[Athletic Training]

CEU

Assessing Postural Stability in the Concussed Athlete: What to Do, What to Expect, and When

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Context: Postural stability assessment is included as part of the diagnostic and monitoring process for sports-related concussions. Particularly, the relatively simple Balance Error Scoring System (BESS) and more sophisticated force plate measures like the Sensory Organization Test (SOT) are suggested.

Evidence Acquisition: Relevant studies were identified via the following electronic databases: PubMed, MEDLINE, EMBASE, Web of Science, ScienceDirect, and CINAHL (1980 to July 2013). Inclusion was based on the evaluation of postural sway or balance in concussed athletes of any age or sex and investigating the reliability or validity of the included tests.

Study Design: Clinical review.

Level of Evidence: Level 4

Results: Both the SOT and the BESS show moderate reliability, but a learning effect due to repetitive testing needs to be considered. Both tests indicate that postural stability returns to baseline by day 3 to 5 in most concussed athletes. While the BESS is a simple and valid method, it is sensitive to subjectivity in scoring and the learning effect. The SOT is very sensitive to even subtle changes in postural sway, and thus, more accurate than the BESS; however, it is a rather expensive method of balance testing.

Conclusion: Both tests serve the purpose of monitoring balance performance in the concussed athlete; however, neither may serve as a stand-alone diagnostic or monitoring tool.

Strength of Recommendation Taxonomy: B

Keywords: concussion; sports; balance; Balance Error Scoring System; Sensory Organization Test

As concussion awareness and diagnosis has changed significantly, there is wide variability in the literature on the epidemiology of concussion. The incidence of sports-related concussion in high school and collegiate athletes is 0.28 per 1000 athlete-exposures, or 5% of the total number of injuries across different sports.[11,24] This equates to 1.6 to 3.8 million concussions annually in the United States alone.[26]

Despite this already alarming number, there is growing concern that concussion may be underreported in sports.[2,31] Apart from athletes failing to report a concussion for various reasons,[31] team physicians may employ too high thresholds for[44] or simply miss the diagnosis.

A fast and accurate diagnosis of concussion is important, particularly in light of potential long-term neurological deficits

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originating from head trauma,[8,52] and various test batteries have been presented and refined over the years.[28,32,34] In addition, postural stability assessment has been included in the diagnostic and monitoring process, as many concussed athletes present with balance impairments.[22]

Postural control requires a complex interaction of musculoskeletal and neural systems.[45] The neural components that contribute essentially to postural stability include motor processes organizing neuromuscular synergies; sensory/perceptional processes that organize and integrate visual, vestibular, and somatosensory systems; and higher level processes essential for mapping sensation to action.[47] Recommended balance tests challenge the balance system with postural tasks of varying difficulty, including the modification of sensory input, unstable/moving surfaces, or single-leg stance to quantify any concussion-induced impairment.

Since 2001, the International Consensus Conference on Concussion in Sports has issued recommendations, which were updated and revised by the 2012 Zurich Consensus Statement,[34] and the American Medical Society for Sports Medicine has provided evidence-based best-practice recommendations in the evaluation and management of sports-related concussions.[23] These statements recommend balance testing to diagnose and monitor concussion. Specifically, a modified version of the Balance Error Scoring System (BESS) is included in the Sideline Concussion Assessment Tool (SCAT3) as part of the sideline assessment. The Sensory Organization Test (SOT) is another test based on force plate measurements to detect and monitor balance impairments following concussion.[39]

METHODS

Balance Error Scoring System

The BESS is an inexpensive, noninstrumented, clinical tool for assessing balance. The test consists of 6 separate 20-second balance tests performed under 3 stance conditions (double-leg, single-leg, and tandem stance) on 2 different surfaces (firm and compliant).[1] For the single-leg stance, the nondominant leg is selected. This test is easy to administer and takes approximately 5 minutes.[41]

The BESS test score is recorded as a quantitative measurement that equals the total number of errors committed by the athlete during the tests. A higher score indicates a more severe postural instability. Error points are given when the athlete is opening the eyes; stepping, stumbling, or falling from the original test position; removing the hands from his or her hips; moving the hip into more than 30° of flexion or abduction; lifting the toes or heels from the test surface; or remaining out of the test position for more than 5 seconds.[41] Because of the number of tests and surfaces, the number of possible error points ranges from 0 to 60 and is expressed as a cumulative score.

