

Original Research

An Evaluation of the Balance Error Scoring System in Female Soccer Players Following Soccer Heading: A Pilot Study

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Background

Soccer is a contact sport during which participants risk injury, including due to concussion. Interestingly, the task most frequently associated with concussions is the act of heading the ball. This study seeks to answer the following research question: Does an acute playing of purposeful soccer heading in female football players lead to changes in BESS normative outcomes and balance? Additionally, we aim to explore the relationship between a gold-standard BESS Test and a Balance Test performed on a force plate.

Methods

This project involved twenty-eight female soccer players (age = 19.6 + 2.96 years, mass = 60.4 + 5.3 kg, and height = 163.6 + 6.4 cm). pre and post the heading condition and the results of the Wilcoxon Signed Ranks Test. The participants were healthy and underwent BESS monitoring on a force plate before and after heading and footing training. Standard 450 g soccer balls were utilized. Participants performed ten headers for the header condition and ten footers for the footer condition. Resultant sway velocity and BESS error outcomes were calculated before and after heading and footing training. I need a brief description of the statistical approach here.

Results

Statistically significant increases after the heading condition were found for Single Leg Stance (COP PATH) score ($Z = -3.986$, $p = 0.000$), BESS score on foam surface ($Z = -2.511$, $p = 0.012$), BESS score on firm surface ($Z = -2.353$, $p = 0.019$). A statistically significant increase after the footer condition was found for the Tandem Stance (mm2) score ($Z = -2.900$, $p = 0.004$). A statistically significant difference between the group conditions was found in the post-BESS score foam difference ($U = 268.500$, $p = 0.042$). BESS score foam mean increase was 1.93 after the heading condition and 0.21 after the footer condition.

Conclusion

This pilot study not only tests the feasibility of using force plates to measure BESS outcomes after heading in female soccer but also underscores the effectiveness of using BESS parameters to evaluate changes in balance function following heading compared to a control footer condition. The findings of this study provide valuable insights into the potential effects of soccer on balance in female players, contributing to the body of knowledge in sports medicine and physical education.

Level of evidence

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INTRODUCTION

Repetitive head impacts (RHI), such that occur due to purposeful soccer heading, and the short- and long-term effects of those impacts on overall physical and mental health pose significant public health concerns in female athletes.¹ Concussion is a brain injury characterized by an alteration in brain function caused by a direct acceleration or deceleration force transmitted to the head of the soccer player. Between 1.6 and 3.8 million sports-related concussions occur every year in the United States.² Concussion is a common injury in contact sports such as soccer and American football. Consensus guidelines recommend removing any player exhibiting signs or symptoms of a concussion for evaluation. Making the diagnosis of a concussion is not always easy, as players can deny symptoms, and neurocognitive testing may be similar or only slightly different from baseline testing. The Balance Error Scoring System (BESS) has been developed as an objective test to assess concussed athletes.^{3,4} The BESS test was created as an outcome measure to assess postural stability. The tool is commonly used in the population of athletes with Sports Related Concussion (SRC). The new American Academy of Neurology concussion guidelines⁵ reports the BESS assessment tool as likely to identify concussion with only low to moderate diagnostic accuracy with a low specificity of 34 to 64% (meaning a false positive rate for concussion of 34 to 64%), but a high degree of specificity of 91% (meaning that the test will only miss one out of ten concussions).^{6,7} The heading element remains controversial, as the potential associations with long-term neurological consequences remain controversial. Nevertheless, although heading is usually asymptomatic and rarely causes concussion, there is evidence to suggest that cumulative heading exposure may lead to brain alterations in adults and affect cognitive function in adolescents. As a result, USA Soccer has implemented rule changes to restrict heading behavior in youth participants, aiming for the primary prevention of head injuries. Female soccer players are vulnerable to the risk of injury from soccer as their brains are still developing, eight and may be particularly vulnerable based on their increased rates of concussion. No studies to date have evaluated the feasibility of assessing BESS outcomes with force plates in female soccer.

Balance-related symptoms (i.e., dizziness and vertigo) are commonly reported in SRC.⁸⁻¹⁰ These symptoms may correlate with neurological findings, such as signs of postural instability. However, subtle postural impairments may be missed during a physical examination.¹⁰ On the one hand, such minor impairments may increase the risk of falls or accidents, particularly in situations of shared attention (i.e., during sports or conversations),¹¹⁻¹³ while on the other hand, balance impairments in the acute period after mTBI (mild Traumatic Brain Injury) have been associated with the persistence of post-concussive symptoms.¹⁴ Therefore, sensitive point-of-care measures may be a reasonable addition to the routine physical examination after mTBI to assess for acute balance impairments and the trajectory of recovery and help guide rehabilitation.¹⁵

The BESS is recommended as a sideline tool to support return-to-play decisions after a suspected head injury during training or competition. The BESS can assess healthy athletes' neurological functions, establishing a "normal" baseline—a score revisited following an SRC. Athletes should not return to play until their scores on the test return to their baseline.

