AUDIO BIOFEEDBACK OF TRUNK ACCELERATIONS IMPROVES BALANCE IN SUBJECTS WITH BILATERAL VESTIBULAR LOSS

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INTRODUCTION

Humans maintain balance based on the information provided by the visual, vestibular and somatosensory systems. When one or more of these sensory systems is not available, balance is affected. Subjects who have lost vestibular function lack linear and angular head acceleration which provides information correlated with body sway and orientation with respect to gravity. Visual biofeedback of standing subjects’ center of pressure (CoP) has been used successfully to reduce postural sway in stroke patients [Shumway-Cook et al, 1988]. Technological advances in the last few years provide new low-cost, portable sensors able to acquire kinematic data. In particular, data from accelerometers have been validated by comparing them with force plate and motion analysis data [Mayagoitia et al. 2002]. We developed an audio biofeedback device that encodes trunk biaxial accelerations into stereo sound. Our hypothesis is that audio information can improve balance in patients with profound bilateral loss of vestibular function (BVL).

METHODS

The ABF system we developed is comprised of a biaxial accelerometer, a laptop PC equipped with an acquisition card, and earphones. The accelerometer was mounted on the subject’s back (L5) to sense the trunk accelerations. The laptop acquired the trunk accelerations and encoded those signals into a stereo sound. Anterior-posterior (AP) trunk acceleration was coded by changing the pitch of the sound. Medial-lateral (ML) trunk acceleration was coded by changing the balance of the volume between the stereo channels. The volume of both stereo channels increased whenever the subjects moved away from their initial stance position. While the subjects were within ±1 degree sway displacement from the initial position a low volume, pure, 400-Hz tone was provided through the earphones. Nine BVL and 9 healthy subjects performed 6, 60-second trials in quiet standing. Subjects stood on 10-cm thick Tempur Foam with eyes closed to increase the importance of vestibular information for postural control. Trunk accelerations were...
recorded as well as CoP displacement with a 100-Hz sample rate. From the CoP displacement we extracted 2 parameters: (1) root mean square distance RMS and (2) frequency containing the 95% of the spectrum power (F95%). We also divided the CoP spectrum into low (0.02 Hz - 0.5 Hz) and high (0.5 Hz – 5 Hz) frequencies. We computed the power for both frequencies bands. ANOVA was used to compare trials with and without ABF. We also determined correlation and coherence between CoP displacement and acceleration.

RESULTS AND DISCUSSION

ABF reduced CoP displacement and increased CoP bandwidth. RMS was reduced by ABF (p<0.05). RMS was reduced more in BVL (23%) than in control (16%) subjects. ABF increased F95% by 9% in BVL and by 8% in control subjects (p<0.05). ABF reduced both high and low frequencies power in BVL subjects (p<0.05). ABF reduced only low frequencies power in control subjects (p<0.05). The correlation between AP-trunk acceleration and AP-CoP displacement was highly significant (r=0.88, p<0.01). The coherence between AP-trunk accelerations and AP-CoP is shown in Fig. 2.

The larger RMS reduction for BVL than control subjects while using ABF supports our hypothesis that ABF effectively substitutes for the lack of vestibular information. The increasing F95% while using ABF suggests that ABF induced more postural corrections, i.e. augmented the postural control. Healthy subjects use ABF to control slow drift of their postural set point whereas BVL subjects also use ABF to improve high frequency postural corrections. The high correlation and coherence between trunk acceleration and CoP displacement, especially at the low frequencies, suggests trunk acceleration is a good substitute for CoP displacement for development of biofeedback devices.

SUMMARY

An accelerometry-based ABF system was tested on BVL subjects during quiet stance on foam with eyes closed. Analysis of CoP showed that: (1) ABF reduces sway of BVL subjects more than controls; (2) BVL subjects reduced both high and low frequencies power. These results support our hypothesis that accelerometry-based ABF information can substitute for lack of vestibular information in BVL subjects.

REFERENCES


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