Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High School Basketball Players

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RESEARCH REPORT

Study Design: Prospective cohort.

Objective: To determine if Star Excursion Balance Test (SEBT) reach distance was associated with risk of lower extremity injury among high school basketball players.

Background: Although balance has been proposed as a risk factor for sports-related injury, few researchers have used a dynamic balance test to examine this relationship.

Methods and Measures: Prior to the 2004 basketball season, the anterior, posteromedial, and posterolateral SEBT reach distances and limb lengths of 235 high school basketball players were measured bilaterally. The Athletic Health Care System Daily Injury Report was used to document time loss injuries. After normalizing for lower limb length, each reach distance, right/left reach distance difference, and composite reach distance were examined using odds ratio and logistic regression analyses.

Results: The reliability of the SEBT components ranged from 0.82 to 0.87 ($ICC_{3,1}$) and was 0.99 for the measurement of limb length. Logistic regression models indicated that players with an anterior right/left reach distance difference greater than 4 cm were 2.5 times more likely to sustain a lower extremity injury ($P<.05$). Girls with a composite reach distance less than 94.0% of their limb length were 6.5 times more likely to have a lower extremity injury ($P<.05$).

Conclusions: We found components of the SEBT to be reliable and predictive measures of lower extremity injury in high school basketball players. Our results suggest that the SEBT can be incorporated into preparticipation physical examinations to identify basketball players who are at increased risk for injury. *J Orthop Sports Phys Ther 2006;36(12):911-919.* doi:10.2519/jospt.2006.2244

Key Words: *female athlete, neuromuscular control, postural stability*

The National Federation of State High School Associations reports that nearly 1 million students participate in high school basketball annually.[1] An estimated 23% of these players sustain injuries and over 65% of these injuries (150 000) occur in the lower extremity.[32] Numerous risk factors for traumatic and overuse lower extremity injury in basketball players have been identified through prospective studies, including previous injury,[25,26] being female,[10,21,27,49] biomechanical alignment and anatomical factors (eg, greater right/left difference in Q-angle, rearfoot valgus, and weight distribution),[16,23,38,40,47] decreased muscle flexibility,[21,46,47] decreased vertical jump height,[47] tape or brace use,[7,48] shortened reflex response time,[47] and poor balance.[24] Of these factors, not all are directly modifiable. Recent reports suggest that neuromuscular control may be the most modifiable risk factor in the prevention of knee injuries.[9,16] The major neuromuscular control elements identified include dynamic lower extremity alignment upon landing from a jump, shock attenuation of peak landing forces, muscle recruitment

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patterns, and postural stability or balance.[9,16,17,28] Because the terms balance and postural stability are frequently used interchangeably to describe different concepts, for the purpose of this paper, balance is defined as the ability to maintain the center of gravity within the base of support.[2]

Although poor balance has been suggested as a risk factor for injury, few studies have examined this relationship. Whereas 3 researchers have reported poor balance as a risk factor for injury in various sports,[24,41,42] others have identified good balance as a risk factor[39] or have reported no correlation between balance and risk of injury.[4] Thus, the relationship between balance and risk of lower extremity injury has not been well established.

Currently, the gold standard for measuring balance requires expensive, not easily portable computerized tests that are time consuming.[24] The Star Excursion Balance Test (SEBT) is an inexpensive, quick method of measuring balance, with good reliability reported.[13,20] Using the SEBT, Olmstead et al[29] found that players with chronic ankle instability had significantly decreased reach distances compared to the uninvolved limb and to the reach distances of healthy controls. Hertel et al[12] simplified the test and through factor analysis found that the posteromedial reach direction identified individuals with chronic ankle instability compared to healthy controls. The SEBT also requires other neuromuscular characteristics such as lower extremity coordination, flexibility, and strength. Furthermore, each reach direction activates muscles to a different extent.[6]

Because high school basketball players are at significant risk for lower extremity injury, methods to identify those at increased risk are needed. There are few published reports regarding balance as a risk factor and these studies have yielded conflicting results.[4,24,39,41,42] Further, injury risk is likely multifactorial and the SEBT requires multiple neuromuscular characteristics that may render it a more effective test to identify athletes who are at greater risk for lower extremity injury. Therefore, the purpose of this study was to examine the relationship between SEBT reach distance and lower extremity injury among high school basketball players. We expected that SEBT reach distance normalized to limb length would be related to risk of lower extremity injury.

