EYE FOR AN EYE: VESTIBULAR CONTROL OF STANDING BALANCE IS MODULATED BY MONOCULAR VISUAL CUES

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INTRODUCTION

The control of standing balance requires the integration and processing of diverse sensorimotor cues (Massion, 1998). With respect to the vestibular control of standing balance, the role of vision is primarily limited to binocular and no vision conditions. Thus, limited data exists on how monocular visual cues alter this standing balance control. Electrical vestibular stimulation (EVS) is a powerful tool to probe the vestibular control of standing balance (Fitzpatrick & Day, 2004). Application of an electrical current over the mastoid processes modulates the firing rates of the primary vestibular afferents, facilitating reflexive responses in muscles actively engaged in maintaining upright balance. These reflexive responses are indicative of the vestibular control of balance and can be quantified in whole-body ground reaction forces and electromyography. The purpose of this study was to characterize how vestibular-evoked muscle and whole-body balance responses are modulated in response to visual cues provided by no, non-dominant eye, dominant eye, and binocular vision conditions.

METHODS

Seventeen healthy subjects (26 ± 5 years, 12 females) were exposed to a random, continuous electrical vestibular stimulation (EVS) signal over the mastoid processes (±3.5 mA, 0-20 Hz). Subjects stood quietly with their heads facing forward and eyes fixated on a visual array (25.4 x 25.4 cm) consisting of white dots (2 mm diameter placed 2 cm apart) during four experimental (no vision, non-dominant eye, dominant eye, binocular) visual conditions. Eye dominance was determined using variations of the Miles and Porta tests. Whole body medial-lateral ground reaction force acting on the body, and muscle (surface electromyography) responses from the left (LMG) and right medial gastrocnemius (RMG) were calculated in time (cumulant density) and frequency (coherence) domains to characterize the vestibular control of standing balance.

RESULTS AND DISCUSSION

All subjects were categorized as right eye dominant. In the time domain, EVS-whole body balance responses, as represented by the medium-latency (ML) peak amplitude, increased progressively with a decrease in visual cues (\(p < 0.05\)). The EVS-whole body balance responses were increased 45, 26 and 18\% greater for no vision, non-dominant eye, and dominant eye visual cues than binocular vision, respectively (\(p < .05\); Figure 1). Both EVS-LMG and EVS-RMG medium-latency peak amplitudes increased progressively with decreases in visual cues from binocular to no vision (\(p < .05\)). There were no detectable differences in vestibular-evoked balance responses between monocular visual conditions for either EVS-LMG or EVS-RMG. In the frequency domain, EVS-whole body forces did not differ for any visual or electrode condition (\(p > .05\)). For EVS-LMG, peak coherence was 27 and 28\% greater for no vision than dominant eye and binocular vision, respectively (\(p < .05\)). There were no differences in peak coherence between monocular visual conditions (\(p > .05\)). The EVS-RMG peak coherence was 15\% greater for dominant eye than non-dominant (\(p < .05\)).

Figure 1: Medium-latency peak amplitudes progressively increase with a decrease in visual cues for the whole-body balance responses (\(p < .05\)). Values are reported as means ± standard deviations.

CONCLUSIONS

Our results indicate that the vestibular control of standing balance is decreased when visual cues are progressively increased. Interestingly, as represented by the EVS-RMG vestibular-evoked balance responses, visual cues provided by the non-dominant eye may not be as reliable as the dominant. As such, the vestibular control of standing balance was greater when visual cues were provided by the non-dominant than dominant eye when examining balance responses, as this was evident in the RMG. While considering monocular visual cues, this study is the first to demonstrate a progressive decrease in vestibular-evoked muscle responses when increasing visual cues. Thus, these data suggest that vestibulo-motor balance responses are modulated based on how the balance system integrates static visual cues from monocular visual sources.

REFERENCES