original research

Comparison of Static and Dynamic Balance in Female Collegiate Soccer, Basketball, and Gymnastics Athletes

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Context: How athletes from different sports perform on balance tests is not well understood. When prescribing balance exercises to athletes in different sports, it may be important to recognize performance variations.

Objective: To compare static and dynamic balance among collegiate athletes competing or training in soccer, basketball, and gymnastics.

Design: A quasi-experimental, between-groups design. Independent variables included limb (dominant and nondominant) and sport played.

Setting: A university athletic training facility.

Patients or Other Participants: Thirty-four female volunteers who competed in National Collegiate Athletic Association Division I soccer (n = 11), basketball (n = 11), or gymnastics (n = 12).

Intervention(s): To assess static balance, participants performed 3 stance variations (double leg, single leg, and tandem leg) on 2 surfaces (stiff and compliant). For assessment of dynamic balance, participants performed multidirectional maximal single-leg reaches from a unilateral base of support.

Main Outcome Measure(s): Errors from the Balance Error Scoring System and normalized leg reach distances from the Star Excursion Balance Test were used to assess static and dynamic balance, respectively.

Results: Balance Error Scoring System error scores for the gymnastics group were 55% lower than for the basketball group (*P* = .01), and Star Excursion Balance Test scores were 7% higher in the soccer group than the basketball group (*P* = .04).

Conclusions: Gymnasts and soccer players did not differ in terms of static and dynamic balance. In contrast, basketball players displayed inferior static balance compared with gymnasts and inferior dynamic balance compared with soccer players.

Key Words: proprioception, postural control, ankle injury, motor learning, attention

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Key Points

- Female basketball players demonstrated inferior static balance compared with gymnasts and inferior dynamic balance compared with soccer players.
- No differences in static or dynamic balance were seen between gymnasts and soccer players.
- Specific sensorimotor challenges, rather than general sport activity, appear to be important in developing optimal balance.

Athletic trainers often prescribe exercises in an attempt to enhance an athlete's postural control or balance and perhaps reduce the risk of injury. Unipedal balance tasks on progressively challenging surfaces (eg, firm floor to ankle disc) are examples of exercises that have improved the balance of athletes after ankle sprains.[1–3] Differences in ankle and knee proprioception between trained athletes and matched controls suggest that sport participation, by challenging sensorimotor systems, may enhance balance.[4,5] What seems to be lacking from this line of research is an appreciation of how athletes from different sports perform on balance tests. With this insight, athletic trainers may prescribe balance exercises more effectively to athletes from different sports.

Postural control or balance can be defined statically as the ability to maintain a base of support with minimal movement and dynamically as the ability to perform a task while maintaining a stable position.[6] Factors that influence balance include sensory information obtained from the somatosensory, visual, and vestibular systems and motor responses that affect

coordination, joint range of motion (ROM), and strength.[7–10] Some evidence in the literature suggests that superior balance among experienced athletes is largely the result of repetitive training experiences that influence motor responses and not greater sensitivity of the vestibular system.[11] Others argue that superior balance is the result of training experiences that influence a person's ability to attend to relevant proprioceptive and visual cues.[12] Although experts may not agree on the mechanism, research suggests that changes in both sensory and motor systems influence balance performance.

Each sport likely requires different levels of sensorimotor processes to perform skills and protect the neuromuscular system from injury. Gymnasts often perform leaping and tumbling maneuvers as well as static poses while barefoot on surfaces that vary in stiffness. Many of their skills require great strength and sometimes exaggerated joint ROM.[13] In contrast, basketball players often perform upper extremity passing, shooting, and dribbling skills while wearing shoes on flat, stiff surfaces. Their skills require great joint accelerations from

jump landings and cutting maneuvers.[14] Soccer players often perform lower extremity passing, shooting, and dribbling skills while wearing cleated or noncleated shoes on variable turf conditions.[15] The skill requirements and environmental demands of these aforementioned sports likely pose different challenges to the sensorimotor systems that cumulatively may influence the balance abilities of trained athletes. To our knowledge, studies comparing balance abilities among athletes competing in different sports do not exist. Therefore, our purpose was to compare static and dynamic balance among collegiate athletes currently competing or training in soccer, basketball, and gymnastics. We hypothesized that postural control would be different among athletes in these sports. An appreciation of postural control among athletes from different sports may give insight into whether sport demands influence balance and may help athletic trainers prescribe balance exercises more effectively.

