

Lower Quarter Y-Balance Test Scores and Lower Extremity Injury in NCAA Division I Athletes

Wilson C. Lai,^{*†} BS, Dean Wang,^{*} MD, James B. Chen,^{*} MD, Jeremy Vail,[‡] MPT, ATC, Caitlin M. Rugg,^{*} MD, and Sharon L. Hame,^{*} MD

Investigation performed at the Department of Orthopaedic Surgery, David Geffen School of Medicine, University of California at Los Angeles, Los Angeles, California, USA

Background: Functional movement tests that are predictive of injury risk in National Collegiate Athletic Association (NCAA) athletes are useful tools for sports medicine professionals. The Lower Quarter Y-Balance Test (YBT-LQ) measures single-leg balance and reach distances in 3 directions.

Purpose: To assess whether the YBT-LQ predicts the laterality and risk of sports-related lower extremity (LE) injury in NCAA athletes.

Study Design: Case-control study; Level of evidence, 3.

Methods: The YBT-LQ was administered to 294 NCAA Division I athletes from 21 sports during preparticipation physical examinations at a single institution. Athletes were followed prospectively over the course of the corresponding season. Correlation analysis was performed between the laterality of reach asymmetry and composite scores (CS) versus the laterality of injury. Receiver operating characteristic (ROC) analysis was used to determine the optimal asymmetry cutoff score for YBT-LQ. A multivariate regression analysis adjusting for sex, sport type, body mass index, and history of prior LE surgery was performed to assess predictors of earlier and higher rates of injury.

Results: Neither the laterality of reach asymmetry nor the CS correlated with the laterality of injury. ROC analysis found optimal cutoff scores of 2, 9, and 3 cm for anterior, posteromedial, and posterolateral reach, respectively. All of these potential cutoff scores, along with a cutoff score of 4 cm used in the majority of prior studies, were associated with poor sensitivity and specificity. Furthermore, none of the asymmetric cutoff scores were associated with earlier or increased rate of injury in the multivariate analyses.

Conclusion: YBT-LQ scores alone do not predict LE injury in this collegiate athlete population. Sports medicine professionals should be cautioned against using the YBT-LQ alone to screen for injury risk in collegiate athletes.

Keywords: collegiate athlete; injury prevention; injury screening; sports; Y-balance test

According to the National Collegiate Athletic Association (NCAA) Injury Surveillance Program (ISP), game injuries in collegiate athletes occur as often as 13.8 times per 1000

athlete-exposures (AEs), with more than half of these injuries occurring in the lower extremity (LE).¹⁰ Furthermore, game injuries requiring 7 days or more before return to full participation occur as often as 2.9 times per 1000 AEs.¹³ Several studies have indicated that poor balance is associated with an increased risk of LE injury.^{11,15,16,22}

Therefore, the use of quantitative athlete movement-screening tests measuring LE balance may be useful for sports medicine professionals to identify athletes at risk for injury. Additionally, predetermined benchmarks on these tests can serve as objective measures of the amount of improvement an athlete has made during rehabilitation and when an athlete can safely return to play after injury.

The Lower Quarter Y-Balance Test (YBT-LQ) is a screening tool that measures single-leg balance and reach distances in 3 directions: anterior, posteromedial (PM), and posterolateral (PL). The YBT-LQ was modified from the Star Excursion Balance Test (SEBT), which measures 8 reach directions. Both the SEBT and the YBT-LQ have been

[†]Address correspondence to Wilson C. Lai, BS, UCLA Department of Orthopaedic Surgery, David Geffen School of Medicine, University of California at Los Angeles, 10833 Le Conte Avenue, 76-143 CHS, Los Angeles, CA 90095-6902, USA (email: wlai@mednet.ucla.edu).

^{*}Department of Orthopaedic Surgery, David Geffen School of Medicine, University of California at Los Angeles, Los Angeles, California, USA.

[‡]Department of Athletics, University of California at Los Angeles, Los Angeles, California, USA.

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shown to be predictive of LE injuries in athletes.^{2,3,7,17,20} However, the YBT-LQ is easier to administer and has higher intra- and interrater reliability compared with the SEBT.⁸ Using the SEBT, Plisky et al¹⁷ was the first to report that an anterior reach asymmetry of more than 4 cm in the lower extremities and a composite reach distance less than 94.0% of limb length were both predictive of LE injury in a cohort of female high school basketball players. Subsequent studies using the YBT-LQ to identify athletes at risk for injury reported conflicting results.^{2,7,20,23} While some studies demonstrated that a reach asymmetry of more than 4 cm was associated with an increased risk of injury,^{7,20} others did not.^{2,23} However, the majority of these studies did not account for known factors associated with increased injury risk, such as AEs, sport type, body mass index (BMI), or prior LE surgery.^{2,6,9,14} Failure to account for these factors could have potentially confounded the results of prior studies.