A modified (simplified) on-field screening version of the BESS, which omits the 3 tests completed on foam, is included in the SCAT3. Accordingly, the maximum error score is 30.[34]

Sensory Organization Test

Developed by Nashner and Peters,[36] the SOT is the most commonly used technical balance test in concussion research. It was designed to systematically disrupt the sensory selection process while a force plate measures vertical ground reaction forces produced by the body's center of pressure (COP) during involuntary sway. While other approaches have been used in past and recent studies,[16,19] the SOT remains the most established test, and new approaches to analyze the results have been proposed.[9]

Three 20-second trials each are performed under 6 different sensory conditions of increasing difficulty (18 measurements total) that manipulate the information received from the somatosensory, visual, and vestibular systems.[21] Measurements are conducted (1) with eyes open, firm surface; (2) eyes closed, firm surface; (3) sway referenced visual surround, firm surface; (4) sway referenced support surface, eyes open; (5) sway referenced support surface, eyes closed; and (6) sway referenced visual and support surface.[39] A percentage score is calculated for each trial, including ratios based on the ability to use visual, vestibular, and somatosensory pathways and a composite score to determine overall postural stability.[38] Computer-generated equilibrium scores range between 100 (no postural sway at all) and 0 (representing a fall).[39]

The major advantage of force plate measures in general is the objectivity and precision in quantifying and describing the sway path of the athlete, which potentially allows the detection of balance impairments for twice as long as the BESS. The aspect of objectivity may be especially important in elite sports, where flawless documentation is essential when justifying return-to-play decisions. The downside of the SOT is the limited clinical availability, as the required complex instrumentation does not allow an easy transfer of the tests to other force plate systems available.

Search Strategy

A comprehensive and systematic literature search strategy was developed by identifying all potentially relevant search terms, categorizing these terms into specific search phases, and subsequently combining them by using Boolean terms (concussion, mild traumatic brain injury, mTBI, balance, postural sway, sensory organization test, SOT, balance error scoring system, BESS). This search strategy was applied to different electronic databases: PubMed, MEDLINE, EMBASE, Web of Science, ScienceDirect, and CINAHL (1980 to June 2013). The inclusion criteria were (1) studies that were fully or partially concerned with the analysis of postural sway or balance in concussed athletes of any age and sex and (2) studies investigating the reliability and validity of the included balance tests.

Occasionally, mild traumatic brain injury (mTBI) and concussion are used interchangeably in the literature, although these 2 terms refer to different injury constructs.[33] To not miss

Table 1. Postural stability in concussed athletes: Balance Error Scoring System

			Participants			
			Concussed		Controls	
Study	Sport	Competitive Level	Sex (Age,[a] y)	No.	Sex (Age,[a] y)	No.
McCrea et al[30]	Football	Collegiate, Divisions I, II, and III	Male (20.0 ± 1.4)[b]	94	Male (20.0 ± 1.4)[b]	56
Riemann et al[41]	Unclear	Collegiate	Mixed (19.2 ± 2.3)	16: 15 males, 1 female	—	—
Guskiewicz et al[21]	Various	Collegiate, Division I	Mixed (19.5 ± 1.3)	72: 50 males, 22 females	Mixed (20.0 ± 2.4)	36: 25 males, 11 females

[a]The age in years is expressed as mean ± standard deviation.
[b]Combined age for both concussed and control group.

potentially relevant studies, the terms *mild traumatic brain injury* and *mTBI* were included in the literature search.

Initially, the online search strategy identified 114 studies, of which abstracts were screened individually and independently by the reviewers. The application of inclusion criteria eliminated 84 papers. Seven studies met the inclusion criteria for the postural sway assessment, while another 24 dealt with aspects of reliability or validity and were included in this review.

