The Value of Balance-Assessment Measurements in Identifying and Monitoring Acute Postural Instability Among Concussed Athletes

Andrea Cripps and Scott C. Livingston

Clinical Scenario: Sport-related concussions are a significant health issue due to the high incidence of concussions sustained each sports season. Current approaches to the evaluation of acutely concussed athletes include the use of balance assessments to identify and monitor underlying postural instability arising from concussion. Balance assessment has been recommended as a primary measurement tool for monitoring recovery and for making return-to-play decisions. Balance impairments have been shown to occur in the initial postconcussion period (ie, 1–10 d). Numerous clinical and laboratory measures have been used in the assessment of balance immediately after concussion, and clinicians are faced with deciding which measures to use. Focused Clinical Question: How do clinical or field-based balance-assessment tools compare to laboratory-based balance measures in identifying deficits in postural stability among acutely concussed athletes?

Keywords: mild traumatic brain injury, sports, Sensory Organization Test, Balance Error Scoring System

Summary of Search, “Best Evidence” Appraised, and Key Findings

• Research studies containing level 2b or higher evidence and that investigated clinical or laboratory measures used to assess balance impairments after a sports-related concussion were sought.
• Three cohort studies were included. All 3 studies demonstrated postconcussion balance deficits as measured by either a clinical or a laboratory balance-assessment technique.

One research study1 used the Sensory Organization Test (SOT). Balance deficits were observed 24 hours after concussion. Balance scores returned to baseline in 1 to 3 days in 1 study, but performance was not similar to that of control subjects until day 5 postinjury.

Two of the studies2,3 used the Balance Error Scoring System (BESS). Decreased balance was observed 1 and 3 days after concussion compared with baseline performance. Concussed subjects demonstrated decreased balance for up to 5 days postinjury.
Clinical Bottom Line

The BESS (a clinical and field-based balance assessment tool) is comparable to the SOT (a laboratory-based balance measure) in identifying balance deficits in acutely concussed athletes. **Strength of Recommendation:** Level B evidence exists that clinical and laboratory measures can be used to measure balance impairments in concussed athletes in the days after a concussion.

Search Strategy

**Terms Used to Guide Search Strategy**

- **Patient/Client group:** child (0–18 y) or young adult (19–25 y) and concussed athletes
- **Intervention/Assessment:** clinical balance assessments
- **Comparison:** clinical- and field-based balance assessments or laboratory-based balance assessments
- **Outcome:** laboratory balance assessment

**Sources of Evidence Searched**

- Medline
- CINAHL
- SPORTDiscus
- Additional resources obtained via forward search, hand search, and expert opinion

**Inclusion and Exclusion Criteria**

**Inclusion Criteria**

- Limited to English language
- Limited to humans
- Limited to the last 11 years (2001–2011)
- Level 2 evidence or higher
- Research studies investigating balance after a single episode of concussion in athletes
- Limited to children (0–18 y) or young adults (19–25 y)

**Exclusion Criteria**

- Review studies
- Samples including subjects more than 25 years of age
- Research studies investigating balance impairments among individuals other than athletes with concussion or mild traumatic brain injury
- Research studies investigating balance impairments associated with dual-task paradigms

**Results of Search**

Three relevant studies were located, and all were categorized as level 2b (Table 1), based on Level of Evidence, Centre for Evidence-Based Medicine, 1998.

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Study design</th>
<th>Number located</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2b</td>
<td>Cohort</td>
<td>3</td>
<td>Cavanaugh et al¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>McCrea et al³</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Guskiewicz et al²</td>
</tr>
</tbody>
</table>

Best Evidence

Three research studies were determined to be the best sources of evidence to answer the clinical question and, therefore, included in this clinically appraised topic (CAT; Table 2). The articles were chosen because of the level of evidence in the design, they measured balance after a concussion in athletes, and they measured balance impairments on either a clinical or a laboratory assessment tool or described both a clinical and a laboratory assessment tool.

