[Athletic Training]

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Systematic Review of the Balance Error Scoring System

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Context: The Balance Error Scoring System (BESS) is commonly used by researchers and clinicians to evaluate balance. A growing number of studies are using the BESS as an outcome measure beyond the scope of its original purpose.

Objective: To provide an objective systematic review of the reliability and validity of the BESS.

Data Sources: PubMed and CINHAL were searched using *Balance Error Scoring System* from January 1999 through December 2010.

Study Selection: Selection was based on establishment of the reliability and validity of the BESS. Research articles were selected if they established reliability or validity (criterion related or construct) of the BESS, were written in English, and used the BESS as an outcome measure. Abstracts were not considered.

Results: Reliability of the total BESS score and individual stances ranged from poor to moderate to good, depending on the type of reliability assessed. The BESS has criterion-related validity with force plate measures; more difficult stances have higher agreement than do easier ones. The BESS is valid to detect balance deficits where large differences exist (concussion or fatigue). It may not be valid when differences are more subtle.

Conclusions: Overall, the BESS has moderate to good reliability to assess static balance. Low levels of reliability have been reported by some authors. The BESS correlates with other measures of balance using testing devices. The BESS can detect balance deficits in participants with concussion and fatigue. BESS scores increase with age and with ankle instability and external ankle bracing. BESS scores improve after training.

Keywords: reliability; validity; concussion; Balance Error Scoring System; fatigue

Balance or postural control is a necessary component of activities of daily living and sport. Static balance involves feedback from the somatosensory, visual, and vestibular systems to achieve steadiness.[16,27] Instrumented testing devices attempt to objectively measure balance and are becoming the gold standard of balance testing.[24] Common variables include sway area and sway velocity using force plates. The NeuroCom Smart Balance System (NeuroCom International, Inc, Clackamas, Oregon) uses the Sensory Organization Test to measure vertical ground reaction forces produced from the body's center of gravity moving around a fixed base of support. The test systematically disrupts the sensory selection process by altering available somatosensory and/or visual information while measuring the ability to minimize postural sway.[17] An equilibrium score can be calculated on the basis of a person's limit of stability.

Clinicians do not often have access to instrumented balance testing devices. The Balance Error Scoring System (BESS) consists of 3 stances: double-leg stance (hands on the hips and feet together), single-leg stance (standing on the nondominant leg with hands on hips), and a tandem stance (nondominant foot behind the dominant foot) in a heel-to-toe fashion (Figure 1). The stances are performed on a firm surface and on a foam surface with the eyes closed, with errors counted during each 20-second trial. An error is defined as opening eyes, lifting hands off hips, stepping, stumbling or falling out of position, lifting forefoot or heel, abducting the hip by more than 30°, or failing to return to the test position in more than 5 seconds.