This underscores the importance and reliability of the BESS as a diagnostic tool in assessing and managing head injuries in sports, providing reassurance and confidence to athletes, coaches, and medical professionals.

This study seeks to answer the following research question: Does an acute playing of purposeful soccer heading in female football players lead to changes in BESS normative outcomes and balance?

METHODS

This study was conducted during the 2022-2023 soccer season. Therapists/trainers and a supervising attending physician from the Department of Neurology follow each team.

The inclusion criteria were for the athletes to be healthy and without injury in the lower leg.

The exclusion criteria are that the athletes suffered a concussion in the last 1 year.

INSTRUMENTED BESS/POSTUROGRAPHY

The BESS consists of three tests lasting 20 seconds each, performed on a force plate with closed eyes and scored based on the number of errors across trials. The player first stands with the feet together, the hands on the hips, and the eyes closed (double leg stance). The task is then repeated with a single-leg stance using the non-dominant foot, and a third time, a heel-toe stance with the non-dominant foot in the rear (tandem stance) is performed. Each twenty-second trial is scored by counting the errors. The examiner counts errors only after the individual has assumed the appropriate testing position.

An error is scored when any of the following occurs:

- Moving the hands off of the iliac crests
- Opening the eyes
- A step, stumble or fall
- Abduction or flexion of the hip beyond 30°
- Lifting the forefoot or heel off of the testing surface
- Remaining out of the proper testing position for more than five seconds
- The maximum total number of errors for any condition is 10.

TEST PROTOCOL

Participants underwent BESS testing on a force plate before and after heading and footing conditions. They performed ten headers for the header condition and ten footers for the footer condition. The BESS trials, pre- and post-header and footer conditions, were assessed for both time and frequency domains.

Two observers assessed BESS performances using force plates in female players with a concussion and a healthy control group cohort. KINVENT DELTAS(KINVENT INC. France) force plates were utilized for static and dynamic balance BESS tests.

The testing procedure consisted of each subject performing a series of 4 single-leg balance trials (2 on each leg) and four double-leg balance trials with eyes closed for 20-second trials on a force plate. During single-leg balance trials, non-dominant legs were tested according to the BESS test procedures, with a proctor counting touches to the ground as the force plate collected data. During double-leg balance trials, both legs were tested according to the BESS test procedures, with a proctor counting any stumbles or extra touches as the force plate collected data. The balance test variable of interest is resultant sway velocity. The BESS test variable of interest is several errors during a trial.

In all tasks, standard 450 g soccer balls (inflated to 8 psi) are thrown at participants from 10 m by a trainer who kicks the ball toward the athletes. Each participant performed ten headers for the header condition, separated by 10-second intervals. For the footer (control) condition, each participant used their foot to volley the ball ten times, separated by 10-second intervals (to match the header condition). The resultant sway velocity pre- and post-heading and footing, as well as several BESS errors, were matched by the trial.

Participants completed two testing conditions (heading and footing pre and post), separated into two weeks. All participants performed the header condition first and the footer (control) condition second. Testing occurred at noon, starting the teams' outdoor training. Participants did not perform physical exercise 24 hours before testing due to its influence on balance modulation.

STATISTICAL ANALYSIS

Wilcoxon Signed Ranks Test was used to identify statistically significant paired differences in the six BESS variables assessed (Double Leg Stance R, Double Leg Stance L, Tandem Stance, Single Leg Stance, BESS score foam, and BESS score firm) before and after the heading condition and before and after the footer condition.

The mean change of all BESS variables was calculated by subtracting the pre-heading and footer scores (initial indicators) from the post-heading and footer scores (final indicators). The Mann-Whitney U was used to test for statistically significant differences between the two independent conditions (groups), heading and footer, regarding the mean change of all BESS variables.

In all cases, the confidence level was 95% ($\alpha=0.05$). SPSS statistical software, in combination with Microsoft Excel spreadsheets, was used for data entry, processing, and analysis.

RESULTS

The subjects recruited and divided into two groups were in the same age range (18-22). Specifically, the mean age of

Table 1. Subject characteristics

Characteristic	Soccer players (n=28)
Age (years)	
mean (SD)	()
Weight (Kg)	
mean (SD)	59.14 (4.29)
Height (m)	
mean (SD)	1.65 (0.07)
BMI	
mean (SD)	21.79 (1.48)

Legend: n, number; SD, standard deviation; BMI, Body mass index

++ Inclusion criteria - Exclusion criteria

the SRC group was 19.35 ± 1.18 years and 20.10 ± 1.18 years in the control group, respectively

The descriptive analysis of the BESS scores pre- and post-heading condition and the Wilcoxon Signed Ranks Test results for the 28 female athletes, are shown in [Table 2](#).