Implications for Practice, Education, and Future Research

The results of all of the research studies reviewed in this CAT demonstrated a significant decline in balance in the days immediately after a concussion when compared with both the control group and baseline data (as measured by the SOT and BESS). These results indicate that both clinical/field and laboratory measures are beneficial in evaluating balance deficits in the first 1 to 5 days after a concussion. When considering which balance assessment to use, it is important to determine the testing environment (eg, laboratory, clinic, sideline) and the available amount of time and resources. The SOT is a commonly used laboratory-based balance-assessment tool²,⁴,⁵ but is not practical for routine clinical or sideline use. Clinical or sideline assessments such as the BESS provide the clinician with a rapid and efficient assessment of balance after concussion on the sideline or in the clinic. The BESS has been validated against the SOT⁶,⁷ and, despite the fact that these tests have different outcome measures, both measure similar constructs. Another important consideration for clinicians assessing postural stability is the frequency and duration of testing in the postconcussion period. As all 3 studies in this review monitored recovery for 5 to 10 days postconcussion, we recommend tracking recovery over a similar time course. Clinicians assessing balance after a concussion should consider which type of balance assessment would be most beneficial to the athlete’s specific needs. The assessment needs to take into account a variety of testing conditions (visual input/feedback, support surface used during testing) and should be administered over a specific period of time. All articles reviewed in this CAT demonstrated deficits in balance after concussion that persisted for up to 5 days, but they failed to track recovery in comparison.
Table 2  Characteristics of Included Studies

<table>
<thead>
<tr>
<th>Study design</th>
<th>Participants</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort</td>
<td>27 Division I college athletes (21 M, 6 F) age 17–22 y (mean 19.5) sustained a concussion between 1997–2003 during practice or competition</td>
<td>All subjects underwent preseason balance testing. Concussed subjects were tested within 48 h after concussion. Control subjects were tested at same time intervals. Subjects completed a SOT on the NeuroCom® Smart Balance Master System. The SOT consisted of 6 conditions with three 20-s trials for each condition. Subjects completed 1 trial from each condition first, then randomly completed the remaining 12 trials.</td>
</tr>
<tr>
<td>Cohort</td>
<td>94 concussed college football players from 15 who sustained concussions in 1999–2001 seasons: age 20.04 ± 1.36 y, academic year 2.78 ± 1.18, height 73.50 ± 2.94 in, weight 105.87 ± 21.10 kg, number of previous concussions in past 7 y 0.58 ± 0.78. 56 control subjects were matched for age, years of education, and baseline performance: age 19.20 ± 1.45 y, academic year 2.02 ± 1.23, height 72.75 ± 3.23 in, weight 98.33 ± 20.79 kg, number of previous concussions in past 7 y 0.39 ± 0.68.</td>
<td>All subjects (N = 150) were assessed preseason using the GSC, the SAC, the BESS, and a neuropsychological test battery that was used in prior studies (including the Hopkins verbal learning test, Trail-Making Test A and B, Digit Span Test, Symbol Digit Modalities Test, Grooved Pegboard Test, dominant and nondominant hand, and the Controlled Oral Word Association Test.) Concussed subjects underwent repeated testing at the same time intervals as controls on the GSC, SAC, and BESS 2–3 h after injury and again on days 1, 2, 3, 5, 7, and 90. Neuropsychological testing was repeated on days 2, 7, and 90 after injury. No blinding was conducted.</td>
</tr>
<tr>
<td>Cohort</td>
<td>36 concussed college athletes (age 19.5 ± 1.34 y) and 36 matched controls (age 20 ± 2.36 y). Athletes completed baseline preseason testing using 2 measures of postural stability (SOT and BESS), as well as a neurocognitive test battery. Control subjects were matched for age, height, weight, and sport and excluded if they had sustained a concussion in the past 6 mo, had a vestibular deficit, or had an acute musculoskeletal injury that affected postural stability or equilibrium. All concussed athletes were evaluated by an ATC and team physician. Number of participants by sport, n = 36 per group: 3 cheerleading, 1 women’s crew, 3 men’s basketball, 1 field hockey, 10 football, 5 men’s lacrosse, 5 women’s lacrosse, 1 women’s rugby, 1 women’s soccer, 1 men’s soccer, 1 softball, 1 men’s track, 3 wrestling.</td>
<td>Two measures of postural stability: (1) SOT using NeuroCom Smart Balance Master, which measured vertical ground-reaction force produced by the body’s center of gravity movement; 18 trials (20 s/trial) under 6 different conditions, and (2) BESS, which measured the number of errors committed during 3 stance positions (single leg, double leg, and tandem) and 2 surface conditions (firm and foam). Subjects completed six 20-s trials. Neurocognitive testing (Trail-Making Test A, Trail-Making B, Wechsler Digit Span Test, Stoop Color Word Test, and Hopkins Verbal Learning Test) were conducted. Postconcussion signs and symptoms were also recorded (scale for recording not stated). All subjects were tested preseason (baseline assessment). Concussed subjects were tested 1, 3, and 5 d after injury. Control subjects were tested at same time intervals.</td>
</tr>
</tbody>
</table>

