Effects of Concussion History on Center of Mass Motion During Modified Balance Error Scoring System (BESS) Testing in Women

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Introduction

Concussion and mTBI continues to account for a substantial proportion of the military healthcare burden.[1] Concussion is commonly associated with balance deficits, which are likely related to impaired processing of sensory information.[2] These deficits, in turn, have the potential to impact activities of daily life, job performance, and risk of re-injury as balance is considered a foundational component of nearly all motor behaviors. Impaired balance may present clinically as increased postural sway, particularly in the absence of posture-relevant sensory information.

It has been reported in athletics and in the armed services that women are concussed at comparable rates,[3] experience more severe concussion-related symptoms and limitations, and have longer recovery times when compared with men.[4] Despite these discrepancies in epidemiology, data concerning female-specific neuromotor effects of concussion/mTBI are lacking.[5,6] This poses unnecessary additional risk to brain-injured women as clinical assessment and decision-making may disproportionately rely on knowledge that was developed through the observation of male research subjects.

Previous work has demonstrated sex differences in movement behaviors[7] as well as the relevance of these differences to injury and injury recovery. It is reasonable therefore to suspect that the postural control effects of concussion/mTBI in females are distinct and should be considered separately. The purpose of this research was to identify neuromotor deficits (specifically, balance) between service-age healthy women (CTRL) and women with a history of concussion/mTBI (mTBI). We hypothesized that that history of concussion would be associated with increased postural sway motion and velocity.

Methods

Thirty-one healthy women and 24 women with a history of concussion/mTBI were performed 3 20-second balance trials. Procedures for balance testing were based on the modified Balance Error Scoring System (BESS[8]) protocol and featured 1 trial each of Double Leg (DS), Single Leg (SS), and Tandem (TS) stance. Each testing condition required subjects to stand barefoot with eyes closed and hands-on-hips. DS was performed in bilateral stance, SS was performed standing on the non-dominant limb with a slight bend in the hip and knee of the non-standing leg, and TS was performed with feet inline heel-to-toe (non-dominant limb behind dominant limb). Participants were instructed 1) to remain as motionless as possible throughout a given trial, and 2) to return to the testing pose quickly should the testing position be lost.

Video, infrared, and depth data were acquired using a Microsoft Kinect 2.0™ at a variable frame rate (maximum 30 Hz, not under direct control of the user). These raw data are used to estimate 3D joint center time histories through an on-board classification algorithm. Joint center displacement histories were stored to a local machine running a custom C# software interface. This data was used then used offline to define segment end points, from which the 3D center of mass (COM) displacement time series was estimated using established methods.

Mean velocity (VEL) and standard deviation (SD) of displacement were used to summarize COM motion for each trial in the anteroposterior (AP) and mediolateral (ML) directions. Group performance (CTRL vs. mTBI) was then compared using one-sided Welch's independent samples t-tests for each outcome/stance combination. The *a priori* significance level was $\alpha = 0.05$.

Results

Significant group effects were observed (CTRL < mTBI) in the DS condition for all outcomes (**VEL_{ML}**: CTRL = 0.93 ± 0.72 cm/s, mTBI = 2.83 ± 2.77 cm/s, $t = -3.17_{(25.41)}$, $p < 0.01$; **VEL_{AP}**: CTRL = 1.55 ± 2.58 cm/s, mTBI = 3.21 ± 2.64 cm/s, $t = -2.07_{(40.44)}$, $p < 0.02$; **SD_{ML}**: CTRL = 0.49 ± 0.50 cm, mTBI = 1.79 ± 1.88 cm, $t = -3.18_{(25.50)}$, $p < 0.01$; **SD_{AP}**: CTRL = 0.89 ± 1.72 cm, mTBI = 1.89 ± 1.60 cm, $t = -1.97_{(39.14)}$, $p < 0.03$).

Significant group effects were observed (CTRL < mTBI) in TS condition for **VEL_{ML}** (CTRL = 2.51 ± 0.95 cm/s, mTBI = 4.55 ± 3.71 cm/s, $t = -2.38_{(21.50)}$, $p < 0.01$) and **SD_{ML}** (CTRL = 1.60 ± 0.78 cm, mTBI = 3.53 ± 3.40 cm, $t = -2.47_{(21.01)}$, $p < 0.01$).

No effects were observed in the SS condition ($p > 0.05$).

Conclusion

These data support the conclusion that, relative to healthy female controls, postural control in women with a history of concussion/mTBI is characterized by increased variability and velocity of the COM. The effects we report appear to be specific to the DS and TS conditions. The null finding in the SS condition was unexpected as, among the three, this stance is frequently associated with the poorest balance outcomes.[8] While this pattern of findings may be anomalous, it is also possible that single leg postural control is not effective in discriminating healthy controls from previously concussed individuals in this population. Previous research has demonstrated sex differences in baseline/uninjured balance outcomes wherein females were observed to have better postural control than males using similar experimental tasks.[9] This could suggest that factors related to sex contribute to the presently observed pattern of group effects (healthy vs. concussion/mTBI history), which may be unexpected owing to underrepresentation of females in prior work. If the effects we report are true, post brain-injury balance testing in women may be more appropriately limited to DS or TS conditions.

Further research is warranted to investigate sex-specific effects of concussion/mTBI on balance behaviors prospectively and in direct comparison with comparable male samples. Future work should also consider mechanisms that might account for differential baseline and post-injury behaviors between men and women, such anthropometrics and lower extremity alignment.

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Disclosure Statement
The authors have no conflicts of interest to disclose.

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