RESULTS

Balance Error Scoring System

Reliability and Validity

Only 3 studies applied the BESS to investigate postural sway following concussion, all of which included collegiate athletes of similar age but engaged in different sports (Table 1).[21,30,42] For most college-aged athletes, error scores return to preseason baseline levels by day 3 to 5 postconcussion (Figure 1). More errors were observed during the more challenging tasks on the foam surface, and these error scores returned to baseline by day 5.[42] However, results may vary in juvenile or older individuals.

Four studies investigated the intrarater reliability by means of the intraclass correlation coefficient (ICC).[14,25,49,51] Only 1 study included collegiate athletes (mean age, 21.3 ± 2.7 years),[49] the results of which integrate best in the age range of studies investigating postural sway following concussion (Table 1). In contrast, the other 3 studies included high school athletes[25,51] or did not provide any demographic information.[14]

Overall, the BESS shows moderate overall test-retest reliability (ICC, 0.50-0.75), irrespective of who conducts the test and whether it is on the same occasion or at different times (Appendix 1, available at http://sph.sagepub.com/content/suppl).[7,14,25,41,49,51]

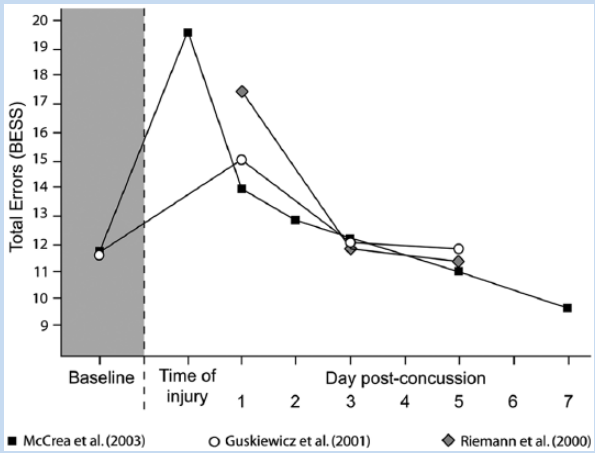

Figure 1. Mean Balance Error Scoring System (BESS) error score at baseline and following concussion.

As may be expected for a clinical test with rather subjective error scoring, the interpretation of results is complicated by studies showing conflicting data (Appendix 1).

Depending on the severity of neurological impairment and the associated clinical symptoms, the clinician may expect an increase of 6 to 20 error points immediately following injury. At day 1, this drops by 2 to 3 error points, further decreasing by another 1 to 2 error points at day 3 (Figure 1).[21,29,30,42] The threshold at which a BESS score represents a significant change compared with baseline as opposed to a measurement error is around 7 points (when conducted by the same clinician) or around 9 error points (when conducted by various examiners).[14] In contrast, an increase of ≥3 error points represented a significant change indicative of concussion-related balance impairments.[51]

Table 2. Postural stability in concussed athletes: Sensory Organization Test

			Participants			
			Concussed		Controls	
Study	Sport	Competitive level	Sex (Age,[a] y)	No.	Sex (Age, y)	No.
Gusciewicz et al[20]	Unclear	Collegiate, Division I	Mixed (18.6 ± 2.0)	11: 8 males, 3 females	Mixed (20.2 ± 1.3)	11: 8 males, 3 females
Riemann et al[41]	Unclear	Collegiate	Mixed (19.2 ± 2.3)	16: 15 males, 1 female	—	—
Gusciewicz et al[21]	Various	Collegiate, Division I	Mixed (19.5 ± 1.3)	72: 50 males, 22 females	Mixed (20.0 ± 2.4)	36 ("sex matched")
Peterson et al[39]	Mixed, mostly football	Collegiate, Division I	Mixed (19.3 ± 1.3)	24: 18 males, 6 females	Unclear (20.2 ± 1.6)	18
Broglio et al[5]	Mixed, mostly football	Unclear	Mixed (unclear)	75	—	—

[a]The age in years is expressed as mean ± standard deviation.