(continued)
Outcome measures

Equilibrium score, AP and ML ApEn values. These values were determined by using the peak-to-peak amplitude of COP AP displacement to estimate the amount of postural sway in the sagittal plane.

Main findings related to balance

Concussed subjects’ ApEn values declined after injury for all sensory conditions ($F_{1.55} = 6.36, P = .02$).

ApEn values were significantly different between groups (concussed and control, $F_{1.165} = 2.75, P = .04$) and between SOT conditions (conditions 1–6; $F_{3.365} = 2.75, P = .04$).

Concussed athletes display a relatively dramatic decrease in variability in COP ML oscillations across all sensory conditions.

Level of evidence

2b
Not applicable
2b

Validity scores

Not applicable
Not applicable
Not applicable

Conclusion

Sport-related concussions result in measurable deficits in postural control using CDP.

Likert rating 0–102 on GSC, total score (0–30) on SAC, number of errors on BESS, and total score on individual measures in neuropsychological tests.

All athletes who sustained a concussion ($n = 94$) participated in the study protocol.

No information on unidentified or unreported concussions.

Most significant deficits in balance occur during first 24 h after concussion but returned to baseline by day 5 postinjury.

Concussed subjects demonstrated decreased postural stability on SOT on day 1 in comparison with their baseline. Deficits in postural stability were observed comparing concussed with control group on each day (1, 3, and 5) after concussion.

A significant group-by-day interaction ($F_{3.210} = 2.68, P < .05$) on the BESS. Concussed subjects demonstrated decreased postural stability on days 1 and 3 when compared with baseline, as well as days 1, 3, and 5 when compared with controls.

Significant changes in postural stability are evident after concussion in athletes (as measured on the SOT and BESS).

Abbreviations: ATC, certified athletic trainer; SOT, Sensory Organization Test; BESS, Balance Error Scoring System; GSC, Graded Symptom Checklist; SAC, Standardized Assessment of Concussion; AP, anteroposterior; ML, mediolateral; ApEn, approximate entropy; COP, center of pressure; CDP, computer dynamic posturography.
with a control group. Tracking deficits over a longer time period may lead to a better understanding of whether balance returns to values comparable to those of healthy controls. Clinicians monitoring and tracking recovery for a period of up to 10 days, or until balance returns to baseline measurements, will be able to make more informed return-to-play decisions. Clinicians should strive to obtain baseline balance measurements using the type of postural-stability assessments that they will use to monitor concussed athletes. Overall, clinicians should strive to obtain baseline values on whichever tools they will be using throughout the sports season. They will achieve similar results with the use of either clinical or laboratory balance-assessment measures but should use a battery of assessment techniques when making return-to-play decisions.

Randomized control trials with assessor blinding need to be conducted on these balance assessments in athletes after a concussion in order to improve the level of evidence available to clinicians and to ensure that balance deficits after a concussion are truly measuring accurate information. In addition, studies that focus on discriminating between athletes who have a concussion and those that do not and that determine acceptable values for balance based on age, sport, and gender would provide increased evidence to support the use of balance testing after concussion in athletes and the use of baseline measurements. Additional studies should also focus on the dual-task paradigm, which would contribute to our understanding of the effect of acute concussion on postural stability. This CAT should be reviewed in 2 years to determine if additional postconcussion postural-stability studies have been conducted and if these research studies have established additional evidence supporting the use of clinical and laboratory balance-assessment techniques to identify and monitor immediate postural-stability deficits after a single episode of concussion; this may ultimately change the clinical bottom line for this specific clinical question.

References