Noise-Enhanced Balance Control: The Worse You Are the Better You Get

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INTRODUCTION

The human balance control system relies, in part, on somatosensory feedback. In older adults, patients with diabetic neuropathy and patients with stroke, diminished somatosensation is associated with increased postural instability during standing and walking. Recently, it has been demonstrated that subsensory mechanical noise can improve somatosensation in healthy young individuals and older adults[1]. Moreover, it has been shown that subsensory mechanical noise applied to the soles of the feet via vibrating insoles can enhance balance control in healthy young[2], elderly individuals[2], patients with diabetic neuropathy[3], and patients with stroke[4]. The goal of this study was to test the hypothesis that the amount of reduction of postural sway during the application of noise to the soles of the feet is directly correlated with the baseline postural sway of the individual.

METHODS

The postural-sway data of twelve healthy elderly[2] (mean 73 years), 15 subjects with diabetic neuropathy[3] (mean 60 years) and 15 subjects with unilateral stroke[4] (mean 61 years) were pooled from three earlier studies. In each of these studies, subjects stood barefoot with eyes closed on gel-based vibrating insoles that applied subsensory random vibrations to the soles of the feet. With the application of noise, both traditional and random-walk postural sway measures, analyzed from the displacement of a shoulder marker, improved significantly across the groups. These results demonstrated promising improvements in balance control; however, they did not address the contributions that balance impairments have on the level of improvement seen in postural sway during the application of noise. To determine these factors across the three populations, we developed a linear regression model. We compared age, height, sensory threshold, and/or baseline sway of each subject to the difference measure (*difference measure = mean value of control condition - mean value of noise condition*) for each sway parameter of each subject, respectively. We hypothesized that increases in these independent variables would lead to an increase in the difference measure for each sway parameter (indicated by positive coefficient estimates for each sway parameter and $p < 0.05$). With the linear regression model, we also analyzed if interactions were present between stimulation (control vs. noise) and condition (subjects with diabetic neuropathy vs. subjects with stroke vs. elderly) on postural sway.

RESULTS AND DISCUSSION

As indicated in Table 1, all coefficient estimates for the mean value of baseline sway of each sway parameter versus the difference measure of each sway parameter, respectively, are statistically significant. Coefficient estimates for age, height and sensory threshold for each sway parameter versus the difference measure for each sway parameter, respectively, were not statistically significant; therefore, these independent variables were removed from the model. No interactions were found between stimulation and age in any of the parameters suggesting that there were no differential effects of mechanical noise in the elderly, patients with diabetic neuropathy and patients with stroke.

Parameters	Estimates	*p*-value
Mean Radius	0.2 ± 0.1	< 0.0001
Swept Area	0.2 ± 0.1	0.0038
Max Radius	0.3 ± 0.1	< 0.0001
Range AP	0.3 ± 0.1	< 0.0001
Range ML	0.4 ± 0.1	< 0.0001
$<\Delta r^2>_c$	0.1 ± 0.1	0.0339
D_{rf} (s^{-1})	0.6 ± 0.1	< 0.0001
H_{rf}	0.4 ± 0.1	< 0.0001

Table 1: Coefficient estimates of the traditional and random-walk sway parameters from the model of base-line postural sway versus the difference measure for each sway parameter of each subject, respectively.

This study shows that reduction of postural sway during the application of noise to the feet is greater in individuals with larger baseline postural sway.

CONCLUSIONS

Noise-based devices, such as randomly vibrating shoe insoles, may prove effective in enhancing performance of dynamic balance activities (e.g., walking) in individuals with balance deficits. Moreover, it may be possible to predict the magnitude of the stimulation effect by measuring the baseline performance of the individual.

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