METHODS

Subjects

All female student-athletes from 3 sports (soccer, basketball, and gymnastics) at a National Collegiate Athletic Association (NCAA) Division I university were asked to volunteer to participate in this study. Thirty-four student-athletes (soccer, n = 11; basketball, n = 11; gymnastics, n = 12) met the inclusion criteria and agreed to participate. We chose female collegiate athletes to better represent a population that displays high rates of ligamentous injuries compared with male collegiate athletes in soccer and basketball.[16] To be included in the study, participants had to be currently competing in only 1 sport for the previous 3 years and not be involved in a balance training program outside of their typical sport training. Participants were excluded if they had a lower extremity injury, vestibular problems (eg, vertigo), visual problems (eg, blind in one eye), or a concussion in the 12 weeks before the study. These exclusions were assessed by questioning the participants and not through physical tests. Participants signed an informed consent document approved by the university ethics committee (which also approved the study) and were asked to refrain from any exercise for 2 hours before testing. The participants' mean age and leg length (mean of both limbs), respectively, were 20.4 ± 1.1 years and 84.3 ± 2.9 cm for soccer, 21.6 ± 1.9 years and 94.8 ± 6.1 cm for basketball, and 21.2 ± 1.7 years and 82.04 ± 4.0 cm for gymnastics.

Protocol

Participants attended a university athletic training facility for 1 test session that included assessment of static balance, dynamic balance, and leg length. For assessment of leg length, we used a tape measure to determine the distance (to the nearest millimeter) between the anterior superior iliac spine and the medial malleolus of the same leg.[17] Both legs were measured, and limb dominance was determined by asking the participant which leg she preferred for kicking a ball. Static balance and dynamic balance were then randomly evaluated using the equipment and procedures described later.

Equipment

Static balance was assessed using the Balance Error Scoring System (BESS) described by Riemann et al.[18] The unstable
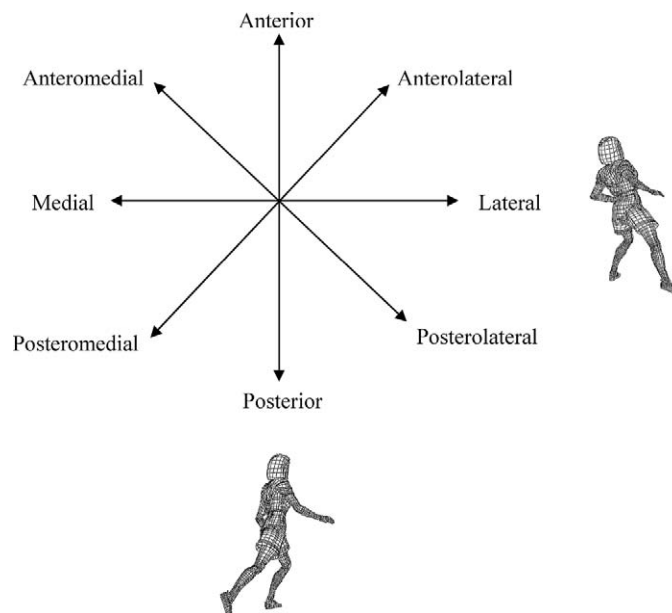
Figure 1. Top view of Star Excursion Balance Test grid. The grid displays directional terms for right leg dominance. Directional terms were mirrored for left leg dominance, and poses represent techniques for posterior and lateral directions.

surface consisted of a 50 × 41 × 6 cm closed-cell foam Airex Balance Pad (Alcan Airex AG, Sins, Switzerland). The stable surface was low-pile carpeting. Dynamic balance was assessed using the Star Excursion Balance Test (SEBT) described by Gribble and Hertel.[17] The testing grid consisted of 8 lines, each 120 cm in length extending from a common point at 45° angle increments (Figure 1), and was created using standard white athletic tape placed on a firm, textured tile surface. The middle of the grid was marked with a small dot that athletes were asked to center the stance foot over during testing. The grid was marked at 1-cm increments from the center outward to facilitate scoring during testing. Researchers have reported high intertester reliability (intraclass correlation coefficients = .78 to .96) and fair to good validity (r = .42 to .79) coefficients for the BESS[18] and high intratester reliability for the SEBT (intraclass correlation coefficients = .78 to .96).[19] Although no validity coefficients are available for the SEBT, authors[20] have provided evidence that the SEBT is sensitive for screening various musculoskeletal injuries.