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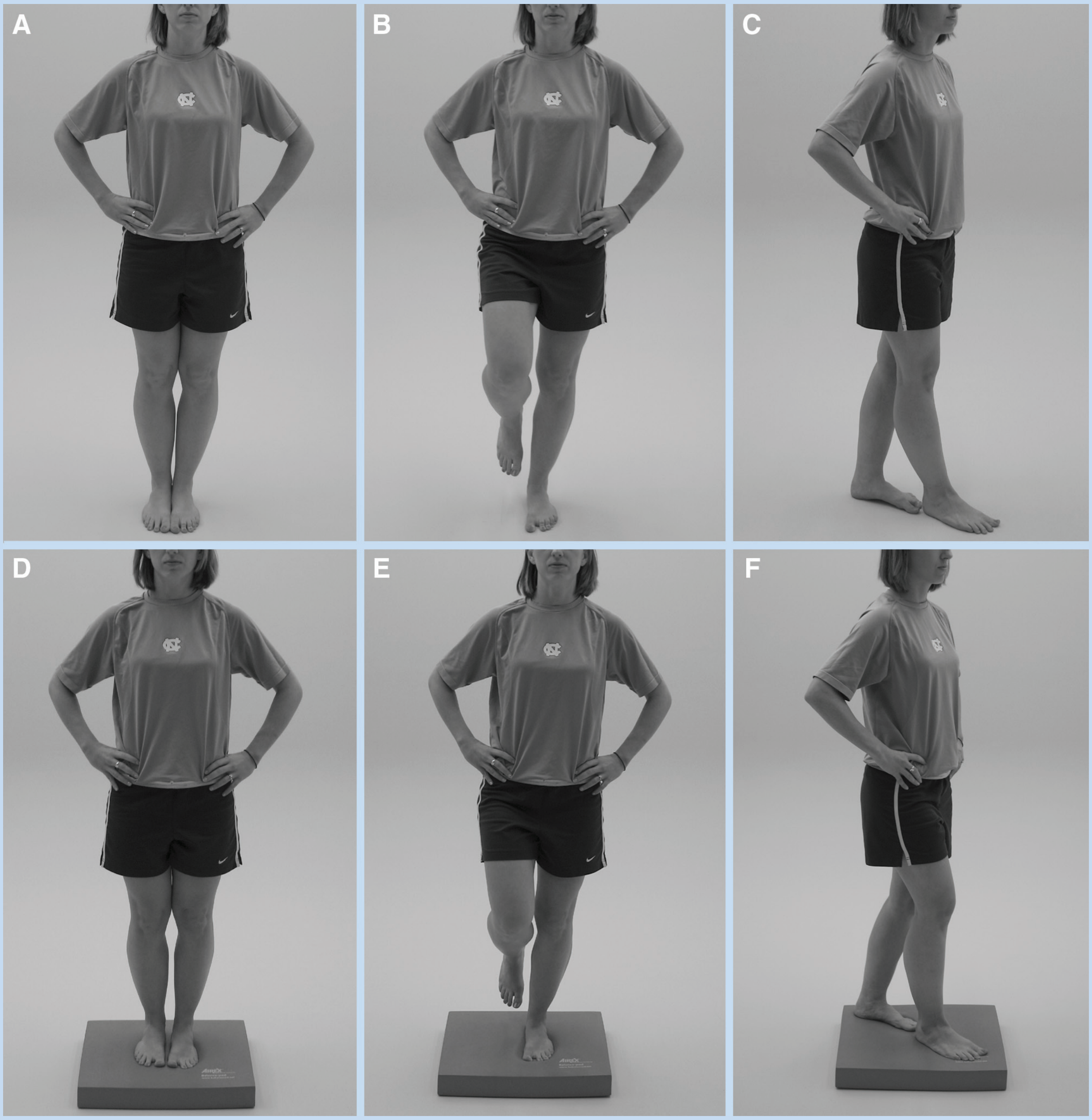

Figure 1. Stances used in Balance Error Scoring System: A, double-leg stance; B, single-leg stance (standing on the nondominant limb); C, tandem stance; D, double-leg stance with foam; E, single leg on foam; F, tandem stance on foam.

LITERATURE REVIEW METHODS AND ARTICLE IDENTIFICATION

Both electronic and manual literature searches were performed from January 1999 through December 2010. The PubMed and the CINAHL databases were searched using the term *Balance Error Scoring System*. PubMed returned 25 articles and CINAHL returned 28. Articles must have included the BESS as an outcome measure, been written in English, and published in a peer-reviewed journal. Abstracts and unpublished articles were not considered, leaving 29 unique articles (Figure 2).

CRITERIA FOR ARTICLE SELECTION

Articles were included in the systematic review if they established either reliability or validity of the BESS. Reliability was defined as interrater, intrarater, or test-retest reliability.[29] Articles were included if they provided criterion-related validity or construct validity. Criterion-related validity is the degree

