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Self-reported balance status is not a reliable indicator of balance performance in adolescents at one-month post-concussion

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ABSTRACT

Objectives: To determine if self-reported balance symptoms can be used as a proxy for measures of the center of pressure (COP) to identify balance deficits in a group of concussed adolescents.

Design: Case-control.

Methods: Thirteen adolescents 1-month post-concussion who reported ongoing balance problems (Balance+), 20 adolescent 1-month post-concussion who reported no balance problems (Balance–), and 30 non-injured adolescents (control) completed a series of balance tests. Participants completed two 2-min trials standing on a Nintendo Wii Balance Board™ during which the COP under their feet was recorded: i) double-leg stance, eyes open; ii) double-leg stance, eyes closed. Participants also completed a dual-task condition combining a double-leg stance and a Stroop Colour-word test.

Results: Participants in both the Balance+ and Balance– group swayed over a larger ellipse area compared to the control group while completing the Eyes Closed (Balance+, $p = 0.002$; Balance–, $p = 0.002$) and Dual-Task (Balance+, $p = 0.001$; Balance–, $p = 0.004$) conditions and performed the Dual-Task condition with faster medio-lateral velocity (Balance+, $p = 0.003$; Balance–, $p = 0.009$). The participants in the Balance– group also swayed over a larger ellipse area compared to the control group while completing the Eyes Open condition ($p = 0.005$). No significant differences were identified between the Balance+ and Balance– groups.

Conclusions: At 1-month post-concussion, adolescents demonstrated balance deficits compared to non-injured adolescents regardless of whether they reported balance problems. These results suggest that self-reported balance status might not be an accurate reflection of balance performance following a concussion in adolescents

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1. Introduction

A concussion can be a significant event in the life of an adolescent and can lead to acute symptoms as well as long-term consequences. In contrast to most other injuries, no simple test can be administered to diagnose a concussion,¹ thus clinicians rely largely on symptoms for diagnosis and management.² Balance problems are an important marker of concussion presenting in approximately 30% of concussion cases³ and affecting up to 50% of adolescents with a sports-related concussion.⁴ Balance problems,

specifically the inability to control the position of the center of gravity during tandem stance, in conjunction with other variables measured within 48 h post-concussion, have been shown to be a moderate predictor for persistent symptoms lasting up to at least 28 days post-injury in children and adolescents.⁵

Balance is defined as the ability to maintain the vertical projection of one's center of mass within the base of support.⁶ During quiet upright standing, small deviations from a perfect upright position continuously occur.⁷ The postural control system coordinates and integrates information from multiple sensory systems to generate the appropriate motor outputs in order to correct for these postural deviations.⁸ These motor outputs, often the dorsi- and plantarflexors at the ankle, directly reflect the neural control of the ankle musculature and result in movement of the center of pressure

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(COP) under the feet. Thus, the trajectory of the center of pressure ensures the appropriate acceleration and deceleration of the center of mass for stability.⁹

Balance problems are often clinically identified with symptom checklists and scales for which the patient is asked to indicate the presence or absence of specific concussive symptoms and is usually required to rate the severity of present symptoms. However, some athletes who have experienced a concussion may not fully disclose their symptoms in order to prevent removal from sport participation or to return to play sooner.¹⁰ As a result, caution should be taken when making clinical decisions based on self-reported symptoms. In addition, although several symptom checklists and scales are available to aid in the assessment of concussions, the psychometric properties of most of these scales and checklists are not known.²

It has been suggested that objective assessments be used in addition to self-reported symptoms in order to increase the sensitivity of a concussion assessment.¹¹ While most concussive symptoms cannot be objectively quantified, balance can be measured objectively by recording anterior-posterior (A/P) and medio-lateral (M/L) movements of the center of pressure (COP). Including such measures in a concussion assessment would likely increase the likelihood of identifying balance deficits in individuals who have experienced a concussion compared to focusing solely on self-reported symptoms. However, there is a paucity of studies examining the association between self-reported balance symptoms and balance performance on COP measures in individuals with concussion.