Procedures

The procedures for the BESS test involved 3 stance positions each on the stable and unstable surfaces for the dominant and nondominant limbs. The 3 stance positions were double-leg stance with feet together, single-leg stance on test limb with contralateral knee in approximately 90° of flexion, and tandem stance with the foot of the test limb in line and anterior to the foot of the contralateral limb (ie, the heel of the test foot touching the toes of the back foot). Each position was held with eyes closed and hands on hips for 20 seconds in duration, and scoring was determined by recording of errors. Errors included (1) opening eyes; (2) lifting hands from hip; (3) touchdown of non-stance foot; (4) step, hop, or other movement of the stance foot or feet; (5) lifting forefoot or heel; (6) moving hip into more than 30° of flexion or abduction; and (7) remaining out of position for longer than 5 sec-

onds.[18] The different stances, surfaces, and limb conditions produced 10 separate BESS tasks that were randomly assigned. The double-leg stance condition was not repeated for dominant and nondominant limbs.

The SEBT protocol described by Gribble and Hertel[17] requires participants to maintain a stable single-leg stance with the test leg and to reach for maximal distance with the other leg in each of the 8 directions (Figure 1). Participants were asked to execute a touchdown without using the reach leg for support. If it was determined that the reach leg was used for support or the stable base of support was compromised, the trial was repeated. The leg tested (dominant, nondominant) and order of reach direction were randomly selected before testing, and a 5-second rest with a 2-footed stance was required between reach attempts. Three trials were performed for each limb, with a 120-second rest period between trials. Before testing, participants were given 180 seconds to familiarize themselves with the SEBT grid and were asked to practice reaching in each direction. This latter period resulted in 6 trials for most directions. Subjects were instructed to reach behind the stance leg when performing trials in the posterior directions (Figure 1). Visual cues, such as objects on the floor and people not involved in the study, were removed from the testing area to help reduce visual and auditory influences. No encouragement or further instruction was given to the participants throughout testing. Reach distance was marked with chalk on the floor immediately next to the athletic tape that corresponded to the site of touchdown. The distance from the center of the grid to the point of touchdown was measured with a tape measure, the value was recorded to the nearest millimeter, and the chalk mark was removed after each reach to reduce visual cues.

Data Analyses

All scoring was performed by the same tester. The error scores from the BESS test were summed for each limb, and the distance scores (cm) for each direction of the SEBT grid were averaged over the 3 trials and normalized to leg length (reach distance/leg length $\times$ 100 = percentage of leg length).[17] The normalized distances in each direction were then summed for both the dominant and nondominant leg. We summed the values to reduce the number of statistical tests and minimize inflation of type I error.

Statistical Design

The independent variables in this study were the type of sport played (soccer, basketball, or gymnastics) and limb used during testing (dominant or nondominant). The dependent variables (errors and normalized distances) were each examined for main effects and interactions with a 3 (sport played) × 2 (limb) analysis of variance with repeated measures on the limb factor. Follow-up multiple comparisons were performed on the sport played factor. The analysis of variance was performed twice, once for each dependent variable. The probability associated with a type I error was set at 0.05 for all observations, and the conservative Scheffé model was used for multiple comparisons to help control for inflation of alpha. We used SPSS (version 13.0; SPSS Inc, Chicago, IL) to analyze our data.

Balance Scores of the Soccer, Basketball, and Gymnastics Athletes*

Sport	Balance Error Scoring System Static Balance, Unitless Error	Star Excursion Balance Test Dynamic Balance, Σ % of Leg Length
Soccer		
Dominant limb	13.3 ± 1.3	756 ± 16.1
Nondominant limb	11.6 ± 1.4	756 ± 13.6
Mean	12.5 ± 1.1	756 ± 14.0†
Basketball		
Dominant limb	13.6 ± 1.1	694 ± 16.1
Nondominant limb	14.5 ± 1.4	714 ± 13.6
Mean	14.1 ± 1.1	704 ± 14.0
Gymnastics		
Dominant limb	8.8 ± 1.1	731 ± 15.4
Nondominant limb	9.3 ± 1.3	739 ± 13.0
Mean	9.1 ± 1.1‡	735 ± 13.4

*Values are mean ± SEM.
†Significantly greater than basketball group, P = .04.
‡Significantly less than basketball group, P = .01.