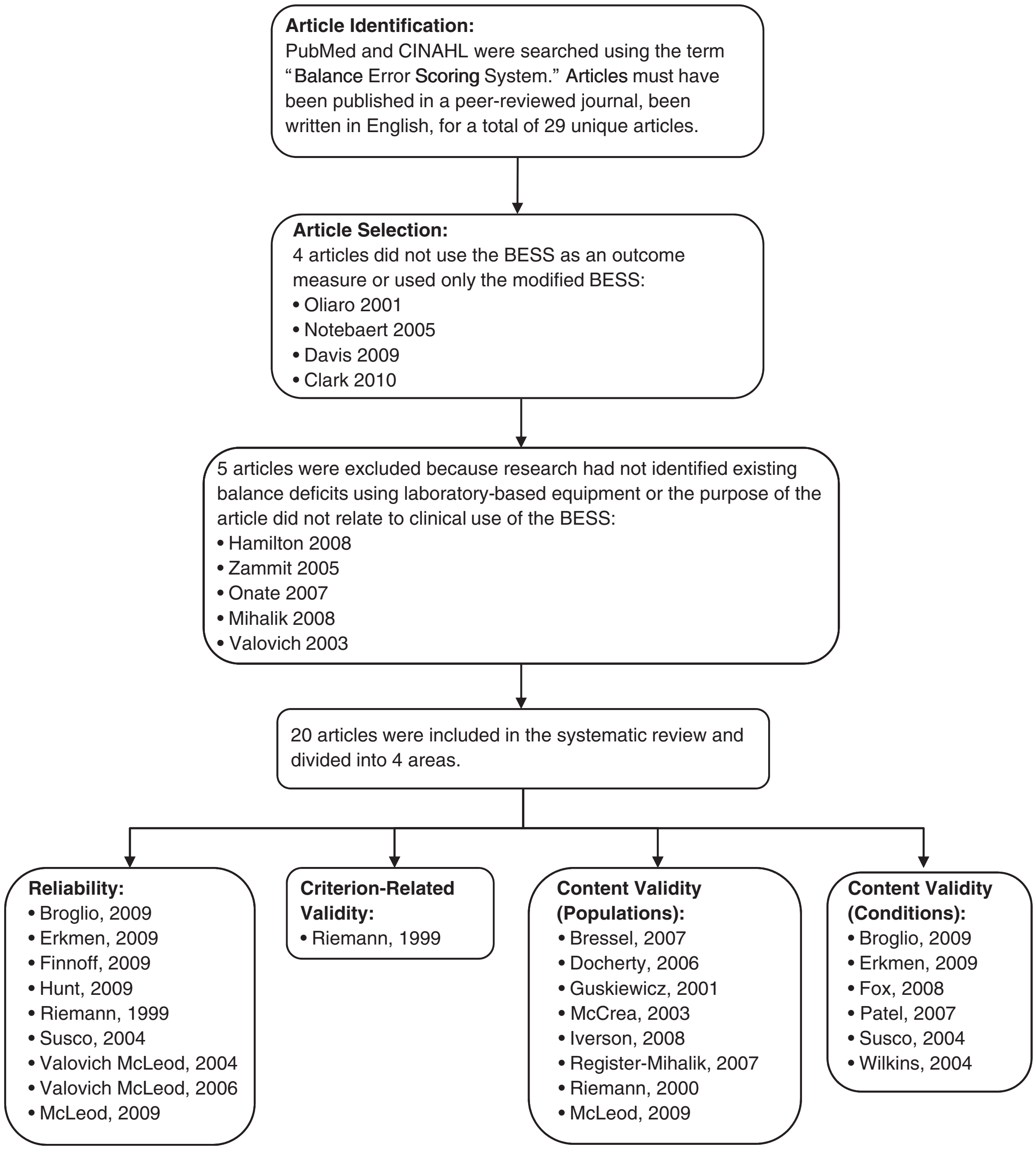

Figure 2. Flowchart of the article selection process.

in which 2 tests correlate with each other[29]—specifically, does the BESS correlate with laboratory-based measures of postural control? Construct validity was established using the known-groups methodology. A test has construct validity if it can discriminate among individuals who are known to have a specific condition.[29] The BESS should differentiate among populations and/or conditions with previously identified balance deficits that used instrumented balance-testing devices.

The 29 articles were reviewed and the populations or conditions compared in each article noted. Previous research was identified that investigated balance using instrumented balance-testing devices. In many cases, the same study examined the BESS and instrumented balance testing. Twenty unique articles met the final criteria and were included in this review.[||]

Articles were reviewed and grouped into pertinent topic areas related to reliability (Table 1), criterion-related validity, or construct validity. It became apparent that articles examining validity generally fit into categories based on statistical design. These studies made group comparisons (ie, concussed vs

[||]References 2-4, 8, 10, 12, 13, 17-19, 23, 25, 28, 30, 32, 33, 36, 39, 40, 42.

Table 1. Reliability of the Balance Error Scoring System (BESS).

