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Short communication

Saccadic and smooth pursuit eye movements attenuate postural sway similarly

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HIGHLIGHTS

- Saccadic eye movement and smooth pursuit reduce body sway compared to fixation.
- Different visual frequencies affect equally the body sway in both eye movements.
- Saccadic eye movements are anticipated, favoring a feed-forward modulation.
- Smooth pursuit eye movements appear to be controlled in an on-line manner.

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ABSTRACT

Saccadic eye movements reduce body sway, yet visually pursuing a moving dot seems to increase body sway. However, how these two types of eye movements affect postural control remains ambiguous, particularly for smooth pursuit eye movements. The aim of this study was to examine the effects of saccade and smooth pursuit eye movements on body sway magnitude during low and high frequencies. Ten young adults (19.5 ± 1.9 years) participants were required to stand upright, barefoot for 70 s using a bipedal stance, with feet hip width apart, fixating or pursuing a target that was displayed on a monitor positioned 100 cm away from their eyes. Each participant performed three trials using both types of eye movements, in particular, slow and fast saccades, and slow and fast smooth pursuit movements. Body sway was obtained using reflective markers attached to a participant's head and trunk, which were recorded by two video cameras. The results indicated that body sway was reduced during both saccadic eye movements and smooth pursuit movements when compared to fixation, independent of visual frequencies. These results suggested similarities in the control of saccades and smooth pursuit on postural control.

1. Introduction

Body sway is attenuated while performing saccadic eye movements when compared to a fixed gaze on a static target [1], especially when combined with a wide support base and a high frequency of visual stimuli [2]. Saccade conditions seem to require greater postural stability to spatially allow more accurate gaze shifts, indicating a functional integration of posture and gaze control [1], which is attained by afferent and efferent copy mechanisms. The afferent mechanism for the visual stabilization of posture tries to minimize the changes of the projected image on the retina; [3] whereas, the efferent copy mechanism tries to attenuate body sway in an attempt to connect pre- and post-saccadic views of the scene [4], which favors the spatial accuracy of the saccade with respect to the target location. Despite all the importance of saccades, this

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is not the only important eye motion, since sports and other activities also require eye movements to track (pursuit) objects moving in the environment [5].

Although, saccadic eye movements reduce body sway [1,2,6,7], visually pursuing a moving dot systematically increases body sway [8]. The different effects between these two eye movements on body sway may be attributed to the suppression of vision during saccades, as well as the continuous participation of smooth pursuit eye movements in the visual control of posture [8] in a non-stationary spatial frame of reference [9]. In addition, while saccade is a discrete movement that quickly changes the orientation of the eyes, translating the object of interest's image to the fovea, smooth pursuit is a continuous movement that rotates the eyes to compensate for the motion of the visual object, minimizing blur [10]. Furthermore, saccades have their magnitude established before the movement begins without the possibility of corrections during its course; whereas smooth pursuit movements are feedback-based such that their initiation depends on target motion. Smooth pursuit eye movement's velocity is linearly related to the target's velocity [4,11].

How these two eye movements affect postural control is still a matter of debate, particularly for smooth pursuit eye movements. Therefore, the aim of this study was to examine the effects of saccade and smooth pursuit eye movements on body sway magnitude during low and high frequencies. Considering, previous studies [1,2,8], it was hypothesized that body sway will decrease during saccades and increase during smooth pursuit movements, when compared to fixation control conditions. Different stimuli frequencies were expected to clarify whether changes in task demands interact with effects of distinct eye movements on postural control performance.

2. Material and methods

Ten young adults (19.5 ± 1.91 years) participated in this study. All participants were blinded to the purposes of the experiment and reported no history of falls, dizziness, or postural instability. One participant wore corrective glasses during the experiment. Prior to experimental procedures, participants signed a written consent form approved by the local ethics committee.