METHODS

Subjects and Setting

The study prospectively followed boys' and girls' basketball teams at 7 high schools in Indiana during the 2004-2005 season. Of the 289 players who were on the roster of the freshmen, junior varsity, and varsity teams, 235 (130 boys, 105 girls) participated in the study. Twenty-three players elected not to participate in the study and 31 players were excluded from the study due to current head cold or vestibular dysfunction, a lower extremity injury within the past month, concussion within the past 3 months, or having elected not to perform the SEBT. The study was approved by the Rocky Mountain University of Health Professionals Institutional Review Board. Informed written consent was obtained from the player and parent or guardian prior to participation in the study and the rights of the subjects were protected throughout the study.

Questionnaire

At the beginning of the season, each player completed a questionnaire providing baseline characteristics, including gender, age, previous time-loss injuries, current lower extremity symptoms, brace or tape use, and participation in conditioning programs.

SEBT Protocol

The players viewed an instructional video demonstrating the test and testing procedures. Because Hertel et al[13] found a significant learning effect with the SEBT where the longest reach distances occurred after 6 trials followed by a plateau, the players practiced 6 trials on each leg in each of the 3 reach directions prior to formal testing. The player stood on 1 leg in the center of a grid, with the most distal aspect of the great toe at the starting line. While maintaining single-leg stance, the player was asked to reach with the free limb in the anterior, posteromedial, and posterolateral directions in relation to the stance foot (Figure 1). The maximal reach distance was measured by marking the tape measure with erasable ink at the point where the most distal part of the foot reached. The trial was discarded and repeated if the player (1) failed to maintain unilateral stance, (2) lifted or moved the stance foot from the grid, (3) touched down with the reach foot, or (4) failed to return the reach foot to the starting position. The process was repeated while standing on the other leg. The greatest of 3 trials for each reach direction was used for analysis of the reach distance in each direction. Also, the greatest reach distance from each direction was summed to yield a composite reach distance for analysis of the overall performance on the test.

Lower Limb Length

On a mat table with the player in supine, a mark was placed with a fine tipped marker on the player's most inferior aspect of each anterior superior iliac spine and on the most distal portion of each lateral malleolus. After the player lifted the hips off the table, the examiner passively straightened the legs to equalize the pelvis. The player's right and left limb length was then measured from the anterior superior iliac spine to the most distal portion of the lateral malleolus with a cloth tape measure.

Reliability of Measures

Prior to the basketball season, we conducted a pilot study to establish the reliability of the SEBT and limb length measurements. We measured 10 female and 4 male basketball players (n = 28 limbs) in each of the reach directions, as described above. After a minimum 5-minute rest, each athlete's reach distance and limb length were measured again. The intrarater reliability was calculated using intraclass correlation coefficient ($ICC_{3,1}$) and method error. The $ICC_{3,1}$ ranged from 0.84 to 0.87 for the 3 reach directions of the SEBT and was 0.99 for limb length (Table 1). At the end of the season, we measured 10 male and 10 female players who participated in the study (n = 40 limbs), to examine the test-retest reliability and response stability of the SEBT. When we compared the preseason measurement to the postseason measurement, we found the SEBT test-retest reliability $ICC_{3,1}$ ranged from 0.89 to 0.93 and the method error coefficient of variation ranged from 3.0% to 4.6%, indicating good measurement stability (Table 2). Method error coefficient of variation is the percentage of variation from the preseason to the postseason measurement and reflects the difference between the scores.[31]