[Table 3](#) shows the descriptive analysis of the BESS scores pre- and post-footer condition and the results of the Wilcoxon Signed Ranks Test for the 28 female athletes.

Statistically significant changes after the footer condition were revealed in the following cases:

Statistically significant increases after the heading condition were found for Single Leg Stance (COP PATH) score ($Z = -3.986$, $p = 0.000$), BESS score on foam surface ($Z = -2.511$, $p = 0.012$), BESS score on firm surface ($Z = -2.353$, $p = 0.019$). A statistically significant increase after the footer condition was found for the Tandem Stance (mm2) score ($Z = -2.900$, $p = 0.004$). A statistically significant difference between the group conditions was found in the post-BESS score foam difference ($U = 268.500$, $p = 0.042$). BESS score foam mean increase was 1.93 after the heading condition and 0.21 after the footer condition.

[Table 4](#) shows the results of the mean BESS score changes between the post-heading and the post-footer condition. A statistically significant difference between the group conditions was found in the post-BESS score foam difference ($U = 268.500$, $p = 0.042$). BESS score foam mean increase was 1.93 after the heading condition and 0.21 after the footer condition.

DISCUSSION

This study seeks to answer the following research question: Does an acute playing of purposeful soccer heading in female football players lead to changes in BESS normative outcomes and balance? Also, this pilot study examines the feasibility of using force plates to measure BESS outcomes after heading in female soccer and highlights the effectiveness of using BESS force plate testing to evaluate changes in balance function following heading compared to control footer conditions.

Table 2. Pre & post heading condition BESS descriptive parameters (n=28)

Variable	Time	Mean	SD	Median	Mean Rank	Z value	p-value
Double Leg Stance R (mm2)	pre	66.32	5.96	66.00	12.21	-1.601 ^b	0.109
	post	64.82	7.41	64.50			
Double Leg Stance L (mm2)	pre	61.00	5.98	61.00	12.39	-1.863 ^c	0.062
	post	64.71	11.02	63.50			
Tandem Stance (mm2)	pre	61.64	10.87	59.50	10.18	-1.851 ^c	0.064
	post	65.68	7.46	63.50			
Single Leg Stance (COP PATH)	pre	2040.86	323.23	2064.50	28.00	-3.986 ^c	0.000
	post	2107.71	423.62	2098.00			
BESS score foam	pre	17.32	2.51	17.00	12.50	-2.511 ^c	0.012
	post	19.25	3.58	19.00			
BESS score firm	pre	13.39	2.51	13.00	6.00	-2.353 ^c	0.019
	post	15.46	4.08	15.00			

Legend: n, number; SD, standard deviation; a Wilcoxon Signed Ranks Test; b, Based on positive ranks; c, Based on hostile ranks

Table 3. Pre & post footer condition BESS descriptive parameters (n=28)

Variable	Time	Mean	SD	Median	Mean Rank	Z value	p-value
Double Leg Stance R (mm2)	pre	66.50	5.71	66.00	11.71	-1.448 ^b	0.148
	post	65.18	6.94	64.50			
Double Leg Stance L (mm2)	pre	61.00	5.98	61.00	14.75	-.289 ^b	0.773
	post	60.71	11.66	59.00			
Tandem Stance (mm2)	pre	57.86	10.24	56.50	13.70	-2.900 ^c	0.004
	post	66.04	7.12	64.00			
Single Leg Stance (COP PATH)	pre	1962.57	354.72	2050.00	11.89	-.229 ^b	0.819
	post	1977.14	340.03	1952.00			
BESS score foam	pre	17.11	3.51	17.00	10.50	-.016 ^c	0.987
	post	17.32	2.78	17.50			
BESS score firm	pre	14.43	3.57	13.50	4.75	-.401 ^b	0.688
	post	14.04	2.67	14.00			

Legend: n, number; SD, standard deviation; a Wilcoxon Signed Ranks Test; b, Based on positive ranks; c, Based on hostile ranks

These findings could impact the understanding of the effects of soccer heading on balance and neuromuscular and postural control in female soccer players.¹⁶

The results suggest that BESS plate tests are a feasible tool that may provide meaningful information to assess heading thresholds in female soccer. Postural control is maintaining one's center of mass within its support base and maintaining an upright stance in response to internal and external perturbations. This dynamic act primarily involves three primary sensory systems: the visual, vestibular, and somatosensory systems.¹⁷