Author, Year	Reliability Assessment	Population	Coefficient
Broglio,[4] 2009	Test-retest	48 young adults (mean = 20.4 years)	
	Generalizability (G)	Total BESS errors	G = 0.64
		Men (n = 25)	G = 0.92
		Women (n = 23)	G = 0.91
		Total BESS: 3 administrations	
		Men	G = 0.81-0.89
		Women	G = 0.79-0.87
Erkmen,[10] 2009	Intratester	19 recreationally active young adults (18-26 years old)	0.92
Finnoff,[12] 2009	Intertester	30 athletes	
	Intratester	Intratester total score	0.74
		Intratester stances	0.50-0.88[a]
		Intertester total score	0.57
		Intertester stances	0.44-0.83[a]
Hunt,[18] 2009	Intratester	High school football players	0.60
McLeod,[25] 2009	Intratester	Described as part of pilot testing and no demographics reported	0.90
	Intertester		0.85
Riemann,[33] 1999	Intertester	18 Division I athletes	0.78-0.96[a,b]
Susco,[36] 2004	Intratester	36 recreationally active college students	0.63-0.82[c]
Valovich-McLeod,[40] 2004	Intratester	20 youth athletes (9-14 years of age)	0.87-0.98[a,d]
Valovich-McLeod,[39] 2006	Test-retest	49 youth athletes (9-14 years of age)	
		Total BESS Errors	0.70[e]
		Males (n = 23)	0.75
		Females (n = 26)	0.61
		Younger (n = 21)	0.56
		Older (n = 28)	0.68

[a]Range for all stances except double-leg firm.
[b]SEM (errors) = 0.04-0.56.
[c]SEM (errors) = 0.62-0.93.
[d]SEM (errors) = 0.28-0.77.
[e]SEM (errors) = 3.3 (values for subgroups not reported).

nonconcussed) (Table 2) or used a repeated measures design by testing the same person multiple times under different conditions (eg, fatigued, braced) (Table 3).

RESULTS

Reliability of the BESS

Riemann et al[33] performed the first study on the reliability of the BESS. Eighteen male National Collegiate Athletic Association Division I varsity athletes were simultaneously evaluated by 3 testers to determine intertester reliability, which was classified as good[29] (intraclass correlations [$ICC_{2,1}$], 0.78-0.96); standard error of the mean for all stances ranged from 0.04 to 0.56 errors. Four stances had ICC values greater than 0.84, with the double-leg foam having the lowest (0.78), which was attributed to a small standard error of the mean. No errors were committed during the double-leg stance (firm), which made it impossible to assess reliability.

Table 2. Balance Error Scoring System differences detected between populations.[a]

Author, Year	Groups	Average Errors	Effect Size (95% Confidence Interval)
Bressel,[2] 2007	Soccer	12.5 ± 5.16	0.64 (–1.51, 2.80) (vs gymnastics)
	Basketball	14.1 ± 5.16	0.96 (–1.18, 3.09) (vs gymnastics)
	Gymnastics	9.1 ± 5.39	
Docherty,[8] 2006	Control (total)	10.7 ± 3.2	1.09 (–0.07, 2.25) (total)
	Unstable (total)	15.7 ± 6.0	
	Stances		
	Tandem foam		0.80 (0.29, 1.31)
	Single firm		0.67 (0.17, 1.16)
	Single foam		0.82 (0.39, 1.25)
Guskiewicz,[17] 2001	Control (baseline)	9 ± 4[b]	1.0 (–0.39, 2.39)
	Concussed (D1)	15 ± 8[b]	
McCrea,[23] 2003	Control (baseline)	12.73 ± 7.57	1.07 (0.16, 2.01)
	Concussed[c]	19 ± 4[b]	
Iverson,[19] 2008	20-39 years	10.97 ± 5.05	
	40-49 years	11.88 ± 5.40	0.17 (–0.44, 0.79) (vs 20-39)
	50-54 years	12.73 ± 6.07	0.32 (–0.45, 1.09) (vs 20-39)
	55-59 years	14.85 ± 7.32	0.63 (–0.25, 1.50) (vs 20-39)
	60-64 years	17.20 ± 7.83	1.02 (0.13, 1.90) (vs 20-39)
	65-69 years	20.38 ± 7.87	1.46 (0.43, 2.48) (vs 20-39)
Riemann,[32] 2000	Control (D1)	8.4 ± 4.0	1.32 (0.52, 2.13)
	Concussed (D1)	17.4 ± 9.6	

[a]Effect sizes were calculated with the following formula: (mean 1 – mean 2) / pooled standard deviation. Confidence intervals were calculated as follows, effect size ± (SE × 1.96), where SE is the standard error of the mean (SE = SD/n^{-1}). Balance Error Scoring System scores are number of errors. D1, day 1 postinjury.
[b]Estimation based on graphical data.
[c]Immediately after.