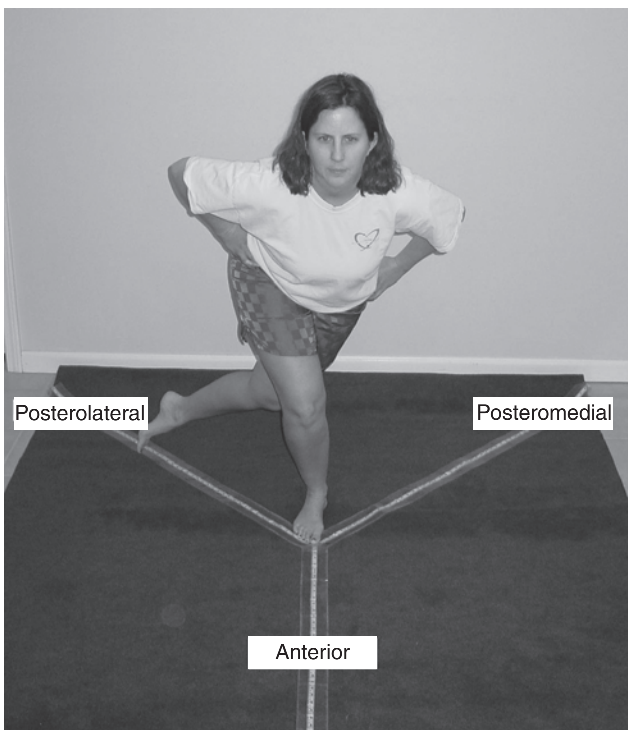

FIGURE 1. Star Excursion Balance Test with reach directions labeled in reference to right stance foot.

TABLE 1. Intraclass correlation coefficient ($ICC_{3,1}$), confidence interval (CI), and method error (ME) for Star Excursion Balance Test reach directions and limb length measurement for intratester reliability (n = 14 [28 limbs]).

	$ICC_{3,1}$	95% CI	ME (CVME)
Anterior reach	0.84	(0.68, 0.92)	2.0 (2.9)
Posteromedial reach	0.82	(0.65, 0.91)	2.5 (2.9)
Posterolateral reach	0.87	(0.75, 0.94)	2.9 (3.4)
Limb length	0.99	(0.98, 0.99)	0.2 (0.2)

Abbreviation: CVME, coefficient of variation of method error (percent variation in measurement between trial 1 and trial 2).

TABLE 2. Intraclass correlation coefficient ($ICC_{3,1}$), confidence interval (CI), and method error (ME) of Star Excursion Balance Test measurement for preseason and postseason measurement stability (n = 40).

	ICC	95% CI	ME (CVME)
Anterior reach	0.89	(0.80, 0.94)	3.0 (3.6)
Posteromedial reach	0.93	(0.87, 0.96)	3.9 (3.5)
Posterolateral reach	0.91	(0.84, 0.95)	4.6 (4.4)

Abbrevation: CVME, coefficient of variation of method error (percent variation in measurement between trial 1 and trial 2).

Injury Surveillance Protocol

Prior to the start of the basketball season, the coaches and certified athletic trainers were trained in the use of the Athletic Health Care System Daily Injury Report (DIR).[34-37] The DIR was primarily maintained by the coaches to record all injuries and athletic participation throughout the basketball season. A lower extremity injury was defined as any injury to the limb including the hip, but not the lumbar spine or sacroiliac joint, that resulted from a team-sponsored basketball practice or game that caused restricted participation or inability to participate in the current or next scheduled practice or game.[24,32,33]

For each injury, the coach recorded the date of injury, body part, type of injury (eg, sprain, contusion), and date of return to unrestricted participation. If the player reported the injury to the certified athletic trainer, the same information was recorded in a standardized format. The DIR was collected monthly to ensure it was completed in detail and to compare the coaches' and certified athletic trainers' reports. If there was a discrepancy between the reports, the coach and certified athletic trainer were interviewed to determine if a time-loss injury occurred.