Regarding NCAA athletes across multiple sports, only a few studies have used the YBT-LQ to identify those at risk for injury.^{20,23} Smith et al²⁰ reported that an anterior asymmetry cutoff score greater than 4 cm was associated with increased risk of injury in the general NCAA population. However, Wright et al²³ reported no such association. Since athletic trainers and physicians often treat athletes from multiple sports, a single YBT-LQ cutoff score that is applicable to the general collegiate athlete population would be ideal. Thus, the purpose of the study was to evaluate whether the YBT-LQ is an effective screening tool for predicting LE injury in the general NCAA population. A receiver operating characteristic (ROC) analysis was performed to identify an optimal cutoff score in each direction. A correlation analysis between the laterality of asymmetry and the laterality of injury was performed. Finally, multivariate analysis was used to evaluate the YBT-LQ score as a predictor of LE injury while accounting for various confounding variables.

METHODS

In total, 294 NCAA Division I collegiate athletes at a single institution for the 2013-2014 and 2014-2015 seasons were identified and participated in the study. Athletes from 21 sports were included—baseball, men's and women's basketball, cross country, football, women's golf, gymnastics, men's and women's soccer, softball, swimming and diving, men's and women's tennis, track and field, men's and women's volleyball, sand volleyball, and men's and women's water polo. As defined by previously published reports,¹⁸ sports were classified into 4 groups based on probability of contact: collision (football), contact (basketball, gymnastics, soccer, water polo), limited contact (baseball, softball, volleyball), and noncontact (cross country, golf, swimming and diving, tennis, track and field). Dual-sport athletes were assigned to the group representing the sport in which they participated the most. Institutional review board approval for this study was obtained.

All athletes were administered a preparticipation physical evaluation (PPE) by a licensed physician. Athlete data such as BMI, sex, sport type, and history of prior surgeries

TABLE 1
NCAA Athlete Characteristics^a

Variable	n (%)
Sex	
Male	177 (60)
Female	117 (40)
Sport	
Collision	84 (29)
Contact	88 (30)
Limited contact	63 (21)
Noncontact	59 (20)
Body mass index, kg/m ²	
18.5-24.9 (normal)	174 (59)
25.0-29.9 (overweight)	90 (31)
≥30 (obese)	30 (10)
Precollegiate lower extremity surgery	
Yes	26 (9)
No	268 (91)
Total	294

^aNCAA, National Collegiate Athletic Association.

were documented during the PPE. A total of 309 athletes completed the PPE. Due to incomplete data acquisition or nonparticipation in the YBT-LQ, 15 athletes were excluded, thus leaving 294 athletes for analysis (Table 1).

Using published protocols, athletic trainers administered the YBT-LQ to athletes at the time of the PPE.^{2,12,20} After preseason collection of the PPE and YBT-LQ, athletes were followed prospectively over the course of the single season. Athletes who sustained an injury over the course of the season were identified through the Sports Injury Monitoring System (SIMS; FlanTech Inc). The SIMS database includes a roster of all athletes and a detailed record of all reportable injuries, including type and location of injury and the medical attention received. Injuries were defined as those causing athletes to miss 7 days or more before return to full participation, similar to the definition of significant injury used by the NCAA-ISP.¹³ This definition was used to identify sport-related injuries that are clinically significant, that limit an athlete's ability to play, and that typically require medical workup, imaging, and a treatment plan. Injury rate was calculated by dividing the number of injuries by the number of AEs. An AE was defined as an athlete's participation in a single game or competition.

The YBT-LQ Protocol

The YBT-LQ was performed by use of a Y-Balance Test Kit (Move2Perform). The YBT-LQ examines maximum LE reach of the free leg in the anterior, PM, and PL directions while the subject maintains a unilateral stance with the opposite leg centered on a platform. This process is repeated after the subject switches to the contralateral leg. According to standardized protocol, a trial was considered invalid if the subject (1) failed to maintain unilateral stance, (2) touched down on the reaching foot, (3) failed to return to the starting position, such as removing the hands from the hips, or (4) pushed or kicked the indicator to increase distance.^{2,12,20} Three

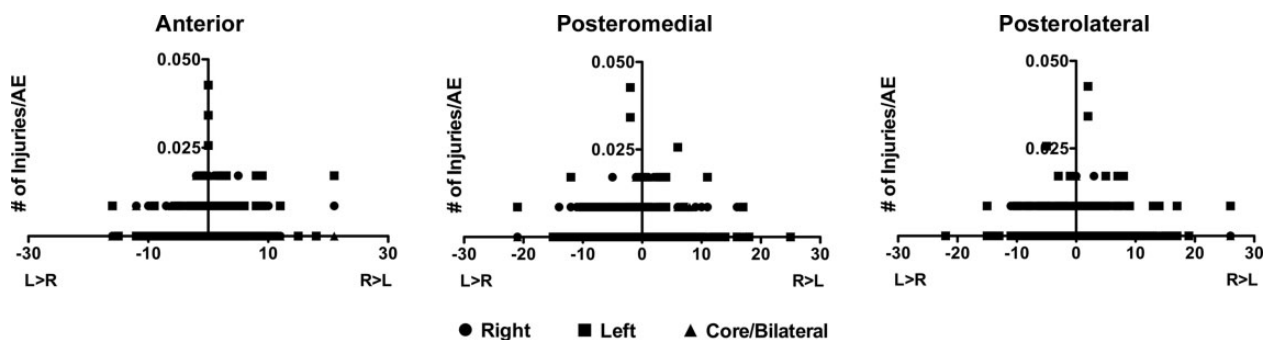


Figure 1. Laterality of reach asymmetry vs laterality of injury. AE, athlete-exposure; L, left; R, right.