Broglio et al[7] observed learning effects with repetitive testing in a group of 48 young adults and found that improvements of 3 to 4 error points may be expected for 3 repetitions over a 5-day period. Mulligan et al[35] recorded 2 to 5 fewer error points at a 2-week follow-up, while 20% showed a learned response exceeding 7 points. This renders the clinical use of the BESS for such individuals highly questionable. To avoid any overinterpretation of the error scores, multiple baseline testing may help to alleviate these learned responses. For this purpose, Broglio et al[7] recommend averaging 3 consecutive repetitions[7] at any occasion, which may also reduce the measurement error at the same time. While there is no accepted recommendation, previous studies performed follow-up testing at days 1, 3, 5, and 7 postconcussion, which may offer good insight into the athlete's recovery.[21,29,30,42]

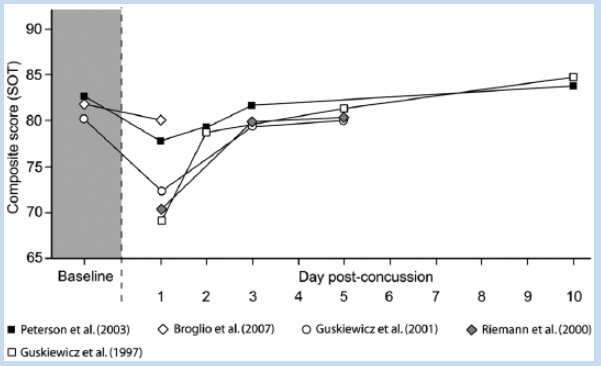

Figure 2. Mean Sensory organization Test (SOT) composite scores at baseline and following concussion.

Sensory Organization Test

Reliability and Validity

Five studies investigated postural sway following concussion using the SOT, 4 of which enrolled collegiate athletes involved in different sports (Table 2).[5,20,21,39,42]

Most research utilizing the SOT has identified deficits lasting an average of 3 to 5 days postconcussion,[5,20,21,39,42] but the test may be capable of demonstrating impaired balance for up to 10 days (Figure 2).[20,39] However, Broglio et al[5] observed that in 75 concussed athletes, nearly 40% did not show decreased balance.

The SOT shows moderate overall reliability with greatly varying results for the 6 individual test conditions.[4,13,15,27,40,50,53] Like the BESS, the SOT is not suitable as a stand-alone diagnostic tool for concussions, although it is very good at identifying those athletes without a concussion. The sensitivity increases with concussion severity.[4]

A change in composite balance score of 4 to 8 points compared with baseline may indicate a significant change in concussed athletes.[5,20,46] Accounting for the reliability of the SOT, the clinician may want to look for changes of around 7 points in the athlete's composite ratio. The corresponding individual values for somatosensory, visual, and vestibular ratios are 7, 6, and 17, respectively (Appendix 2, available at http://sph.sagepub.com/content/suppl).[4]

At postinjury day 1, 40% of concussed athletes showed impaired postural stability, as expressed by the composite score, whereby the somatosensory ratio was affected in 40% and the visual ratio in 30%. The vestibular system was impaired in just

more than 20%.[5] In contrast to the BESS, where about 35% of concussed individuals were identified as showing postural abnormalities,[29] the SOT demonstrated impaired balance in at least 1 test component in more than 60% of affected athletes.[5]

As with the BESS, learning effects have also been observed with repetitive SOT testing[53] and may correspond to a 10% improvement in balance composite scores.[21,39] Wrisley et al[53] showed that this effect reaches a plateau after 3 to 4 repetitions in healthy, young individuals. Consequently, 3 repetitions of the full SOT sequence (18 trials each) may be advisable within a few days to establish baseline values. Postconcussion measurements can then be compared with these results, whereby a single-session improvement of 8 points may be indicative of recovery, taking into account the expected learning effects.[53]

DISCUSSION

Balance is only 1 aspect of assessing the concussed athlete, and its impairment may not always be present.[18] As one of few objective measures, balance testing plays a role in a multifaceted approach in diagnosing and managing sports-related concussion.[17]

Clinicians need to be aware of the clinical and practical applications and limitations in using either clinical or force plate balance tests.

Balance Error Scoring System

While the BESS is a valid clinical balance test,[41] it is unsuitable in isolation to identify concussed athletes both at the time of injury and at follow-up.[29] In the light of conflicting results, error scores may only be of clinical value at the time of injury. However, conflicting data originate from calculations depending on the reliability of the BESS, which may be affected by scoring variability and differences in foam thickness and resistance. Therefore, averaging several tests may allow more confidence in any observed differences, as reliability generally increases with the number of repetitions.

