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# Tracking postural stability of young concussion patients using dual-task interference

Jason C. Dorman[a,*], Verle D. Valentine[b,c], Thayne A. Munce[a,c], B. Joel Tjarks[c], Paul A. Thompson[c,d], Michael F. Bergeron[a,c]

[a] National Institute for Athletic Health & Performance, Sanford USD Medical Center, United States
[b] Sanford Orthopedics & Sports Medicine, Sanford USD Medical Center, United States
[c] Sanford School of Medicine, University of South Dakota, United States
[d] Methodology and Data Analysis Center, Sanford Research, United States

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ABSTRACT

*Objectives:* This study examined the diagnostic benefit of using dual-task interference balance testing in young concussion patients and the longitudinal changes in postural stability that occur relative to other standard clinical assessments of concussion injury.
*Design:* Longitudinal, case–control.
*Methods:* Eighteen patients (16.6 (1.6) y) diagnosed with a concussion provided 22 separate ratings to characterize the severity of their current concussion-related symptoms and were evaluated for postural stability at each of four clinical visits. Twenty-six injury-free adolescents (17 (2.8) y) performed balance testing on two occasions, separated by ~1 week.
*Results:* There was a progressive decrease in self-reported symptoms from visit 1 to visit 4 ($P < 0.0001$–$0.001$). A similar improvement occurred in postural stability, indicated by 95% ellipse area and velocity. However, the differences in ellipse area and velocity were significant only between visit 1 and the rest of the visits as a whole ($P < 0.0001$–$0.05$). There was a significant difference between concussion patients and healthy, injury-free participants in ellipse area and velocity during visit 1. A group difference was also observed in ellipse area on visit 2, but only during the two balance tests that involved a concomitant secondary cognitive task.
*Conclusions:* Improvements in postural stability coincide with reductions in reported symptoms, though apparent recovery of these selected measures of postural stability seemingly occurs sooner. Because of the distinguishing time course of recovery indicated by dual-task interference balance testing, this type of balance testing assessment may be particularly valuable in evaluating integrated functional impairment and recovery in young concussion patients.


## 1. Introduction

The signs and symptoms of a concussion are critical to the evaluation and treatment of mild traumatic brain injury. Symptoms can be subtle, may not appear immediately, and can last for varying periods (hours, days, or weeks). Medical personnel are dependent upon patients' self-appraisal and reporting of concussion symptoms during a clinical evaluation; however, self-reporting might not always be reliable.[1–3] In sports, this may be due to an athlete's desire to play outweighing the value of an honest response, being conditioned to downplay pain and injury to coaches, teammates and opponents, or thinking that the symptoms are not due to head trauma and a resulting concussion.[1] Alternatively, patients are asked to subjectively rate their current post-concussion symptoms at that particular moment in time in circumstances that may not prompt symptoms. This can lessen accurate characterization of symptoms that the patient is currently experiencing. Self-reported symptom scales can indeed aid in detection of concussions and assist clinicians in determining when a patient can return to play and resume other activities. However, clinicians should also appreciate that these scales have not gone through comprehensive scientific scrutiny and validation.[4] Accordingly, there is a recognized need for more objective measures that can independently determine and clarify concussion recovery. There would be even greater utility if more sensitive and objective measures indicated incomplete concussion recovery beyond resolution of standard signs and symptoms. If validated,

* Corresponding author.
*E-mail addresses:* jason.dorman@sanfordhealth.org, jachdo@hotmail.com (J.C. Dorman).

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such new diagnostic tools could prompt and support continued accommodation and potential activity restrictions, while more assuredly averting premature full return.

With a concussion, there is often a temporary reduction in postural stability that is particularly evident when an affected individual is evaluated close to time of injury.[5] Postural stability may be further challenged and a balance deficit revealed with a dual-task scenario (i.e., simultaneous cognitive and balance demands).[5] In this study, we examined the diagnostic utility of using dual-task cognitive interference balance testing (BT) in young concussion patients. We also investigated the longitudinal changes in these and other balance measures relative to standard clinical assessments and indicators of concussion injury. Accordingly, we hypothesized that a sequential analysis of postural stability using these selected BT protocols would provide a discrete, independent indicator of concussion status and recovery, as indicated by a parallel resolution of concussion symptoms. Secondly, we expected that the dual-task BT incorporating a concomitant cognitive challenge would be a more discriminating indicator of a postural stability deficit and progressive concussion recovery than BT without a cognitive interference.

Because BT with an added cognitive task is a relatively new assessment in concussion care, optimal protocols and reference standards have not yet been established. Accordingly, this research helps to establish the validity of this method, while offering clinicians another objective tool to assist in the evaluation and management of this increasingly prevalent condition.