At the end of the basketball season, the players completed a questionnaire that addressed whether the player had experienced a time-loss injury, used lower extremity bracing or taping, or participated in a balance or performance training program. This questionnaire was compared to the DIR and the certified athletic trainers' reports to ensure that all time-loss injuries were recorded. If an injury was missing from the DIR, the coach and certified athletic trainer were interviewed to determine if the time-loss injury should be included according to the study's standardized injury definition.

Data Analysis

Means and standard deviations were calculated for the baseline characteristics, SEBT reach distance, and limb length. As reach distance has been associated with limb length,[8] reach distance was normalized to limb length to allow more precise comparison between players. To express reach distance as a percentage of limb length, the normalized value was calculated as reach distance divided by limb length then multiplied by 100. Composite reach distance was the sum of the 3 reach directions divided by 3 times limb length, then multiplied by 100.

Because cutoff points for each reach direction have not been reported, a receiver operating characteristic (ROC) curve analysis was used to identify the cutoff point for reach distance for right and left limbs, as well as right/left reach distance difference. The point on the curve was identified as the reach distance that maximized both sensitivity and specificity.[31] For right/left reach distance difference, cutoff point of 4.0 cm was selected a priori to classify a player at increased risk for injury based on Olmstead et al,[29] who found that a right/left reach distance difference of approximately 4.0 cm identified individuals with chronic ankle instability. Post hoc ROC curve analysis yielded a similar cutoff point of 3.75 cm, but given the error of the measurement and the clinical insignificance of 0.25-cm difference, a 4.0-cm difference was used for analysis.

Crude odds ratios and 95% confidence intervals were calculated for lower extremity injury, comparing the proportion of individuals in a high-risk group (as determined by the ROC curves) with the proportion of individuals in the referent group for each potential risk factor. For multivariate analyses, the measures of association were the adjusted odds ratios, which were generated from a multiple logistic regression analysis. We loaded potential confounding factors (gender, grade, previous injury, participation in a neuromuscular training program since initial measurement, and lower extremity tape/brace use) in the model first. Then, independent variables that were significant in the univariate analysis (crude odds ratios) were added individually with the potential confounders to determine the final adjusted model.

An alpha level of $P \leq .05$ was used to determine statistical significance. All data were analyzed using SPSS for Windows, Version 13.0 (SPSS Inc, Chicago, IL).

RESULTS

Baseline characteristics of the basketball players are shown in Table 3. The mean limb length, reach distances, reach distances normalized to limb length for the 3 reach directions, and normalized composite reach are presented in Table 4.

Of the 235 players who participated in the study, 54 players (23.0%) incurred a lower extremity injury. Fifty (92.5%) of the injuries were traumatic in nature

TABLE 3. Baseline characteristics of high school basketball players during the 2004-2005 season. Values expressed as n (%).

	Total (n = 235)*	Girls (n = 105)	Boys (n = 130)
Grade			
9th	61 (26.0)	25 (23.8)	36 (27.7)
10th	71 (30.2)	30 (28.6)	41 (31.5)
11th	61 (26.0)	35 (33.3)	26 (20.0)
12th	42 (17.9)	15 (14.3)	27 (20.8)
Use lower extremity brace/tape			
Yes	89 (37.9)	35 (33.3)	54 (41.5)
No	146 (62.1)	70 (66.7)	76 (58.5)
Number of previous injuries			
0	98 (41.7)	43 (41.0)	55 (42.3)
1	91 (38.7)	35 (33.3)	56 (43.1)
2	34 (14.5)	19 (18.1)	15 (11.5)
3	8 (3.4)	6 (5.7)	2 (1.5)
≥4	3 (1.7)	2 (1.9)	2 (1.5)

* Included only players who completed Star Excursion Balance testing. Demographics for players who did not complete Star Excursion Balance testing were not significantly different.

TABLE 4. Mean reach distance and limb length of high school basketball players during the 2004-2005 season. Values expressed as mean ± SD.