RESULTS

Measures of central tendency and spread for BESS and SEBT data are reported in the Table. No sport-by-limb interactions were noted for either the BESS ($F_{2,31}$ = 1.46, P = .25, partial η^2 = .09, 1 − β = .29) or the SEBT ($F_{2,31}$ = 1.12, P = .34, partial η^2 = .07, 1 − β = .23). Similarly, no main effects were seen for the limb factor for either the BESS ($F_{1,32}$ = .028, P = .87, partial η^2 = .001, 1 − β = .05) or the SEBT ($F_{1,32}$ = 2.86, P = .10, partial η^2 = .08, 1 − β = .37).

Main effects were observed for the sport factor for the BESS ($F_{2,31}$ = 5.25, P = .01, partial η^2 = .25, 1 − β = .80) and the SEBT ($F_{2,31}$ = 3.54, P = .04, partial η^2 = .20, 1 − β = .62). Multiple comparisons revealed that BESS scores were different between basketball and gymnastics (P = .01, effect size = .86). Additionally, a difference between soccer and basketball was observed for SEBT scores (P = .04, effect size = 1.0). The BESS error scores for the gymnastics group were 55% lower than for the basketball group (Figure 2), and SEBT scores were 7% greater in the soccer than in the basketball group (Figure 3).

DISCUSSION

We hypothesized that static and dynamic balance scores would be different among collegiate athletes competing in different sports. Female basketball players demonstrated inferior static balance compared with gymnasts and inferior dynamic balance compared with soccer players. No differences were noted between gymnasts and soccer players. Although the idea that sport involvement improves balance is not new,[4,5] our study extends this knowledge to particular sports and suggests that specific sensorimotor challenges, rather than just general sport activity, are important for the development of optimal balance.

Our static balance scores for soccer players (12.5 ± 1.1) closely match the static balance scores reported by Riemann et al[18] (12.2 ± 8.7) that included NCAA football, soccer, lacrosse, and wrestling athletes. The SEBT scores were more difficult to compare with those in the literature because of the
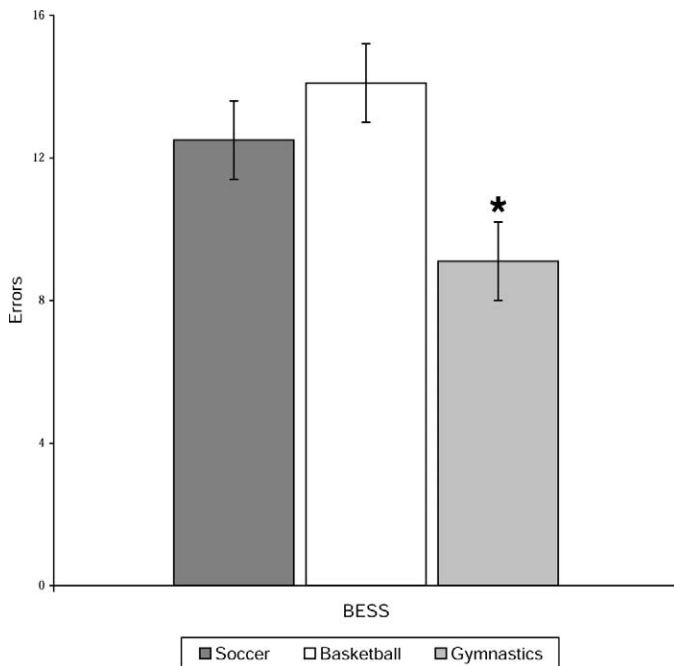
Figure 2. Balance Error Scoring System (BESS) values (mean ± SEM) for soccer, basketball, and gymnastics athletes. Values are the means for the dominant and nondominant limbs. *Indicates that gymnasts committed fewer errors than basketball players did (*P* = .01).
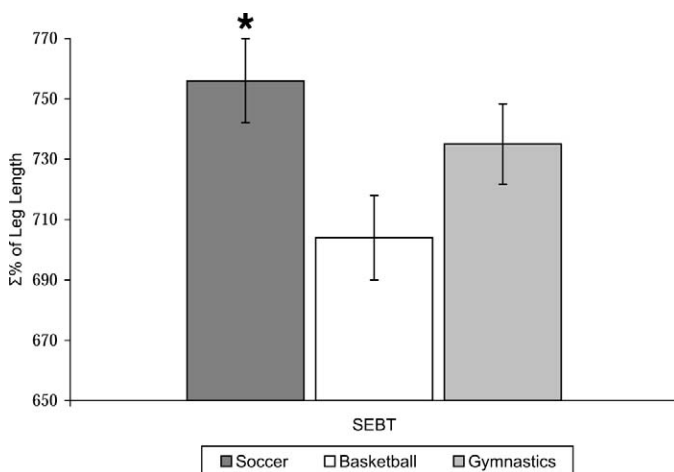
Figure 3. Star Excursion Balance Test (SEBT) values (mean ± SEM) for soccer, basketball, and gymnastics athletes. Values represent the means for the dominant and nondominant limbs. *Indicates that soccer players displayed greater reach distances than basketball players did (*P* = .04).