The lack of agreement between self-report and objective measures of balance has been proposed in a previous study.¹² Children and adolescents within 6 h post-concussion had larger COP displacements during quiet standing than control participants suggesting impaired balance. The results also revealed that self-reported balance symptoms were not predictive of standing balance performance in concussed adolescents, suggesting that self-reported symptoms are not associated with COP measures following a concussion. Yet, it is not clear if this lack of association is due to lack of reporting (e.g., the adolescents identified as having impaired balance on the COP measures did not disclose balance-related symptoms) or due to lack of fidelity of the assessment to detect deficits (e.g., quiet standing does not have adequate sensitivity to detect impaired balance in those adolescents reporting balance-related symptoms).

The purpose of this study was to further explore the relationship between self-reported balance problems and objectively measured balance performance in adolescents who have experienced a concussion to determine whether self-reported balance status is an adequate proxy for objective measures of balance. COP velocity and displacement values were compared between adolescents at 1-month post-concussion who reported ongoing balance problems, adolescents at 1-month post-concussion who reported no balance problems, and non-injured age-matched control participants. It was hypothesized that the group of concussed adolescents reporting balance problems would show significant differences on the COP measures compared to the control group, but that there would be no significant group differences between the group of concussed adolescents reporting no balance problems and the control group.

2. Methods

Adolescents (aged 12–17 years) diagnosed with a concussion by a physician in the emergency department (ED) at a regional tertiary hospital were recruited through a larger study.⁵ The adolescents were recruited in the ED and contacted by phone to schedule an appointment to complete the protocol for the current study. The

diagnosis of concussion used for the larger study was based on the criteria from the Zurich consensus statement:¹³

A direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head, resulting in one or more symptoms in one or more of the following clinical domains (which may or may not have involved loss of consciousness):

- Somatic symptoms (e.g., headache, nausea, loss of balance, dizziness, sensitivity to light or noise, visual problems and clumsiness).
- Cognitive symptoms (e.g., feeling like in a fog, difficulty concentrating or remembering, answering questions more slowly and confused with directions/tasks).
- Emotional/behavioural symptoms (e.g., irritable, sad, nervous and emotional lability).
- Sleep disturbance (e.g., sleeping more, fatigue, drowsiness and insomnia).

Exclusion criteria were Glasgow Coma Scale¹⁴ less than 14, abnormalities observed on neuroimaging (if performed), operative intervention or procedural sedation required, or presentation with multisystem injuries requiring admission.

Participants with concussion were divided into two groups based on whether their self-reported balance status at 1-month post-injury was as good as/better than before their injury (Balance– group) or worse than before their injury (Balance+ group). A third group of participants (control group) consisted of adolescents between the same ages who reported no concussive symptoms and who had not suffered any head trauma within the last year. These participants were recruited from the community at large.

Self-reported balance status was determined based on the participant's response to the balance-related item on the Post-Concussion Symptoms Inventory (PCSI).¹⁵ Participants completed the PCSI when they completed the protocol for the current study at approximately 1-month post-injury. Participants used a 6 point scale to rate their balance problems pre- and post-injury with "0" indicating no problem, "3" indicating a moderate problem and "6" indicating a severe problem. Participants reporting a 1-point or more increase in balance problems between their post-injury rating and their pre-injury rating were placed in the Balance+ group. Participants who reported no change or a decrease in balance problems between their post- and pre-injury rating were placed in the Balance– group.

Prior to participating in the study, all participants and their parent provided written informed consent. This study was approved by the institution's ethics research board (Children's Hospital of Eastern Ontario Research Ethics Board). All participants completed the balance testing protocol once. Participants with concussion completed the protocol between 28 and 40 days post-injury. Participants completed a series of balance tasks while standing on a Nintendo Wii Balance Board. The Wii Balance Board has been shown to be a valid alternative to a force plate to collect the COP. The error between COP trajectories recorded with a Wii Balance Board and a force plate has been shown to be minimal: 0.33 mm–0.58 mm in the medio-lateral direction and 0.31 mm–0.63 mm in the anterior-posterior direction.¹⁶ In addition, very strong correlations ranging from 0.99 to 1.00 have been reported between COP trajectories recorded with both devices and variables computed from these trajectories.^{16,17}

Participants first stood with their feet shoulder width apart and held this position for two minutes with their eyes open (Eyes Open) and then with their eyes closed (Eyes Closed). For both conditions, participants were instructed to focus on standing as still as possible for the entire trial. Participants then completed a dual-task condition (Dual-Task), which consisted of standing on the Wii Balance Board with their feet shoulder width apart while completing

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