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Original Research

Balance Error Scoring System Performance Differences in Figure Skaters Based on Discipline

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Background

Balance and postural stability are required of figure skaters throughout on-ice performance. Spinning, jumping, and landing each rely on this skill set to maintain control while skaters manage changing demands for each skating discipline.

Hypothesis/Purpose

The aim of this study was to compare balance error scoring system (BESS) performance in figure skaters between disciplines and determine if age was related to BESS performance.

Study Design

Cross-sectional study.

Methods

Three hundred and fifty-eight figure skaters (age: 15.4±3.3 years, 213 females, 145 males) of multiple disciplines completed the BESS during the United States Figure Skating's Standardized Testing of Athleticism to Recognize Skaters (S.T.A.R.S.) combine. Errors during each condition of the BESS were recorded by trained evaluators. A 3x6 ANOVA was used to determine BESS differences based on skating discipline. Spearman's rho (ρ) correlation coefficients were calculated for relationships between BESS errors and age.

Results

Ice dancers had more errors than singles and pairs for bipedal foam ($p<0.001$) but had fewer errors than single skaters for single leg foam ($p=0.002$). Tandem on a firm surface also showed an increase in errors for ice dancers and pairs skaters compared to singles ($p<0.001$). There were significant weak negative relationships noted between age and bipedal foam and single leg firm conditions ($\rho=-0.14, -0.23$, $p<0.05$).

Conclusion

Figure skaters of different disciplines have varying levels of static postural stability. Assessing postural stability in figure skaters can provide insight to improve performance and may identify skaters at risk of injury.

Level of Evidence

3

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INTRODUCTION

Postural stability and balance are important to figure skaters of all ages as they influence flexibility and control. As figure skaters develop their on-ice skills from an early age, training may focus on specific jumps or spins, however the balance required to improve upon those initial skills can be measured independently from skating performance.[1] Jumping and landing on a single leg requires power, strength, balance, and stability.[2] Investigators have identified greater hamstring strength and hamstrings to quadriceps strength ratios in female figure skaters compared to female soccer players.[3] Trunk flexion and extension forces while standing and were higher in an athlete sample, including figure skaters, that was evaluated against a non-athlete group.[4] In junior elite figure skaters, knee extension strength was positively correlated to single axel and double axel height.[5] Strength investigations in the figure skating population are more prevalent, revealing a gap in the balance and stability literature for this group of athletes. Clinicians can easily implement functional balance assessments to measure these characteristics.

The Balance Error Scoring System (BESS) is a clinical assessment originally developed for measuring postural control characteristics in healthy athletes without expensive equipment.[6] Although the BESS is often utilized in concussion testing, this tool can be used to establish normative values for static postural stability that can be compared to values after musculoskeletal injury.[7] The BESS involves testing balance in three different stance conditions: bipedal, single leg, and tandem. As an assessment tool for postural imbalances, both firm and foam surfaces are commonly used. An athletic setting may increase the amount of external attentional demands experienced by the test taker which may influence their BESS score. Ideally the test should be administered in a controlled environment.[8]

Tests of postural stability such as the BESS can provide insight into athletic capabilities, but also can be influenced by factors such as age,[9] ankle instability,[10] or head injury.[6] Although the BESS may not have a relationship with the occurrence of acute lower extremity injuries, the test is advantageous to understand how balance differs between levels of sport.[11] In figure skaters, dynamic postural stability has been assessed with the Y-Balance test to compare between sexes,[12] but static postural stability has only been tested in a limited manner with the stork pose, which tests only single leg balance.[12] Static postural stability is influenced during figure skating as positions are held isometrically for extended periods of time, whether in bipedal, single leg or tandem positions. In adolescents and young adults, older age improves BESS performance, likely due to cognitive and physical development.[13] Therefore, it is important to use broader assessments such as the BESS to more fully understand variations in static postural stability in figure skaters across disciplines and ages.