Participants were required to stand upright, barefoot for 70 s using a bipedal stance with feet hip width apart, fixating or pursuing a target that was displayed in a monitor positioned 100 cm away from their eyes. The target was a red dot 2 cm in diameter on a white background with a subtended visual angle of approximately 1.15°. The total distance between right and left side targets comprised a visual angle of 11° to avoid head movements [1]. Stimuli were generated by the software Flash Mx (Macromedia) and presented on a LCD monitor (37.5 cm × 30 cm, LG, Faltron L1952H, 50/60 Hz, 0.8 A). Each participant performed three trials under each of the following experimental conditions: a) eye fixed on the target—the target was displayed in the center of the monitor throughout the trial and the participants fixated their gaze on it; b) slow saccadic eye movement—participants performed saccades directed to the target appearing on one side of the monitor, then disappearing and reappearing immediately on the opposite side with a frequency of 0.5 Hz; c) fast saccadic eye movement—same task as the previous condition, but with a frequency of 1.1 Hz; d) slow smooth pursuit eye movement—participants pursued a target moving rectilinear and uniformly from one side of the monitor to the other with their eyes, with a frequency of 0.5 Hz; and e) fast smooth pursuit eye movement—same task as the previous condition, but with a frequency of 1.1 Hz. Trials were performed in a randomized order. One experimenter observed and verified each participant's appropriate eye movements using a small camera (Microsoft webcam, model 1407, 60 Hz) positioned above the monitor. After data collection, videos were analyzed to reconfirm the required eye movements for each condition.

Body sway was measured using reflective markers attached to the participant's head (posterior part, just above the occipital bone) and trunk (between the scapulae). The reflective markers were recorded using two video cameras (Sony DCR DVD 205 and 405) during each task with a sample frequency of 60 Hz. The recorded video images of all trials were cropped, tridimensionally reconstructed, and analyzed based on the space coordinates of the tracked markers (Software APAS, Ariel Dynamics, version 1).

A trial started 10 s after the subject and experimental condition commenced. The following dependent variables were obtained: trunk and head mean sway amplitude in the anterior–posterior (AP) and medial-lateral (ML) directions as the standard deviation in direction for the positional data throughout the trial; mean velocity in the AP and ML directions using displacement in each direction divided by the time of each trial; trunk and head total displacement calculated from the total trajectory length of the respective marker during the trial; and the sway area as the 95% confidence ellipse area of the data. Furthermore, the trunk and head mean and 95% of the frequency were calculated by employing spectral analysis of the position time series separately in each direction (Matlab software version 7.10, Mathworks).

For each dependent variable, a one-way analyses of variance (ANOVAs) with the 5 conditions (fixation, slow saccade, fast saccade, slow smooth pursuit, and fast smooth pursuit) treated as a repeated measures factor was performed. Tukey's post-hoc tests were carried out to identify the significant differences when the main effect was identified. All the analyses were performed using SPSS (version 15.0) and the significance level was set at 0.05.

3. Results

The ANOVA indicated significant differences only for the trunk and head mean sway amplitude in the AP direction (trunk: $F_{4,36} = 3.99$, $p = 0.05$ | head: $F_{4,36} = 4.67$, $p = 0.02$), total displacement (trunk: $F_{4,36} = 5.15$, $p = 0.01$ | head: $F_{4,36} = 4.52$, $p = 0.02$), and mean frequency in the AP direction (trunk: $F_{4,36} = 3.34$, $p = 0.04$ | head: $F_{4,36} = 2.77$, $p = 0.05$). No statistical significant differences were found for any other variable tested.

Trunk and head mean sway amplitude in the AP direction and total displacement were significantly affected by the visual condition (Table 1). Specifically, post-hoc analysis indicated significantly larger trunk and head sway during eye fixation when compared to the other four conditions. However, mean sway trunk and head frequencies, in the AP direction, were decreased during the fixation condition when compared to the other four conditions (Table 1).

4. Discussion

We manipulated visual conditions (fixation, saccades, and smooth pursuit eye movements) in order to examine their effects on postural control. We hypothesized that body sway would decrease during saccades and increase during smooth pursuit when compared to a fixed gaze. The findings of this present study confirmed our hypothesis for saccadic eye movements, but not for smooth pursuit eye movements. That is, eye movement using either type of movement, saccades or smooth pursuit, reduced body sway when compared to fixation, which concurs with the notion that reduction of body sway occurred to facilitate eye movements [1,2], contradictory to what previous studies reported about smooth pursuit effects on body sway [8]. Methodological differences between this study and the study of Laurens et al. [8] might account for the different results. Their experimental situation included hor-