	Total	Girls	Boys
Reach distance*			
Anterior	78.2 ± 8.2	73.1 ± 5.8	82.3 ± 7.6
Posteromedial	107.0 ± 11.7	98.9 ± 9.3	113.6 ± 8.9
Posterolateral	100.4 ± 12.0	93.0 ± 9.7	106.4 ± 10.3
Composite†	285.6 ± 30.0	265.0 ± 22.8	302.2 ± 24.3
Limb length*	94.3 ± 6.1	89.9 ± 3.9	97.9 ± 5.1
Normalized reach distance‡			
Anterior	83.9 ± 7.1	81.4 ± 6.2	84.1 ± 7.6
Posteromedial	113.4 ± 9.7	110.1 ± 10.0	116.1 ± 8.5
Posterolateral	106.4 ± 10.8	103.6 ± 10.7	108.7 ± 10.3
Composite§	100.9 ± 8.4	98.4 ± 8.2	103.0 ± 8.0

* Average of right and left limb in centimeters.
† Sum of the 3 reach distances (anterior, posteromedial, and posterolateral) in centimeters.
‡ Reach distance divided by limb length multiplied by 100.
§ Sum of the 3 normalized reach distances (anterior, posteromedial, and posterolateral), divided by 3 times limb length, multiplied by 100.

(eg, ankle sprain, knee sprain) and 4 injuries were considered overuse-related injuries (eg, medial tibial stress syndrome, patellar tendonitis). Table 5 displays the risk of lower extremity injury by grade level, reach distance, and right/left reach distance difference. For all players, anterior right/left reach distance difference greater than or equal to 4 cm, decreased normalized right anterior reach distance, and decreased normalized posteromedial, posterolateral, and composite reach distances bilaterally were significantly associated with lower extremity injury ($P<.05$). For girls, anterior right/left reach distance difference of greater than or equal to 4 cm and decreased normalized anterior, posteromedial, posterolateral, and composite reach distances bilaterally were significantly associated with lower extremity injury ($P<.05$). For boys, only anterior right/left reach distance difference greater than or equal to 4 cm was significantly associated with lower extremity injury ($P<.05$).

After adjusting for gender, grade, previous injury, participation in a neuromuscular training program since initial measurement, lower extremity tape/brace use and all potential factors found to be associated with risk of lower extremity injury, the final logistic regression model is shown in Table 6. Normalized composite right reach distance of less than or equal to 94.0% was significantly associated with lower extremity injury for all players and for girls ($P<.05$). Figure 2 shows a plot of girls' normalized composite right reach distance, with girls below the 94% criterion line at greater risk of injury. In addition, anterior right/left reach distance difference of 4 cm or more was significantly associated with lower extremity injury for all players and boys ($P<.05$).

DISCUSSION

The purpose of this study was to determine if the SEBT could predict lower extremity injury in high school basketball players. Our results indicated that a decreased normalized right composite reach distance and greater anterior right/left reach distance difference on the SEBT predicted lower extremity injury. Our findings are consistent with McGuine et al,[24] who reported that basketball players with poor balance were more susceptible to ankle injury. They measured postural sway with eyes open and closed in 210 high school basketball players using force plate analysis and then monitored injuries during a basketball season. They also found that higher postural sway scores correlated with more severe ankle injury.[24] Additionally, other studies of soccer, Gaelic football, and hurling players[41,42] have found that athletes with poor balance had a greater risk of sustaining an ankle injury.

