Postural Response to Slow Perturbations: A Preliminary Study of Young vs. Elderly Subjects

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Abstract—The sensitivity to detect a perturbation at low speed and small magnitude was evaluated to determine the physiological response differences that arise with age. Seven slow speeds ranging from 1.25 – 4.3 cm/s were chosen to evaluate the postural responses (electromyograms) and postural behavior (center of pressure) while subjects stood on a platform that was perturbed anteriorly. This preliminary study indicated that the muscle activation latency is longer in the older population, though both groups show an effect of speed. A significant difference does exist between groups at the intermediate speeds, but center of pressure data showed little differences between groups in regard to the behavior of the body's movements. Future tests will include larger subject groups, neurological deficit groups, and the addition of kinematic data to evaluate joint rotations.

Keywords—Postural response, slow platform movement, postural balance, EMG, perturbation, aging.

I. INTRODUCTION

The maintenance of balance involves a complex postural control system that depends on the integration of sensory information from the vestibular, visual, and somatosensory information, and the initiation of an appropriate response to any disturbance to balance. The increase of falls in the elderly population has led many researchers to believe that one or more of these systems may be deteriorating with age. Additionally the peripheral and central nervous system are affected by in increased risk of disease with age [1]. Still, the specific source of disequilibrium is questioned.

The moveable platform paradigm has been used as a means to evaluate the postural response to a perturbation. Most of these studies have focused on speeds that are faster than 10 cm/s [2, 3]. These types of studies focus on the physiologic response to large perturbations that challenge the stability limits and may cause falls [4]. Very few studies evaluate the postural response to platform movement at slower speeds, focusing on the threshold to movement detection. Richerson et al. evaluated subjects’ postural response at similar speeds that this study proposed. They studied the effects of acceleration using psychometric measures to determine the acceleration thresholds for subjects tested [5]. In the current study, we present preliminary findings of physiologic response (electromyograms) and behavioral response (center of pressure) to slow movements on a platform. The aim is to determine if postural responses to slow speeds (non-threatening) vary between a young and elderly population.

II. METHODOLOGY

A. Subjects

Three healthy, older adults (one female, two male, mean 73 ± 2) and three healthy young adults (all female, mean 25 ± 2) volunteered for the study. All older adults self-reported that they were free of neurological disease, and had no history of falls. All participants signed informed consent prior to participation in the study in accordance with the Institutional Review Board at Arizona State University.

B. Protocol

Subjects stood on a movable platform that was perturbed anteriorly at seven different speeds (1.25 – 4.3 cm/s). The experiment comprised of five blocks of 15 trials each. Each block presented two speeds at the same condition before presenting the next condition speed, with the addition of a catch trial that accounted for a zero-velocity condition. Platform velocity was randomized between blocks. Each trial was 5-seconds in duration with a continuous perturbation movement. Subjects were provided a five-minute break between trials to minimize the effects of fatigue.

Prior to data collection two maximal voluntary contractions were collected for each muscle with the subject in a seated position. Electromyography data (Noraxon, Inc.) were collected from the tibialis anterior (TA), soleus (SO), and gastrocnemius (GA) for both the right and left legs, and from the rectus femoris (RF) and bicep femoris (BF) of the right leg.

Subjects then stood barefoot on the Tekscan Matscan placed on the moveable platform. Subjects were asked to stand in a comfortable stance, and this position was marked and traced for each subject so the feet position would be consistent from trial to trial. Surface electromyograms (sEMG) and encoder data were sampled in LabVIEW at 5000 Hz. while CoP data from Tekscan software was sampled at 60 Hz.

C. Data Analysis

Post processing of sEMG and CoP data was performed in Matlab. The sEMG was high-passed filtered at 20Hz,
recertified, low-pass filtered at 40 Hz, then resample to 1 KHz. The data were then normalized to the maximum contractions. The initial sEMG parameter chosen for analysis was latency response to the perturbation. The mean and standard deviation (s.d.) baseline was found 200 ms prior to perturbation. Muscle activation onset was recorded as the point when the EMG was 3 S.D. above mean baseline for 25 ms.