The purpose of this study was to compare balance error scoring system (BESS) performance in figure skaters between disciplines and determine if age was related to BESS performance. A secondary purpose was to compare BESS errors between males and females, regardless of discipline. It was expected that skaters would display fewer errors during the bipedal and firm surface conditions across all disciplines. It was hypothesized that singles skaters would perform better on the BESS. For the secondary aim, females were expected to exhibit fewer errors than males. Age was expected to have a negative relationship indicating that as skater age increased, their errors decreased in each BESS condition.

METHODS

STUDY DESIGN

A cross-sectional study evaluated the balance of participants in the United States Figure Skating's Standardized Testing of Athleticism to Recognize Skaters (S.T.A.R.S.) combine. Deidentification of all data was performed before analysis and therefore this study was deemed exempt by the University Institutional Review Board.

PARTICIPANTS

The 358 participants did not have any current injury that limited their ability to complete the BESS test during the S.T.A.R.S. combine. The BESS was administered as part of combine testing by United States Figure Skating trained evaluators, which has sufficient interrater reliability for stance condition scores.[14]

TESTING PROCEDURES

Prior to balance testing, individuals self-reported age, sex, landing leg, and skating discipline. Landing leg length was measured from the greater trochanter to the lateral malleolus in centimeters using a tape measure and recorded.[15] All skaters completed balance testing in the same order of conditions, starting with a firm then foam surface. The participants were barefoot when completing conditions as follows: bipedal firm, bipedal foam, single leg firm, single leg foam, tandem firm, and finally tandem foam. The single leg tasks were completed on their non-dominant or non-landing leg, and this leg was also placed behind the landing leg in the tandem stance conditions.[16] Skaters were asked to balance with their eyes closed for 20-seconds for each trial.[7] Errors were counted real-time by evaluators according to standardized BESS scoring with a maximum of 10 errors for each condition.

STATISTICAL ANALYSES

Participant characteristics (age, sex, leg length, skating discipline) were used to calculate descriptive statistics. Errors observed were averaged for each BESS condition grouped by skating discipline and sex. A 3x6 ANOVA with Bonferroni post-hoc tests was performed to examine differences between discipline and condition. Mean differences (MD), standard error (SE), and 95% confidence intervals (CI) were calculated for significant effects identified from ANOVA. Independent t-tests were used to evaluate sex differences. For non-normally distributed data, assessed by Shapiro-

Table 1. Errors on Balance Error Scoring System by Skating Discipline

BESS Condition	Singles	Pairs	Ice Dance
Bipedal Firm	0.01±0.07	0.00±0.00	0.02±0.18
Bipedal Foam**, ***	0.35±1.00	0.00±0.00	1.24±2.89
Single Leg Firm	2.26±2.48	1.75±1.68	1.89±2.11
Single Leg Foam**	5.13±3.28	5.20±1.73	3.80±3.82
Tandem Firm*, **	1.68±2.23	3.53±2.24	3.81±3.68
Tandem Foam	3.66±2.44	3.13±2.19	3.84±2.80

*p<0.05, difference between singles and pairs
**p<0.05, difference between singles and ice dancers
***p<0.05, difference between pairs and ice dancers
BESS, balance error scoring system.

Wilk tests, Spearman's rho correlation coefficients were utilized to calculate relationships between age and BESS performance in each condition. Alpha was set *a priori* to p≤.05. All SPSS v.28.0.1.0 (SPSS, Chicago, IL) was used for all statistical analyses.