In contrast to our findings, others have found good balance to be a risk factor for injury,[39] or found no correlation between balance and risk of injury.[3] One potential explanation for the different findings may be due to the statistical management of poor balance in 1 limb. Because several studies have found increased injury risk for athletes with a side-to-side difference in strength, flexibility, and neuromuscular control,[14,17,21,39] we used the concept of limb imbalance in our study.[15] A decreased reach distance in 1 limb was treated as a potential risk factor for injury to either limb. This concept has several implications for increasing the likelihood of injury. First, 1 less adept lower extremity might alter how the athlete reacts to situations, causing increased stress to the more adept lower extremity. Second, the more adept lower extremity may absorb excessive force due to instability resulting from poor balance on the less adept lower extremity. Finally, the less adept lower extremity may not provide a stable base on which to land or pivot.[15,43] Thus, studies that either averaged the balance score of both limbs[39] or only examined the balance of the injured limb[4] may not have identified poor balance as a risk factor. Soderman et al[39] found that female soccer players with better balance were at increased risk for lower extremity injury. They used the average postural sway score of both limbs and the median postural sway score as the cutoff value to determine the high-risk group. However, by using the average postural sway of both limbs, a limb with poor balance could be masked by a contralateral limb with good stability. In addition, their use of the median postural sway score to determine high-risk and referent groups may have incorrectly identified the high-risk group if the cutoff value were anywhere else except at the median.

Another explanation of the conflicting results among studies is that in addition to assessing balance, the SEBT also requires lower extremity strength, range of motion, and coordination, which may increase its sensitivity to predict injuries. Additionally, Earl and Hertel[6] found that each reach direction activated the stance lower extremity muscles to a different extent. They reported that in the anterior reach direction the vastus medialis and lateralis were most active. During the posterolateral reach, the biceps femoris and anterior tibialis were most active. The anterior tibialis was most active in the posteromedial reach direction. Thus, Beynnon et al[4] may not have found an association between the risk of ankle injury and postural sway values because their test did not have the dynamic components of the SEBT.

In addition, the influence of other risk factors (eg, flexibility, strength, or other anatomic or biomechanical causes) should be considered. For example, it may be possible that ankle range of motion or quadriceps strength were underlying risk factors that manifested in the SEBT. Because this study did not measure

RESEARCH REPORT

TABLE 5. Potential risk factors for lower extremity injury among high school basketball players during 2004-2005 season.