Eight other articles reported on the reliability of the BESS.[¶] Intratester reliability ranged from an ICC of 0.60[18] to 0.92[10] for the total BESS score and 0.50[12] to 0.98[40] for individual stances. Intertester reliability ranged from 0.57[12] to 0.85[25] for the total BESS score and 0.44[12] to 0.96[33] for individual stances. Test-retest reliability was moderate[29] in youth participants aged 9-14 years[41] ($ICC_{2,1}$ = 0.70, standard error of the mean = 3.3 errors) and young adults (generalizability coefficient = 0.64).[4] Administering the BESS 3 times and averaging total scores improved test-retest reliability, especially when sexes were examined independently (generalizability coefficient: male = 0.92, female = 0.91).[4]

¶References 4, 10, 12, 18, 25, 36, 39, 40.

Validity of the BESS

Criterion-related validity. Criterion-related validity of the BESS was established by correlating BESS scores with target sway in male athletes.[33] Target sway compares the sway generated by an individual to a theoretical sway area (lower is better). Significant correlations were observed for 5 of the 6 stances (r = 0.31-0.79, $P < 0.01$; double-leg firm could not be calculated, because no errors were committed). BESS errors ranged from 0 (double-leg firm) to 5.76 (single-leg foam).

BESS construct validity: populations. The BESS has been used to investigate balance in athletes with a sports-related concussion,[17,23,31,32] ankle injury,[8] and varied training backgrounds,[2] as well as among community-dwelling adults.[19] Balance

Table 3. Balance Error Scoring System in different conditions.[a]

Author, Year	Conditions	Errors	Effect Size (95% Confidence Interval)
Broglio,[3] 2009	Brace	13.37 ± 1.11	2.59 (2.26, 2.92) (vs barefoot)
	Tape	13.84 ± 1.04	3.14 (2.82, 3.46) (vs barefoot)
	Barefoot	10.68 ± 0.97	
Erkmen,[10] 2009	Males		
	Prefatigue	13.10 ± 2.69	1.74 (–0.91, 4.38) (prefatigue vs postfatigue)
	Postfatigue	20.50 ± 5.84	
	Females		
	Prefatigue	8.78 ± 2.39	1.64 (0.81, 3.10) (prefatigue vs postfatigue)
	Postfatigue	12.44 ± 2.07	
Fox,[13] 2008	Anaerobic	8.08 ± 3.10	1.18 (0.56, 1.81) (vs baseline)
	Aerobic	10.03 ± 3.19	1.88 (1.24, 2.51) (vs baseline)
	Baseline	4.89 ± 2.29	
McLeod,[25] 2009	Control		
	Pretest	13.7 ± 1.0	0.45 (–0.04, 0.95) (pretest vs posttest)
	Posttest	14.2 ± 1.2	
	Trained		
	Pretest	10.6 ± 1.1	3.91 (3.51, 4.32) (pretest vs posttest)
	Posttest	7.1 ± 0.7	7.47 (7.19, 7.76) (posttest vs posttest)
Patel,[28] 2007	Euhydrated	8.29 ± 4.07	0.13 (–1.06, 1.31)
	Dehydrated	8.82 ± 4.31	
Susco,[36] 2004	Control (BL)	17.9 ± 4.0	2.12 (0.82, 3.42)
	Fatigue[b]	26.8 ± 4.4	
Wilkins,[42] 2004	Control	13.32 ± 3.77[c]	0.89 (–0.63, 2.42)
	Fatigue	16.93 ± 4.32[c]	

[a]Balance Error Scoring System scores are total errors for all conditions. Effect sizes were calculated with the following formula: (mean 1 – mean 2) / pooled standard deviation. Confidence intervals were calculated as follows, effect size ± (SE × 1.96), where SE is the standard error of the mean (SE = SD/n^{-1}). Values with the greatest difference between means were used for effect size calculations.
[b]Balance Error Scoring System score assessed immediately postfatigue.
[c]Indicates that the total Balance Error Scoring System score is an average of 9 conditions (3 stances on 3 surfaces including the firm, foam, and tremor box).

differences have been identified in these populations using instrumented balance-testing devices.[5,9,14,17,22]