RESULTS

There were 358 participants included in this study including singles, pairs, and dancers (age: 15.4±3.3 years, leg length: 84.7±7.3 cm, 213 females, 145 males). Mean and standard deviation for errors completed in each BESS condition by discipline are summarized in Table 1. The ANOVA revealed between group differences based on discipline for the bipedal foam (F: 16.42, p<0.001), single leg foam (F: 6.56, p=0.002), and tandem firm (F: 23.90, p<0.001). There were no significant interactions between discipline and BESS condition. In the bipedal foam stance, ice dancers had more errors than both pairs (MD: 1.24, SE: 0.28, 95% CI: 0.57, 1.91) and singles skaters (MD: 0.89, SE: 0.18, 95% CI: 0.47, 1.32). Singles skaters had more errors than ice dancers in the single leg foam stance (MD: -1.34, SE: 0.39, 95% CI: -2.26, -0.41). In the tandem firm position, ice dancers had more errors than singles skaters (MD: 2.13, SE: 0.32, 95% CI: 1.35, 2.91), and pairs had more errors than singles skaters (MD: 1.85, SE: 0.49, 95% CI: 0.67, 3.03). There were no differences between males and females in any BESS conditions (Table 2), although males were significantly older (Males: 16.7±3.5 years, Females: 14.5±2.9years, p<0.001) and had a longer leg length (Males: 88.8±7.4 cm, Females: 81.9±5.8 cm, p<0.001). Age had a weak, negative relationship with bipedal foam (ρ=-.14, p=.001) and with single leg firm (ρ=-.23, p<0.001).

DISCUSSION

The results of this study support that BESS performance varies based on skating discipline. There were differences between disciplines for the bipedal foam, single leg foam, and tandem firm stances. The BESS effectively identifies static postural instability, especially in stances performed on foam surfaces.[6] Singles skaters perform higher difficulty jumps and more technical elements during their routines, so they require a greater degree of postural stability.[17] Ice dancers do not perform jumps, so they may not require the same level of postural stability needed for take-off and landing by singles skaters, as demonstrated by the poorer BESS performance in the bipedal foam and tandem firm stances (Table 1).

Past research has found varying performance on other measures of athleticism across skating discipline, specifically testing agility, strength, and flexibility.[1] For example, the Y-Balance test is a dynamic test that has been used to measure the posterolateral reach in figure skaters, which corresponds with the landing position.[15] A shorter reach distance during the posterolateral reach within the Y-Balance test has been correlated with skating speed. The Star Excursion Balance Test, from which the Y-Balance test was derived, has been incorporated into a previous study evaluating a proprioceptive training protocol in 10–18-year-old figure skaters.[18] All participants in their sample showed improvement in the Star Excursion Balance Test following the strength and proprioception training.[18] It has been reported that females have a greater Y-Balance composite score than males,[15] but skating discipline has not previously been assessed. Comparing Y-Balance and BESS performance can provide insight into both dynamic and static stability.

Noting differences in postural stability allows for a discipline-specific understanding of the sport's requirements. It has also been reported that dancers have decreased lumbar and hamstring flexibility compared to singles and pairs skaters, which may impact stability.[1] The same decrease in postural stability and balance manifested in our present study with a greater number of errors in the bipedal foam and tandem firm stances (Table 1). This discipline-specific approach to balance can impact training and performance, injury prevention and rehabilitation strategies, and establishment of reference values for the BESS.

There were no discipline-specific differences in BESS performance for the bipedal firm, single leg firm, or tandem foam stances. These findings suggest that the easier, initial position, the bipedal firm stance, may not provide an adequate challenge to postural stability. Single leg firm can be a more challenging position, which is supported by the current findings when noting that single leg firm had more errors than the other firm stances in this sample, regardless of lack of difference between disciplines. However, single

Table 2. Errors on Balance Error Scoring System by Sex

BESS Condition	Females (n=213)	Males (n=145)	All (n=358)
Bipedal Firm	0.00±0.00	0.02±0.18	0.01±0.12
Bipedal Foam	0.63±1.61	0.60±1.60	0.62±1.60
Single Leg Firm	2.14±2.40	1.98±2.11	2.08±2.28
Single Leg Foam	4.56±3.46	4.86±3.32	4.68±3.40
Tandem Firm	2.51±2.92	2.78±3.11	2.62±2.99
Tandem Foam	3.68±2.62	3.64±2.45	3.66±2.55

BESS, balance error scoring system.