The CoP displacement and the maximum velocities in the posterior and anterior direction were used to describe subjects’ postural behavior. The specific parameters included (1) time to 5mm posterior displacement, (2) time to max posterior displacement, (3) max posterior displacement, (4) max posterior velocity, (5) max anterior velocity.

III. RESULTS

A. EMG

The trends plotted in Fig. 1 & 2 show that generally the latency for young subjects was shorter than that of the older subjects. Note that the speeds indicated on the horizontal axis do not increase linearly. In addition, the young subjects displayed a more graded response with speed than the older subjects, though an effect of speed in seen in both groups. The latencies of the SO, GA, and BF are slightly longer than the TA and RF as is expected since the anterior muscles are the primary mover for an anterior perturbation. But differences between young and older subjects in these posterior muscles are not as noticeable as in the TA & RF.

One-way ANOVA was run on the right and left tibialis anterior latencies between groups. Significant differences between groups were found at the intermediate speeds (see Table I). Only the TA latencies are statistically analyzed since they are the primary movers of small, anterior perturbations.

B. Center of Pressure

Several parameters were evaluated for the CoP movement and three are shown in Fig. 3-5. The trends between young and elderly show very little difference in the CoP response.

### Table I

**ONE-WAY ANOVA FOR TA LATENCIES BETWEEN GROUPS**

<table>
<thead>
<tr>
<th>Speed (cm/s)</th>
<th>Left TA</th>
<th>Right TA</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>Sig.</td>
<td>F</td>
</tr>
<tr>
<td>1.25</td>
<td>.958</td>
<td>.383</td>
</tr>
<tr>
<td>1.75</td>
<td>.847</td>
<td>.409</td>
</tr>
<tr>
<td>2.0</td>
<td>.684</td>
<td>.073</td>
</tr>
<tr>
<td>2.25</td>
<td>28.017</td>
<td>.006*</td>
</tr>
<tr>
<td>2.5</td>
<td>22.969</td>
<td>.009*</td>
</tr>
<tr>
<td>3.3</td>
<td>6.908</td>
<td>.058</td>
</tr>
<tr>
<td>4.3</td>
<td>4.3</td>
<td>3.898</td>
</tr>
</tbody>
</table>
A good understanding of how people respond to large magnitude perturbations has been established over the years from many experiments [1, 2, 4]. Yet the ability to adopt effective balance control strategies has not been correlated with the ability to prevent fall. The overall purpose of this preliminary study was to determine if young and elderly subjects respond to slow speed and small magnitude perturbations differently as observed and analyzed in EMG and CoP data. A longer time latency and low sensitivity in detecting a perturbation may reveal one fundamental factor in a person’s ability to overcome a perturbation in balance control. This investigation is a new attempt to determine whether there is fundamental difference in young and elderly, normal and neurologically impaired populations, in their ability to respond to a perturbation promptly and effectively.

Since the subject group size was small (three young and three elderly) in this pilot project, the power of statistical analysis would be limited. Therefore, only general trends in the data were evaluated and reported. Overall, the latencies in muscle response to the perturbations were longer in the older subjects than in the younger subjects. There does appear to be an effect of speed for both groups, though the young subjects have a more graded response suggesting that postural control was more sensitive to these slow speeds. The elderly subjects do not show such a marked change in latency with speeds, but additional subjects are needed to determine any significance in the postural response across speeds.

V. CONCLUSION

In conclusion, the preliminary results of this study are positive though not conclusive and warrant further testing at the slower platform speeds. If differences are found, conclusions may be drawn about the sensory system responsible for detecting movement and the overall elicited response. Future studies will include groups with neurological deficits (e.g. diabetic neuropathy patients) to determine the source of the change in response and the addition of kinematic data to analyze joint movement.

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REFERENCES