Three studies examined the BESS and sports-related concussion.[17,23,32] Initially, concussed (n = 16) and healthy (n = 16) individuals were compared 1, 3, 5, and 10 days after injury on the BESS and Sensory Organization Test. Concussed persons had more errors day 1 postinjury (P = 0.03) but returned to baseline within 3 (firm) to 5 (foam) days postinjury. Compared with controls, the concussed group had more errors on the double-leg (P = 0.01), single-leg (P = 0.01), and tandem (P = 0.00) stances on foam. The average BESS score was 17 errors 1 day after injury, compared with approximately 8 errors for a healthy control. Guskiewicz et al[17] validated the BESS against the Sensory Organization Test in a concussed population and included a baseline measure. Thirty-six Division I college athletes with concussions were compared with matched controls. The concussed group had worse balance at days 1, 3, and 5 postinjury but returned to baseline levels by day 3. Finally, using a prospective design, McCrea et al[23] examined the recovery of postural stability following concussion: 1631 football players had baseline BESS scores preseason, 94 of whom went on to sustain a concussion and were compared to 56 controls. BESS scores were similar at baseline, but the concussed group had worse postural stability immediately after injury, which returned to baseline 3 to 5 days after concussion (day 5 mean difference = –0.31, 95% confidence interval = –3.02, 2.40 errors). Instrumented balance-testing measures were not used in this study, but those suffering concussion exhibited the same recovery profile on the BESS as previous studies using instrumented balance-testing devices.[17,32]

The BESS does not discriminate between concussed athletes with and without headache. Collegiate athletes who sustained a concussion were grouped into those with a headache after injury (n = 82) and without (n = 26).[31] Athletes with a headache had worse balance compared with those without, as detected by instrumented balance-testing devices.[31] The BESS ($P = 0.87$) was unable to detect differences in 247 concussed collegiate and high school athletes (with or without headache).[30]

Persons with functional ankle instability perform worse on the BESS. Compared with controls, those with unstable ankles committed more errors on the total BESS score ($P < 0.01$), single-leg firm condition (unstable: 2.9 ± 2.1 errors, control: 1.6 ± 1.3 errors), tandem foam condition (unstable: 4.3 ± 2.4 errors, control: 2.7 ± 1.6 errors), and single-leg foam condition (unstable: 7.0 ± 1.6 errors, control: 5.6 ± 1.8 errors).[8] Populations with unstable ankles also have balance deficits using instrumented balance-testing devices.[6,14,34,38]

Balance differences have been detected between training backgrounds using instrumented balance testing.[22] Gymnasts (n = 12) had superior balance to basketball players (n = 11, $P = 0.01$) but not soccer players (n = 11).[2]

Balance worsens with age on instrumented balance testing[5,9] and the BESS.[19] BESS score and age were correlated (589 adults; age range, 20-69 years) indicating that as age increases, so does BESS score ($r = 0.36$, $P < 0.01$). BESS performance worsened after 50 years of age ($P < 0.01$).

BESS construct validity: conditions. Fatigue, bracing, dehydration, and neuromuscular training have been investigated with repeated measures design.[3,13,25,28,36,42] These conditions are also known to influence balance using instrumented balance-testing devices.[#]

Balance is impaired after whole-body or central fatigue[13,21,26,37] when measured by instrumented balance-testing devices. Athletes (n = 14) and controls (n = 13) showed an increase in total BESS score after fatigue ($P < 0.01$; fatigue: pretest = 14.36 ± 4.73 errors, posttest = 16.93 ± 4.32 errors; control: pretest = 13.32 ± 3.77 errors, posttest = 11.08 ± 3.88 errors).[42] Balance on the BESS was worse 0 to 15 minutes after fatigue ($P < 0.01$), and returned to pretest values 20 minutes after exertion.[36] Aerobic and anaerobic fatigue was studied among 36 athletes for total BESS and force plate measures (center of pressure sway velocity and elliptical sway area).[13] Both protocols increased BESS score ($P < 0.01$), sway velocity ($P < 0.01$), and elliptical sway area ($P < 0.01$) 3 minutes after fatigue. Athletes returned to baseline scores 13 minutes postfatigue. Similar increases in BESS score were observed using a progressive treadmill fatiguing protocol.[10]

#References 1, 7, 13, 15, 20, 35, 43, 44.