## 2. Methods

Eighteen patients (10 male, 8 female; 16.6 (1.6) y) diagnosed with a concussion (INJ) by a board-certified sports medicine physician were recruited through a local sports medicine clinic (Sanford Orthopedics & Sports Medicine Clinic; Sioux Falls, SD, USA) to participate in this study. Twenty-six injury-free adolescents (14 male, 12 female; 17.2 (2.8) y) were recruited from local sport teams as healthy, normative (NORM) participants. Prior to being involved in the study, participants 18 y and older provided informed consent, while all younger participants provided assent with parents providing informed consent. The study was approved by an ethics committee (Sanford Health Institutional Review Board) designated for all human investigations and the ethical guidelines for recruitment, informed consent and conduct of the study were closely followed by the investigators.

An INJ patient was eligible to participate in the study if his/her initial examination in our clinic was within 10 days of a suspected head injury and the resulting clinical condition was determined to be a concussion by a sports medicine physician trained in diagnosing and treating concussions. Only patients who had been evaluated and performed concussion-related testing at least four times in the clinic over the course of their recovery period were included in these analyses. It should be noted that these inclusion criteria resulted in the selection of a unique cohort of concussion patients, as they had unresolved concussion symptoms over an extended period of time. The amount of time between each of the four clinical visits (V1–4) varied from patient-to-patient, and was based on the recommendation from the examining physician (average was 15 days between V1 and V2; 24 days between V2 and V3; and 29 days between V3 and V4). The concussion evaluation procedure included assessments of self-reported symptom scores and balance tests for postural stability at concomitant time points.

Potential NORM participants were excluded if they had a concussion in the past year and/or had any vision, vestibular or other known condition that could have negatively affected postural stability. Each NORM participant was evaluated two times, separated by approximately one week. The NORM group was included in this investigation to establish reference values for the selected balance protocol and outcome measures in age-matched, healthy individuals, as well as to establish the reliability and consistency of the outcome measures across repeated measurements. Only two visits were deemed necessary to determine reliability of the balance protocol. Moreover, no further changes were anticipated over time in the NORM group that would have necessitated additional visits.

BT for postural stability was performed on a strain gauge force platform (AMTI Newton, MA). Each subject stood on the force platform, without shoes on, facing forward, with his/her feet shoulder width apart and hands on hips, while attempting to be as steady as possible under four conditions: (1) eyes open (O), (2) eyes open with a cognitive task (reciting months of the year backwards; OT), (3) eyes closed (C) and (4) eyes closed with the same cognitive task (CT). All tests were performed in the same order on each subsequent visit in order to consistently assess clinical progress. For each test condition, participants' center of pressure (COP) positional changes were tracked for a period of 20 s with a sampling rate of 100 Hz and recorded using an integrated computer and diagnostic software (BioAnalysis). Two commonly used COP testing variables, 95% ellipse area (EA) and velocity ($V$) were used as markers of postural stability for each study participant.

During each INJ patient's four clinical visits, a certified athletic trainer asked the patient to characterize the severity of his/her current concussion-related symptoms using a post-concussion symptom scale (PCSS). Responses for rating each of the 22 symptoms were based on a 7-point Likert-type scale ("0" = no symptom; "6" = severe symptom). Symptoms were grouped into four clusters: physical-, cognitive-, emotional- and sleep-related. The NORM participants were not asked to provide any symptom ratings.

Data were examined and screened for extrema (none considered unusual were found). A power analysis (subject sample size) was not performed because the study, done in conjunction with clinical assessment and treatment, was exploratory in nature. Summary statistics for EA, $V$, and PCSS were computed. The data were structured as a 4-factor design, including Participants (INJ or NORM), Visual Condition (Eyes Open or Closed), Cognitive Task (No Task or Task), and Time (V1–4 for INJ; V1 and V2 for NORM). The Visual Condition and Cognitive Task factors were combined to provide the 4 BT levels (O, OT, C and CT). Primary statistical analysis was performed using PROC MIXED in SAS V 9.3, with an AR(1) model for the covariance matrix. As the most important lines of inquiry were between specific combinations and comparisons of design cells within the four-factor design, planned contrasts were used to properly test these specific questions. The overall 4-factor design (main effects and interactions) was not examined per se for several reasons. First, visits are not entirely comparable between INJ and NORM, as the two groups have different numbers of and time between visits. Secondly, total symptoms scores were collected only in INJ. To examine the change in balance measures (EA and $V$) for each condition over all visits and in symptoms over all INJ visits, mixed-model repeated measures were used. For these analyses, unstructured covariance matrices were used to impose a no-covariance structure. V1 was compared against the remaining three visits, V2 against the remaining two and V3 against V4, in order to detect a "break" in the slope of means. All data for EA, $V$ and PCSS are expressed as mean (SD). Statistical significance for all analyses was set at $P < 0.05$.

## 3. Results

There was a progressive decrease in PCSS scores from V1 to V4 (Fig. 1). Compared to V1, scores for V2, V3, and V4 were collectively lower ($P < 0.0001$), as was the case for V3 and V4 compared to V2 ($P < 0.0001$). Symptom scores for V4 were also lower than