-direction on the platform with a harness tied loosely around their chests to prevent falls. The subjects were asked to raise their arms to shoulder-level and stretch them as far as possible away from their body without losing balance while bimanually holding on to an empty plastic box of negligible weight. Once a balanced position was achieved, the forces and moments in the x-, y-, and z-directions were obtained for a minimum of 10 seconds. Figure 1 shows the experimental setup.

The data were acquired using an AMTI Force Platform Data Acquisition System and then amplified.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Injury level</th>
<th>Months post-injury</th>
<th>Months post-surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>29</td>
<td>168</td>
<td>56.8</td>
<td>C7, ASIA A</td>
<td>32</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>35</td>
<td>175</td>
<td>90.0</td>
<td>T5, ASIA B</td>
<td>209</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>48</td>
<td>173</td>
<td>86.4</td>
<td>T6, ASIA A</td>
<td>27</td>
<td>13</td>
</tr>
</tbody>
</table>
Fig. 1: Experimental Setup

This procedure was performed without stimulation of the trunk extensor muscles, and then followed by a trial with stimulation. A charge-balanced biphasic stimulus waveform was delivered bilaterally to each electrode by the RF-controlled implanted receiver-stimulator. Stimulus timing was preprogrammed and controlled by a series of switches on the enclosure. The stimulus amplitude was fixed at 20mA and the frequency at 30Hz. Stimulus pulse duration was customized for each electrode in each subject and set to values that achieved maximal trunk extension without spillover to unwanted muscles. The right and left electrodes in subject 1 were at 200 µs and 80 µs, respectively, those in subject 2 were 50 µs and 200 µs, and those in subject 3 were 90 µs and 150 µs. Two trials under each condition (trunk stimulation ON and OFF) were performed for a total of four trials per subject.

Results

Figure 2 shows the COP excursion in the first set of trials for each of the subjects with and without stimulation. It can be seen that the COP excursions without stimulation for all three subjects lie in different areas of the plot. This is probably due to variations in initial sitting position relative to the fixed reference frame of the force platforms. In all of the subjects, there is an anterior (positive x-direction) shift in the COP. Figure 3 shows the shift in the average COP after trunk stimulation was used. Subject 1 had the largest shift, and subject 2 had the smallest shift.

![Fig. 2: COP excursions. The number in the circled label refers to the subject number, ‘a’ is the trial without stimulation, and ‘b’ is the trial with stimulation.](image)

![Fig. 3: Anterior shift in average COP with stimulation](image)
Table 2: The change in sway area with electrical stimulation

<table>
<thead>
<tr>
<th>Subject</th>
<th>Sway area before stim (cm²)</th>
<th>Sway area after stim (cm²)</th>
<th>Change (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.22</td>
<td>0.70</td>
<td>0.48 †</td>
</tr>
<tr>
<td>2</td>
<td>0.27</td>
<td>1.60</td>
<td>1.33 †</td>
</tr>
<tr>
<td>3</td>
<td>1.88</td>
<td>0.68</td>
<td>1.2 ↓</td>
</tr>
</tbody>
</table>

Qualitatively, it was evident that subject 1 was the most stable, as she did not lose her balance. She was able to achieve a balanced position quickly and remain that way without falling. She was also able to extend her arms further. Subject 1 mentioned that the trunk stimulation gave her more confidence in reaching forward. Subject 2 had a more difficult time stabilizing himself when the stimulation was on and lost his balance once and had to be caught by the harness. Finally, subject 3 lost his balance several times with and without stimulation, and also experienced difficulty in holding the box with his arms outstretched. In order to keep his balance, he kept his arms closer to his body. In spite of this, all three subjects expressed a preference for trunk stimulation and the new posture it provided, as well as desire for regular trunk extension exercises in their wheelchairs.

Discussion/Conclusions

Stimulation of the lumbar trunk extensors appears to be an effective means to modulate seated posture in the sagittal plane. Activation of the ES muscles consistently resulted in an anterior shift of the seated center of pressure. Without stimulation, subjects tended to sit in a slouched posture with a posterior pelvic tilt and concave (kyphotic) curvature of the spine. When the stimulation is turned ON, the subjects’ trunks are extended, moving their shoulders upward and allowing them to assume an equilibrium point forward from the unstimulated case. This more erect posture results in an anterior shift of the COP between 2.54cm and 3.67cm. This shift may indicate that the subjects can perform bimanual tasks in front of the body with greater ease when stimulation is ON. This is because the COP moves forward during such tasks and active contraction of the extensor muscles can counteract the flexion moments caused by the weight of the outstretched arms and objects being carried. This is supported by the feeling of increased confidence reported by subject 1 while stretching her arms during trunk stimulation.

It was hypothesized that the sway area would decrease with trunk stimulation, indicating increased stability. However, it is evident from Figure 2 and Table 2 that there is no discernable trend in the change in sway area with stimulation. Subjects 1 and 2 experienced increases in sway area, and subject 3 experienced a decrease. No conclusions can be drawn from these results regarding the stability of the subjects with stimulation and further investigation is warranted to determine whether there is a consistent effect on the sway area. More study is also required to determine quantitatively the effects of trunk stimulation on functional reach, workspace and the ergonomics of the seated operator with paraplegia.

The subjects in this study had varying amounts of experience using the implanted ES electrodes. Subject 2 only received the electrodes 5 months prior to testing, whereas subjects 1 and 3 received them 14 and 13 months earlier. The results may have also been a function of how much exercise the subjects had been getting prior to testing. In addition, subjects were not well practiced in sitting on surfaces without backrests or armrests, especially with ES stimulation. While they often balance themselves in such a manner without stimulation during the course of their daily lives, sitting with trunk stimulation was a new experience for them, which may have confounded the results. Finally, the results of these experiments may be different while sitting in the wheelchair with an appropriate backrest.

These preliminary data are encouraging and suggest that stimulation of the trunk extensor musculature may have functional benefits for people with cervical and thoracic spinal cord injuries. Research on the effects of ES stimulation on seated balance and bimanual workspace is ongoing.

References


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