leg balance on a firm surface has been assessed in a figure skating population using the stork pose, which found greater hold times in ice dancers than singles and pairs skaters.[1] Therefore, measuring stability with an endurance component may provide an additional challenge to compare between these athletes. Very few errors were recorded across groups for the bipedal firm and single leg firm positions (Table 1). The small number of errors agrees with previous findings which reported few BESS errors and minimal sway measured with a force platform in these positions.[16] Conversely, the tandem foam stance may have been similarly challenging due to sway for all disciplines, as that condition averaged approximately three errors for all disciplines. Three errors during tandem foam is comparable to other studies investigating the BESS in healthy collegiate baseball players[8] (2.9 errors), and a mixed sample of youth (3.8 errors), high school (3.5 errors), and college athletes (2.9 errors).[13] These similarities in errors for tandem foam reinforce the notion that the highest degree of postural instability was in this stance as quantified by a force platform measuring sway.[16] Together, these non-significant findings indicate that the least and most difficult conditions were not able to distinguish between skating disciplines in this sample. The overall body of evidence surrounding the BESS promotes its use to assess postural stability for baseline testing, musculoskeletal injury, and head injury purposes.[6,13,19] Comparable findings have been reported when examining head injuries, where the bipedal firm and single leg firm stances do not differ between concussed and non-concussed athletes.[6]

There were weak negative correlations between age and bipedal foam and single leg firm conditions, implying that as age increased, errors decreased. Previous findings suggest a stronger relationship between age and BESS performance in adolescents and young adults, where college athletes scored significantly better than both high school and youth athletes.[13] However, in this sample of elite young athletes, these relationships were less extreme. Youth athletes can increase balance and postural stability through sports and resistance training,[20] and these participants' athletic development and postural stability likely is greater than comparable non-athletes of the same age. Similarly, there has been an increase in agility and strength reported in more advanced skaters (junior and senior level) compared to novices.[1] These findings suggest early sport specialization and a focus on strength and balance training throughout the stages of development in young athletes can improve athletic capabilities and performance.[21]

Although not the primary aim of the study, sex differences in BESS performance were assessed due to the frequency of this comparison in the current figure skating testing literature.[12,15] There was no statistically significant difference between males and females on BESS performance in any condition. This conflicts with a study of normative scores on the BESS which reported fewer errors by females than males in a similar age range of young athletes.[13] However, they found no differences in BESS errors between collegiate-level males and females.[13] Comparing to college athletes may be more representative of our sample, as the figure skaters compete at a national level, and for the elite, an international level. They may be more athletically mature and specialized in their discipline despite the average age of the current participants (15.4±3.3 years) matching more closely to the high school cohort.

There were some limitations to the present study. Participants' injury history, and previous musculoskeletal or head injuries were not available and may have been confounding variables which altered BESS performance. The performance of the BESS barefoot or shod, does not consider how skaters balance while in their skating boot and on the ice, and limits the authors' ability to understand their balance on-ice. Also, access to the skaters' level (e.g., novice, junior, senior) was not provided, which could have provided further understanding of the role of experience or skill level in postural stability. Age was relied upon for this comparison, but age does not necessarily relate to skill level. Future research should compare static postural stability such as the BESS across levels in figure skating. This could provide athletes, clinicians, and coaches information to use for training programs, injury rehabilitation, and talent identification.

CONCLUSION

The results of this study support the hypothesis that BESS performance in some stances varies based on skating discipline in elite figure skaters. Singles skaters tended to display the least errors, specifically on the bipedal foam and tandem firm stances, but ice dancers had fewer errors than singles in a more challenging stance, the single leg foam. These findings support the idea that static postural stability can vary across skating discipline, and therefore using

the BESS to test postural stability off-ice in figure skaters may provide insight on performance improvement and injury risk. Additional factors such as age and sex do not tend to display a strong association with BESS performance in this population.

DECLARATION OF CONFLICTING INTERESTS

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