VIBROTACTILE TILT FEEDBACK REDUCES MEDIOLATERAL TILT IN VESTIBULOPATHIC SUBJECTS DURING LOCOMOTOR TASKS

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INTRODUCTION

We have developed a novel wearable device that augments or replaces compromised vestibular information by providing vibrotactile cues of body motion. Estimates of body tilt derived from accelerometers and gyroscopes are presented to a subject's torso in the form of small vibrations by vibrotactile elements similar to pager motors. Single- and multi- axis vibrotactile feedback has been shown to significantly reduce the root-mean-square (RMS) tilt in vestibulopathic subjects during quiet standing and single- and multi-axis perturbations (Kentala et. al, 2003, Kentala and Wall, 2005, Sienko et. al, 2008).

METHODS AND PROCEDURES

Eight vestibular-deficient subjects participated in a proof-of-concept study involving real-time M/L vibrotactile tilt feedback during various locomotor tasks including slow- and self-paced walking, walking on a foam surface, and walking along a narrow walkway. Locomotor tasks ranging from easy to challenging were selected for this exploratory study since the utility of vibrotactile feedback for improving gait stability was previously unproven. Prior to testing, subjects trained for approximately 45 minutes with the device. Two feedback configurations in addition to the device off configuration were tested: continuously displayed M/L tilt (continuous) and M/L tilt displayed for 200 ms beginning at the heel-strike event (intermittent). The intermittent display design was motivated by the findings of Bent et al. (2004) demonstrating that vestibular information is used during double support phase to affect the M/L position of subsequent foot placement. The RMS tilt was calculated for all locomotor tasks by taking the square root of the squared sum of the estimated tilt as derived from the processed inertial sensing assembly data. Step width was calculated by taking the difference between the M/L shank positions derived from kinematic data. Step width variability was characterized by averaging the standard deviation step width values for all single support phases within a trial. Step length was calculated by taking the difference between the A/P shank positions. A modified five point Likert scale was used to assess the subject's impression regarding the usefulness of the device in improving stability. A one-way, repeated-measure analysis of variance was performed on each dependent variable, with a level of significance set at $p < 0.05$.

RESULTS

Use of M/L vibrotactile tilt feedback resulted in decreased M/L tilt for slow-, self-paced, narrow stance, and foam walking tasks. This decrease was statistically significant for the narrow stance walking task (Figure 1). Step width and step length were significantly reduced during slow-paced walking when M/L tilt feedback was provided. Step width variability was significantly reduced by M/L tilt feedback for both slow- and self-paced walking trials. Although not significant, subjects decreased their pace during trials in which feedback was provided. The subjects perceived the usefulness of the device as 4.05 and 3.73 out of 5 (where 1 = very unhelpful, 3 = neutral, and 5 = very helpful) for the continuous and intermittent feedback displays, respectively.

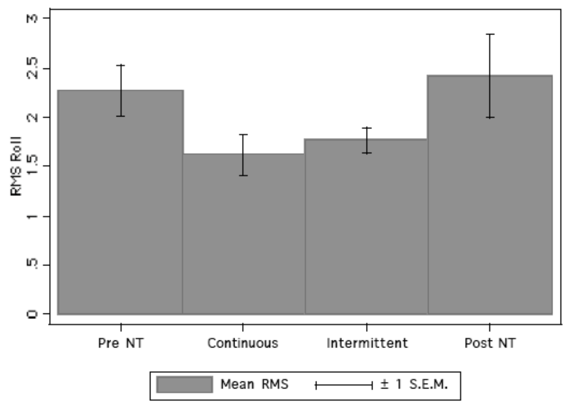

Figure 1. Average RMS M/L tilt (RMS roll) for narrow stance walking trials. Pre NT = device off (no feedback) trials preceding device on (feedback) trials. Post NT = device off trials following device on trials.

DISCUSSION

This study is the first to show that M/L vibrotactile tilt feedback improves M/L stability in vestibular deficient subjects during locomotor tasks. M/L tilt feedback resulted in decreased M/L tilt for all locomotor tasks; however, the difference was only significant for the narrow stance trials (the most challenging locomotor task). Additional subjects should be evaluated to determine if this trend is significant for slow-, self-paced, and foam walking tasks. In general, subjects walked at a slower, although not significantly slower pace when feedback was provided. Subjects were likely decreasing their gait velocity in an attempt to cognitively process and use the feedback information. This finding may suggest that the subjects were not sufficiently practiced at using the device and that long training sessions potentially spanning days may be required for effective use of a biofeedback device during locomotor activities. No significant difference was identified between the two device configurations evaluated. Subjects as a whole found the continuous display configuration to be more useful and verbally indicated an increased level of confidence when their tilt information was displayed continuously vs. intermittently.

SUMMARY

This proof-of-concept study demonstrates that vestibular-deficient subjects can decrease their RMS M/L tilt during narrow stance walking by using M/L vibrotactile tilt feedback.

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ACKNOWLEDGEMENTS

This study was supported by NIH Research Grant R01 DC06201-01. We acknowledge the assistance of David Balkwill with data processing and analysis, Jimmy Robertsson with device development, and Matthew Christensen with testing subjects.