HEAD ACCELERATIONS AFTER SLIPPING AND TRIPPING EXCEED THOSE DURING WALKING

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INTRODUCTION
Slipping and tripping contribute to a large number of falls and fall-related injuries among older adults [1]. Detecting the onset of a loss of balance after a slip or trip is critical in preventing a fall. The vestibular system provides sensory feedback on head orientation and motion. The purpose of this study was to compare peak linear head accelerations after slipping or tripping to those experienced during walking. This information can help determine whether vestibular information may be used to detect the onset of a slip or trip, and may guide the development of fall prevention strategies.

METHODS
Twelve young male adults (mean ± SD age: 20.9 ± 2.2 years) performed several walking trials along a 10m walkway at a prescribed gait speed (~1.5 m/s). After a minimum of 20 walking trials, an unexpected slip or trip (but not both) was induced to the dominant (right) foot.

Body segment positions of select anatomical landmarks on the head and feet were sampled at 200 Hz using a Vicon MX motion analysis system with T-10 cameras (Vicon Motion Systems, Inc., Los Angeles, CA). Head acceleration was sampled at 800 Hz using a lightweight six degree-of-freedom inertial measurement unit (IMU) (Memsense, LLC., Rapid City, SD) attached to the forehead. Marker position and acceleration data were low-passed filtered at 5 and 20 Hz, respectively.

Using methods similar to Startzell et al. [2] and Rivera et al. [3], head accelerations were converted to coordinate system aligned with the skull and transformed to an approximate location of the vestibular organ within the skull.

RESULTS AND DISCUSSION
Peak accelerations in each direction (anterior/posterior, rightward/leftward, superior/inferior) were determined over six time intervals following perturbation onset, and compared between tasks (walking, slipping, tripping) and time intervals using a two-way repeated measures analysis of variance on the ranks (due to non-normal distributions). In the event of a significant condition by time interval interaction, contrasts were performed within each time interval. Statistical analyses were performed using JMP Pro 11 (SAS Institute, Inc., Cary, NC) with a significance level of \( p \leq 0.05 \).

After slipping (Fig. 2), peak head acceleration did not differ from walking until the 100-150ms time interval after slip onset, and was 2.00 m/s² higher in the inferior direction compared to walking. Several other differences in peak head acceleration between tripping and walking were found over 50-300ms time interval after trip onset (\( p<0.05 \)), and the magnitude of these differences tended to increase with time (Fig. 1).
the magnitude of these differences tended to increase with time, but the magnitude of these differences was smaller than those seen during tripping.

Previous studies have shown muscle latency times of approximately 55-150ms [4] following trip onset. Because differences in head acceleration between tripping and walking were seen within 0-50ms of trip onset, these results suggest that vestibular information may play a role in generating a balance recovery response from a trip. However, previous studies have shown muscle latency times following a slip to be 90-160ms following a slip [5]. Differences in head acceleration between slipping and walking were not seen until 100-150ms of slip onset, suggesting that the vestibular system is less likely involved in the initial neuromuscular response to a slip.

Figure 1: Peak head acceleration (m/s\(^2\)) after tripping (dark gray) and during walking (white). Time 0 indicates the instant of trip onset and mid-swing during walking. * denotes a difference between tripping and walking (p<0.05). # denotes a main effect of condition (p<0.001). The top of columns indicate the mean and SD in the positive direction (anterior, right, and inferior), and the bottom of the columns indicate the mean and SD in the negative direction (posterior, left, and superior).

CONCLUSIONS
Peak head acceleration after slipping and tripping differed from those during walking. Differences occurred sooner after tripping compared to slipping, and the magnitude of these differences was larger after tripping than those after slipping. These results suggest that vestibular information may play a role in initiating a balance recovery response to a trip, but it remains unclear if such information contributes to recovery from a slip.

REFERENCES

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