Characteristic	Total (n = 235) n at Risk	Total % Injured	Total OR*	Total (95% CI)	Girls (n = 105) n at Risk	Girls % Injured	Girls OR*	Girls (95% CI)	Boys (n = 130) n at Risk	Boys % Injured	Boys OR*	Boys (95% CI)
Grade												
9th	61	19.7	1.0		25	28.0	1.0		36	13.9	1.0	
10th	71	18.3	0.9	(0.4,2.2)	30	20.0	0.6	(0.2, 2.2)	41	17.1	1.3	(0.4,4.4)
11th	61	27.9	1.6	(0.7,3.7)	35	25.7	0.9	(0.3, 2.8)	26	30.8	2.8	(0.8,9.7)
12th	42	28.6	1.6	(0.7,4.1)	15	46.7	2.3	(0.6, 8.6)	27	18.5	1.4	(0.4,5.5)
Anterior reach distance difference*												
<4 cm	141	17.0	1.0		72	22.2	1.0		69	11.6	1.0	
≥4 cm	94	31.9	2.3‡	(1.2,4.2)	33	39.4	2.3‡	(0.9, 5.6)	61	27.9	2.9‡	(1.2,7.4)
Normalized anterior reach distance†												
R>84.3	95	16.8	1.0		34	11.8	1.0		61	19.7	1.0	
R≤84.3	140	27.1	1.8‡	(1.0,3.5)	71	35.2	4.1‡	(1.3,12.9)	69	18.8	0.9	(0.4,2.3)
L>84.4	112	18.8	1.0		39	12.8	1.0		73	21.9	1.0	
L≤84.4	123	26.8	1.6	(0.9,3.0)	66	36.4	3.9‡	(1.3,11.3)	57	15.8	0.7	(0.3,1.6)
Posteromedial reach distance difference*												
<4 cm	111	24.3	1.0		56	28.6	1.0		55	20.0	1.0	
≥4 cm	124	21.8	0.9	(0.5,1.6)	49	26.5	0.9	(0.4, 2.1)	75	18.7	0.9	(0.4,2.2)
Normalized posteromedial reach distance†												
R>109.0	161	17.4	1.0		60	15.0	1.0		101	18.8	1.0	
R≤109.0	74	35.1	2.6‡	(1.4,4.8)	45	44.4	4.5‡	(1.8,11.4)	29	20.7	1.1	(0.4,3.2)
L>108.7	167	19.2	1.0		63	19.0	1.0		104	19.2	1.0	
L≤108.7	68	32.4	2.0‡	(1.1,3.8)	42	40.5	2.9‡	(1.2, 7.0)	26	19.2	1.0	(0.3,3.0)
Posterolateral reach distance difference*												
<4 cm	102	27.5	1.0		54	31.5	1.0		48	22.9	1.0	
≥4 cm	133	19.5	0.6	(0.3,1.2)	51	23.5	0.7	(0.3, 1.6)	82	17.1	0.7	(0.3,1.7)
Normalized posterolateral reach distance†												
R>105.6	121	17.4	1.0		42	11.9	1.0		79	20.3	1.0	
R≤105.6	114	28.9	1.9‡	(1.0,3.6)	63	38.1	4.6‡	(1.6,13.2)	51	17.6	0.8	(0.3,2.1)
L>105.5	135	18.5	1.0		50	16.0	1.0		85	20.0	1.0	
L≤105.5	100	29.0	1.8‡	(1.0,3.3)	55	38.2	3.2‡	(1.3, 8.2)	45	17.8	0.9	(0.3,2.2)
Composite reach distance difference*												
<12 cm	153	22.2	1.0		76	27.6	1.0		77	16.9	1.0	
≥12 cm	82	24.4	1.1	(0.6,2.1)	29	27.6	1.0	(0.4, 2.6)	53	22.6	1.4	(0.6,3.5)
Normalized composite reach distance†												
R>94.0	174	17.8	1.0		67	14.9	1.0		107	19.6	1.0	
R≤94.0	61	37.7	2.8‡	(1.5,5.3)	38	50.0	5.7‡	(2.3,14.4)	23	17.4	0.9	(0.3,2.8)
L>95.6	176	18.8	1.0		67	17.9	1.0		109	19.3	1.0	
L≤95.6	59	35.6	2.4‡	(1.2,4.6)	38	44.7	3.7‡	(1.5, 9.1)	21	19.0	1.0	(0.3,3.2)

Abbreviations: OR, odds ratio.
* Difference between right and left reach distances.
† Normalized reach distance is reach distance divided by limb length multiplied by 100.
‡ $P<.05$

these factors, we cannot ascertain which factors most influence the results of the SEBT.

Interestingly, we found that girls with composite reach distance less than 94.0% of their limb length were more than 6 times more likely to have a lower extremity injury, but this risk factor was not significant for boys. This finding is important in that it may help identify 1 risk factor difference (ie, neuromuscular control) between boys and girls, as researchers have consistently reported that girls have higher injury rates than boys in high school basketball[10,22,27,49] and other high school sports played by both genders.[19,26] More importantly, several authors have reported that women are 2 to 6 times more likely to injure their knee than men.[3,11,14,49] Thus, the SEBT may be a useful measure that can help identify a component of the neuromuscular differences found between boys and girls.

We have demonstrated that the SEBT can be quickly and reliably performed on a large group of basketball players. If our results are confirmed, the SEBT could be incorporated into preparticipation physical examinations to help identify basketball players who possess specific deficits and it may be possible to improve these deficits through a neuromuscular training program prior to release for competition. Various researchers have reported the effectiveness of neuromuscular training programs to decrease risk of lower extremity injuries in athletes, especially those which included ankle disc balance training.[5,14,44,45] Further, Holm et al[18] and Paterno et al[30] demonstrated that balance could be improved after 6 to 7 weeks of training.

TABLE 6. Adjusted odds ratios for potential lower extremity injury risk factors among high school basketball players.

