INTRODUCTION

An increased risk of a second concussion following the first has been reported (Guskiewicz et al., 2000; Zemper, 2003). This indicates that a sensitive examination of post-injury recovery may be a critical component in concussion management. Gait balance disturbances have been identified in individuals following concussion. Individuals with concussion exhibit greater displacement and velocity of whole body center-of-mass (COM) in the frontal plane and smaller peak COM velocity in the sagittal plane during dual-task walking than individually matched and uninjured controls (Howell et al., 2013, 2014, 2015; Parker et al., 2006).

Laboratory-based measurements require substantial equipment not often available in clinical settings where post-concussion assessments are conducted. Hence, a need exists to develop protocols utilizing inexpensive, easily implemented alternatives that provide detection comparable to camera-based systems for measuring gait stability. Accelerometry offers such a cost-effective, readily available alternative for the objective measurement of gait following concussion.

The objective of this study was to examine sagittal and frontal plane accelerations, measured with an accelerometer during dual-task walking, in a cohort of participants with concussion regularly over a 2-month post-injury period and similarly in uninjured controls. It was hypothesized that differences in sagittal and frontal plane accelerations at critical gait events would be observed between concussion and control groups.

METHODS

Seventeen subjects were identified and recruited for testing. Ten subjects (7M/3F; mean age: 19.0±5.5 years) were diagnosed with a concussion by a healthcare professional (physician/athletic trainer) and were assessed in the laboratory within 72 hours of injury and approximately one week, two weeks, one month, and two months post-injury. Seven control subjects (3M/4F; mean age: 20.0±4.5 years) were also tested according to the same timeline. Prior to data collection, all subjects and parents/guardians (if under the age of 18) provided written consent to participate in the study.

All study participants walked barefoot at a self-selected speed along a walkway while simultaneously completing an auditory Stroop test. The Stroop test consisted of the subject listening to four auditory stimuli: the recorded words “high” or “low” spoken in either a high or low pitch. Subjects were instructed to identify the pitch of the word, regardless of whether the pitch was congruent with the word. While walking, participants wore an accelerometer (APDM Opal Sensor, Portland, OR) attached with an elastic belt at L5, so that the reference coordinate system x-axis was oriented vertically downward, the y-axis was oriented to the right, and the z-axis was oriented orthogonal to the x- and y-axes toward the front. Accelerometer data were used to identify linear accelerations in the anterior-posterior and medial-lateral directions, obtained at a sampling frequency of 128Hz and saved via data-logger for offline post-processing.

The peak forward acceleration was identified at approximately 50% of the gait cycle (Figure 1A). Three distinct peak medial-lateral accelerations were identified: 1) during 25–45% of the gait cycle, 2) during 45–55% of the gait cycle, and 3) during 55–75% of the gait cycle.
Figure 1: Exemplary COM acceleration profiles in the (A) forward and (B) medial-lateral directions for a gait cycle.

55–75% of the gait cycle (Figure 1B). Absolute values were used in further analysis to normalize between right and left directions. Peak accelerations were analyzed by two-way mixed effects analyses of covariance, with average gait velocity as a covariate, in order to determine the effect of group (concussion and control), time (72 hours, 1 week, 2 weeks, 1 month, and 2 months post-injury) and the interaction between these two independent variables.

RESULTS

Results indicated no significant interactions, or main effects of group or time for mean peak forward acceleration (Figure 2A, \( p > .05 \)). Peak medial-lateral accelerations 1 and 2 analyses also revealed no significant interaction effects, or main effects of group or time (Figures 2B and 2C, \( p > .05 \)). Peak acceleration 3 results indicated that subjects with concussion displayed less peak frontal plane acceleration during 55%-75% of the gait cycle during dual-task walking than control participants throughout the two months of testing (main effect of group \( p = .04 \), Figure 2D).

DISSCUSSION AND CONCLUSIONS

Data from this study indicate that during dual-task walking, participants with concussion displayed less peak medial-lateral acceleration than control participants during 55%-75% gait cycle, representing the transition from double-support to single-support phases and suggest that concussion may affect the ability to regulate whole-body side-to-side balance control during dual-task gait, possibly due to poor COM acceleration generation and regulation. The examination of acceleration may provide a feasible way to detect dynamic balance deficits in the clinical setting using readily available technology.

Figure 2: Mean ± SE peak acceleration data for concussion and control groups across the two months of testing peak forward (A) and peak medial-lateral (B/C/D) directions. Including average gait velocity as a covariate, results indicated a significant difference between groups across the two months of testing for peak acceleration 3 (D).

REFERENCES