different techniques used in analyzing data (eg, normalized versus nonnormalized).

Within our study, the statistical differences observed among sports may, in part, be related to the unique sensorimotor challenges imposed by each sport. For example, gymnasts often practice motionless balance skills on the balance beam, similar to skills required in the BESS. Hence, gymnasts may develop superior attention focus on cues that alter balance performance, such as small changes in joint position and acceleration.[12] In contrast, basketball players rarely balance motionless on one leg and often attend to ball and player position cues.

Their static balance might be less developed than that of gymnasts, as supported by the results of this study. With respect to dynamic balance, soccer players often perform single-leg reaching movements outside their base of support during passing, receiving, and shooting, which may in part explain why their dynamic balance was better than basketball players' although no direct evidence supports this contention. Because static and dynamic balance scores were not different between soccer players and gymnasts, some sensorimotor challenges may be common in these 2 sports, or it may be that the BESS and SEBT were not sensitive enough to pick up the differences.

The specific changes in sensorimotor systems that result from sport participation are multifaceted. Some indirect evidence suggests the probability of detecting a change in joint position (proprioception) is improved after skill training[21] and that learning to pay attention to biomechanical cues (eg, joint acceleration) may be the mechanism for this change.[12] Training experiences that improve neuromuscular coordination, joint strength, and ROM are also likely mechanisms that lead to improved balance.[5,11,22] Although strength and ROM data were not available for our groups, ground reaction force data from previous researchers suggest that soccer players and gymnasts experience greater forces than basketball players for some skill maneuvers.[23–25] Hence, it may be that balance scores were different among groups in our study simply because of differences in joint strength. Future researchers may benefit from examining specific components of balance (eg, proprioception, vision, joint ROM, and strength) in athletes participating in different sports to determine which sensorimotor systems are more affected.

Intuitively, balance training reduces the risk of some musculoskeletal injuries, such as ankle sprains, especially if one or more balance components (eg, proprioception and joint ROM) are not optimal at the start. The literature seems to support this contention in that athletes in different sports displayed fewer ankle sprains and other musculoskeletal injuries than control subjects after static and dynamic balance training.[26–28] Athletic trainers will find a variety of balance training programs that may be effective at improving balance, including unipedal balance exercises on progressively challenging surfaces.[1–3]

In addition to knowing which balance training programs are effective, athletic trainers would benefit from knowing which athletes require more balance training to reduce musculoskeletal injuries. Because we observed inferior balance scores among basketball players and inferior balance scores may be a strong predictor of future ankle sprains,[29] athletic trainers may find it useful to prescribe more balance training to basketball players than to soccer players and gymnasts. This is not to say that soccer players and gymnasts would not benefit from balance training but that balance exercises may be more necessary for basketball players.

The BESS and SEBT assessments may be considered limitations of this study. Postural sway variables from a force platform have often been considered the ''gold standard'' for measuring static balance,[18] and although no gold standard has been defined for dynamic balance, more sophisticated techniques, such as the Dynamic Postural Control Index[30] and the time-to-stabilization test, are available.[31] Accordingly, a variety of balance tests exist and we therefore chose 2 tests that are reliable and considered by some to be valid.[18,19] Practically, the BESS and SEBT require minimal equipment and are

clinically "friendly," particularly when conducted with fewer trials or reach directions.[32] Given that we observed differences in balance among athletes in 2 sports, an additional application of this study may be that athletic trainers will use these tests on athletes in sports that were not tested to help expedite the prescription of balance exercises.

Within these limitations, we can conclude that soccer players and gymnasts did not differ in terms of static and dynamic balance on the BESS or SEBT. In contrast, basketball players displayed inferior static balance to gymnasts and inferior dynamic balance to soccer players.

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