Risk Factor	Category	LE Injury AOR‡ (95% CI)
All players		
Normalized composite right reach distance*	≤94.0%	3.0 (1.5, 6.1)
Anterior reach distance difference†	≥4 cm	2.7 (1.4, 5.3)
Girls		
Normalized composite right reach distance*	≤94.0%	6.5 (2.4, 17.5)
Boys		
Anterior reach distance difference†	≥4 cm	3.0 (1.1, 7.7)

* Reach distance is reach distance divided by limb length multiplied by 100. Right reach done by standing on left limb and reaching with the right limb.

† Difference between right and left anterior reach distances.

‡ Adjusted odds ratio for gender, grade, previous injury, participation in a neuromuscular training program since initial measurement, and lower extremity tape/brace use.

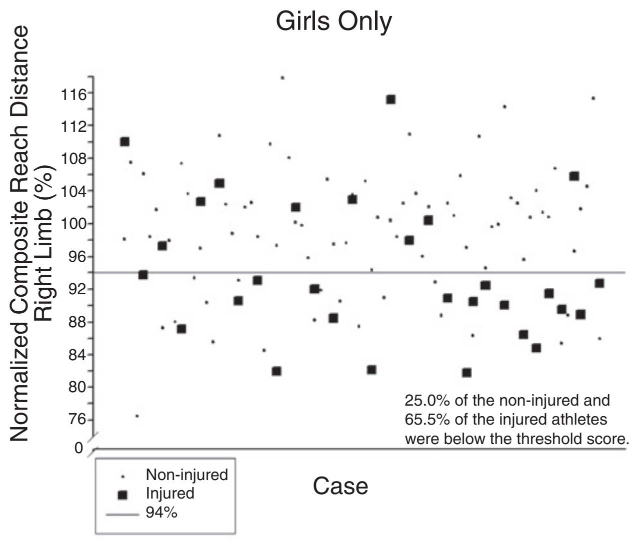

FIGURE 2. Plot of girls' normalized composite right reach distance with girls below the 94% criterion line at greater risk of injury.

Our study's prospective design allowed the characteristics of each player to be established before the injury occurred, thus minimizing measurement and recall bias. Further, our study used a comprehensive injury surveillance system that may have more accurately identified all lower extremity injuries. The coach and the certified athletic trainer prospectively recorded time-loss injuries in an effort to capture all injuries, as some athletes may report injuries to the certified athletic trainer rather than to the coach and vice versa. An end-of-season questionnaire was completed by the athlete to identify any injury that may not have been reported by the coach or a certified athletic trainer. Only injuries that met the study injury definition were included in the analysis.

Some limitations of this study should be noted. First, our data were based on 1 basketball season at 7 high schools, which may limit our external validity. Also, the same data set that was used to determine the ROC cutoff point was used to test the cutoff point in the prediction model. This may have lead to an inflated prediction value. Further, because we collected the DIR on a monthly basis, the accuracy of the DIR may have been lower than if we had collected it weekly. Also, future studies should have the athletes complete an injury questionnaire monthly, rather than just at the end of the season, to increase the accuracy of identifying time-loss injuries.

CONCLUSION

We found components of the SEBT to be reliable and predictive measures of lower extremity injury in high school basketball players. Specifically, players with a greater anterior right/left reach distance difference were 2.5 times more likely to sustain a lower extremity injury. Additionally, girls with a decreased normalized composite reach distance were 6.5 times more likely to have a lower extremity injury. If our results are confirmed, the SEBT could be incorporated into preparticipation physical examinations to identify basketball players who possess specific deficits, and it may be possible to improve these deficits through a neuromuscular training program prior to release for competition. Additional studies are needed to determine if the SEBT reach distance is associated with lower extremity injury in other high school basketball and sport populations. We also recommend that the relationship between SEBT reach distance and specific injuries (eg, ankle sprain, anterior cruciate ligament tear) be examined in more depth. Further, future studies should examine which anatomical and biomechanical factors most influence SEBT reach distance and if assessment of lower extremity alignment while performing the SEBT adds additional predictive value. Finally, future studies should investigate whether the SEBT reach distances improve after completing neuromuscular training programs.

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