The effect of dehydration on balance is conflicting, with some researchers concluding that balance worsens after dehydration[7,15] and with others reporting that it does not.[28] BESS performance is not influenced mild dehydration ($P = 0.43$).[28]

Ankle bracing and taping may influence postural stability.[1,11,20] Healthy college-age individuals completed 3 testing sessions: barefoot, taped, or braced.[3] Participants were evaluated on the BESS and Sensory Organization Test before and after a 20-minute treadmill walk. Barefoot BESS performance was better than the braced condition ($P = 0.04$) before walking and better than braced ($P = 0.03$) or taped ($P = 0.04$) after walking. Differences were not seen in the Sensory Organization Test between conditions.

Balance on force plates improves after neuromuscular training.[43,44] A comprehensive neuromuscular training program produced fewer errors on the single-leg foam, tandem foam, and total BESS.[25]

DISCUSSION

The reliability of the BESS ranges from moderate (< 0.75) to good (> 0.75)[29] while some studies report reliability coefficients below clinically acceptable levels (< 0.75).[29] With such a wide range of reliability, clinicians and researchers should establish reliability before using the BESS. The same individual should administer the BESS for serial testing. Training is encouraged to establish consistency among multiple raters when using the BESS as an outcome measure, and such training should be reported. Multiple errors committed simultaneously should be counted as 1 error (eg, stepping, eye opening, and hands lifting off from the hips all at once). Finally, the average of 3 BESS administrations should be used to improve reliability.[4] A modified version of the BESS has demonstrated good reliability.[18] The current review focused on the traditional BESS because it is the most commonly used method.

The BESS has moderate to high criterion-related validity, but the level of agreement depends on the testing condition. Difficult stances had better agreement (single-leg foam: $r = 0.79$, tandem-foam: $r = 0.64$) compared with easier stances (single-leg firm: $r = 0.42$, double-leg foam, $r = 0.31$).

The BESS has high content validity in identifying balance deficits in concussed[17,23,32] and fatigued[10,13,36,42] populations. Balance worsens as a result of concussion or fatigue.** Studies of balance after concussion have large effect sizes (range, 1.00-1.32) (Table 2): 2 of 3 have 95% confidence intervals that do not include zero. Fatigue studies have moderate to large effect sizes (range, 0.54-1.86) (Table 3): 2 of 3 also have 95% confidence intervals that do not include zero. Both concussion and fatigue significantly influence balance when measured by the BESS. The average BESS score after concussion is 17 errors (range, 15-19 errors[17,23]), compared with 10 errors at baseline (range, 8.4-12.73 errors[23,32]). The average prefatigue BESS score is 11.6 errors, with 15.8 errors postfatigue (range, 8.08-26.8 errors).[13,36]

**References 10, 13, 17, 23, 32, 36, 42.

The BESS also has good content validity for identifying balance deficits in functional ankle instability,[8] ankle bracing,[3] aging populations,[19] and those completing neuromuscular training.[25] The effect size between healthy controls and ankle instability patients is large, with the unstable group having a larger BESS scores.[8] External ankle support (braced: 13.37 errors, taped: 13.84 errors) increased BESS errors as compared with barefoot (10.68 errors) (Table 3).[3] BESS score tends to increase with age, as indicated in a study by Iverson et al[19] in which a majority of participants were older than 30 years. The effect size in trained athletes after a comprehensive neuromuscular training program is large compared with controls.[25] Limited agreement exists between laboratory measures and the BESS in athletes with different training backgrounds.[2] Gymnasts had lower BESS scores compared to other athletes.[2]

The average number of BESS errors in healthy controls depends on the stance and surface. Very few errors (range, 0-3)[33] are associated with the double-limb stance on either the firm or foam surfaces.[8,33] Errors added to the total BESS score during the tandem stance average 1 error on the firm surface (range, 0-6)[33] and 3 on foam[8,33] (range, 0-8).[33] The single-leg stance is responsible for adding 2 errors[8,33] to the total BESS score on the firm surface (range, 0-8)[33] and 6 errors[8,33] on foam (range, 0-13 errors).[33] Averaging the 20- to 39-year-old data and the healthy controls results in a BESS score of 10.93 errors in youth, who would often use the BESS (Table 2). This agrees with normative data indicating an average BESS score of 10.97 in 104 community-dwelling adults.[19]

CONCLUSION

The BESS is a clinical evaluation of balance that usually has moderate to good reliability. The BESS correlates with laboratory-based measures for criterion-related validity and has construct validity. Scores increase with concussion, functional ankle instability, external ankle bracing, fatigue, and age. Scores should improve after completing a comprehensive neuromuscular training program.

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