It is difficult to determine a clinically (and statistically) significant difference when compared with baseline values given the issues of the learning effects and the measurement errors, which render the BESS a less reliable clinical test. A return to baseline values may therefore not necessarily mean a full recovery. Also, because of the expected learning response, failure to improve at follow-up may be indicative of concussion-related impairments.

Normative values of 11 errors[7] to 19 errors[49] have been reported for college-aged individuals. This great variation between studies enrolling otherwise similar participants underlines the difficulty with subjective scoring. It remains questionable whether normative values can replace baseline testing, especially in an athlete population where significant individual differences are observed between sports.[3] Also, sex differences have to be considered,[10] whereby males score worse than females do.[51] Accordingly, we recommend that repetitive individual tests at baseline should be performed.

The scoring system of the BESS appears to be rather simple. However, it may account for the moderate interrater (and probably also intrarater) reliability. Accurately visually assessing when hip abduction or flexion exceeds 30° or whether the forefoot or heel is lifted, particularly on a foam surface, requires practice.[14] To overcome this issue of subjective rating, assessing sway data of the BESS conducted on any force plate may be an option worth exploring.

Practical Considerations

Using the BESS (modified or original) as a sideline test may also encounter several practical issues depending on how baseline values were established. Wearing of protective equipment by players often renders the test impractical as a quick screening tool because the gear may modify the athlete's ability to maintain static balance. Athletic tape or ankle braces may also require removal.[6]

Athletes tend to score significantly worse on sideline assessment because of external distractions. In 21 healthy collegiate athletes, 11.0 ± 6.6 and 14.3 ± 5.7 errors were reported in a locker room and at the sideline, respectively.[37] Therefore, BESS baseline values should be obtained in the environment in which injury testing will most likely be conducted.[37]

The athlete's level of exhaustion must be considered when comparing sideline data with baseline values.[49] If baseline testing was performed when the athlete is well rested, the results can be expected to deviate from those obtained in the middle of a game or practice. This effect may last 20 minutes postexercise.[49]

Sensory Organization Test

Reported normative composite scores for college-aged athletes range from 80 (Schmidt et al[46]) to 92 (Sosnoff et al[48]). As Sosnoff et al[48] enrolled the highest number of participants (n = 224), the latter value may more accurately reflect the mean baseline performance. Despite strong theoretical rationale for using individual baseline measures for comparison postinjury, normative values may be acceptable.[46]

Pain affects postural stability.[12,43] Since subtle changes in body sway are registered, pain may influence the force plate measures more than a clinical balance test like the BESS.

CONCLUSION

There is an easy, low-cost, and quick-to-administer sideline balance test (BESS), with the weakness of subjective scoring. The expensive but objective force plate systems (SOT) have limited mobility. Both tests show moderate reliability and learning effects due to repetitive testing. Both suggest that postural stability returns to baseline by day 3 to day 5 in most concussed college-aged athletes. Because of the subjectivity in scoring, the learning effect, and the moderate reliability in the BESS, it is unclear what constitutes a relevant and reliable change in error scores after injury. The SOT is more objective and quantitates subtle changes in postural stability. The detection rate for some form of postconcussion postural impairment is nearly twice with SOT. However, its complexity and limited mobility renders it less attractive to the field clinician.

Clinical Recommendations

SORT: Strength of Recommendation Taxonomy
A: consistent, good-quality patient-oriented evidence
B: inconsistent or limited-quality patient-oriented evidence
C: consensus, disease-oriented evidence, usual practice, expert opinion, or case series

Clinical Recommendation	SORT Evidence Rating
After an initial decrease in postural stability, expect balance performance to return to baseline values between day 3 and 5 postinjury for both BESS[21,30,42] and SOT.[5,20,21,39,42]	B
A return to baseline values does not necessarily indicate full recovery as learning effects have to be considered.[7,21,35,39]	B
When interpreting balance results, a change of 7 to 8 points for the SOT composite score[4,46] and of ≥3 error points for the BESS[51] indicates a significant change.	B

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