According to a study by J. Caccese et al. (2024), the results suggest that persistent balance deficits at RTP in some individuals or that return-to-exercise occurring prior to RTP may exacerbate balance impairments. Moreover, changes in COP measures, in the absence of changes in BESS scores, suggest that the BESS may not be a sensitive enough tool for identifying changes in postural control.¹⁸

The study from Kakavas et al. (2023) shows that neurocognitive and neuromuscular deficits after a ball heading are likely subtle and not easily detected with current assessment strategies, yet they may have a significant clinical impact on subsequent injury risk as such deficits are likely to be magnified with more challenging athletic tasks. Hence, these deficits may create a "window of susceptibility" to musculoskeletal injury following a return to play after a concussion. The duration of this "window" of musculoskeletal injury is poorly understood.¹⁹

Sensory information from these three systems determines the body's upright position in space and relative movements made from internal or external forces. In turn, the central nervous system uses this information to react to or plan for muscular adjustments to maintain the upright body position via feedback and feedforward strategies.²⁰ The clinical analog of postural control is commonly denoted as balance during an upright stance. Both constructs (postural control and balance) can indirectly assess the im-

Table 4. Post header & footer condition mean BESS scores' changes (n=28)

Variable	Condition	Mean	SD	Mean Rank	U value	p-value
pre-post Double Leg Stance R difference (mm2)	Post-Header	-1.50	4.57	28.13	381.500	0.863
	Post-Footer	-1.32	4.53	28.88		
pre-post Double Leg Stance L difference (mm2)	Post-Header	3.71	10.07	31.82	299.000	0.127
	Post-Footer	-0.29	12.33	25.18		
Pre-post tandem Stance difference (mm2)	Post-Header	4.04	10.74	25.63	311.500	0.187
	Post-Footer	8.18	12.39	31.38		
pre-post Single Leg Stance (COP PATH) difference	Post-Header	66.86	174.74	31.91	296.500	0.118
	Post-Footer	14.57	307.61	25.09		
pre-post BESS score foam difference	Post-Header	1.93	3.79	32.91	268.500	0.042
	Post-Footer	0.21	3.64	24.09		
pre-post BESS score firm difference	Post-Header	2.07	4.09	32.16	289.500	0.062
	Post-Footer	-0.39	4.31	24.84		

Legend: n, number; SD, standard deviation; a Mann-Whitney U Test

pect on the nervous system because of the interplay between sensory and action systems (motor).^{21,22}

Postural control deficits are a cardinal sign of concussion regardless of mechanism (i.e., sports activity, car accidents, falls, and the like). Ball heading may impact postural control via different neurocognitive pathways. In recent years, the acute and long-term effects of concussion, specifically sport-related concussion, on postural sway have been well documented with clinical resolution at 2 to 5 days post-injury but with potential lingering issues beyond six months.²³

Studies usually used the same heading testing and conditions; the same ball trajectory and speed were used for all participants. The relatively low variability between header impact accelerations suggests that the head impacts measured from the seven instrumented players reflect the heading exposures for the entire cohort. While the present study shows evidence of balance changes following 10 headers, impairments are related to the severity of head injury.^{24, 25} However, whether a more significant number of headers or larger head impact accelerations would show transient changes in balance function remains unknown.²⁶⁻²⁸

LIMITATIONS OF THE STUDY

Experts believe that the BESS is best used when a baseline BESS score is obtained before the start of the season when a player is healthy. Then, repeated scores after a concussion can be used to monitor recovery. One limitation of this study is that only female players were evaluated; however, investigating female soccer players is relevant as females may be more prone to concussions than males. In addition, due to the pilot study design and small sample size, it cannot be assessed whether athletes' head impacts over the study period negatively influenced balance or nervous system functioning.

Future research must focus on the force-plate-collected balance BESS test. It must also deliver strategies expanding baseline testing (which most think of solely in terms of computerized neurocognitive testing), routinely performed at the elite level and, increasingly, at the high school level, to include a balanced assessment like BESS.

CONCLUSION

Heading is a crucial part of soccer and is unlikely to be discontinued. The results of this pilot study indicate that the instrumented BESS with force plates as a point-of-care tool provides insights into possibly helpful age-appropriate adoptions in the explanation and procedure of testing.

By combining the clinical BESS testing with force plates, this work adds valuable information regarding the magnitude, responsiveness, and trajectory of body sway in several testing positions. Such testing complements clinical assessment in investigating postural control in children and adolescents. While the BESS score only allows for considering a total score approximating postural control, the BESS with force plates gives several parameters representing the responsiveness and magnitude of body sway and a detailed analysis of movement trajectory.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest.

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