trials were repeated for each direction, in which the examiner recorded the maximum reach score. Differences in the maximum reach distance in centimeters for each limb were compared to examine right and left asymmetry for each anterior, PM, and PL direction. The normalized composite score (CS) was calculated by summing the maximum reach in each of the 3 directions, then dividing by 3 times the leg length for that side.³ Leg length was standardized to the right leg and was measured from the inferior tip of the anterior superior iliac spine to the distal end of the medial malleolus.

Statistical Analysis

The laterality of reach asymmetry was determined by subtracting the maximum reach score of the left leg from that of the right leg. Thus, a positive value indicated a longer reach with the right leg, and a negative value indicated a longer reach with the left leg. This value was then correlated with the laterality of injury per AE in each athlete. A correlation analysis was performed between the CS and laterality of injury per AE, with calculation of coefficients of determination (R^2). ROC analysis was used to determine the optimal predictive value cutoff score for YBT-LQ asymmetry in the anterior, PM, and PL directions, along with its respective sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under the curve (AUC). These values were compared with a cutoff score of 4 cm, identified by other studies as a predictor of LE injury.^{7,17,20} Finally, all variables were entered into a backward, stepwise, multivariate linear regression analysis to evaluate potential predictor variables. Those variables with $P < .20$ were considered further in a multivariate Cox and linear regression analysis to assess predictors of earlier injury and the number of injuries per AE, respectively. Significance was indicated by $P < .05$. All analyses were performed with JMP Pro 12 (SAS Institute).

RESULTS

Of the 294 athletes in the study, 177 (60%) were male and 117 (40%) were female. The PPE documented that 26

TABLE 2
Correlation Between Composite Scores and Number of Injuries Per Games Played^a

CS Laterality	R^2	P Value
CS of right leg (mean = 1.0134 ± 0.0862)		
Right-side LE injury	0	.35
Left-side LE injury	0.01	.12
Core/bilateral LE	0	.98
CS of left leg (mean = 1.1029 ± 0.0850)		
Right-side LE injury	0	.32
Left-side LE injury	0.02	.03
Core/bilateral LE	0	.82

^aCS, composite score (the sum of 3 normalized reach distances [anterior, posteromedial, and posterolateral] divided by 3 times limb length); LE, lower extremity.

athletes (9%) had undergone precollegiate LE surgery (Table 1). Among all athletes, 27.6% (n = 81) sustained at least 1 LE injury within 12 months after their PPE date.

No significant correlation was found between the laterality of reach asymmetry and the laterality of injury in the anterior, PM, and PL directions, suggesting that laterality of reach asymmetry does not predict the laterality of injury (Figure 1).

A weak correlation was found between left-side CS and the number of left-side LE injuries per AE, with an $R^2 = 0.02$ ($P = .03$) (Table 2). Otherwise, no significant correlation was found between CS and the number of right-side, left-side, or core/bilateral LE injuries.

ROC analysis found optimal cutoff scores of 2, 9, and 3 cm for anterior, PM, and PL reach, respectively (Table 3). No significant independent predictors of earlier injury were identified by use of these asymmetry cutoff scores. Similarly, no significant independent predictors of earlier injury were identified by use of the cutoff of 4 cm for anterior, PM, and PL. Anterior asymmetry more than 2 cm and PL asymmetry more than 3 cm were associated with a lower number of injuries per AE, with rate ratios of 0.52 (95% confidence interval [CI], 0.49-0.55) and 0.73 (95%CI, 0.69-0.78), respectively ($P < .01$). Similarly, when 4 cm was used as the cutoff for anterior and PM asymmetry, the number of injuries per AE was lower, with rate ratios of 0.66 (95%

TABLE 3
Predictive Value of Y-Balance Asymmetry: Receiver Operating Characteristic Analysis

Cutoff	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	Area Under the Curve
Anterior					0.54
2 cm	52.4	55.5	29.9	76.4	
4 cm	74.4	30.4	27.9	76.7	
Posteromedial					0.49
9 cm	17.1	89.9	37.8	75.0	
4 cm	48.8	44.5	24.1	70.6	
Posterolateral					0.54
3 cm	54.9	54.6	30.4	77.0	
4 cm	59.8	40.5	26.6	73.6	

CI, 0.62-0.70) and 0.68 (95% CI, 0.64-0.72), respectively ($P < .01$). Female sex, sport type (collision, limited contact, and noncontact), BMI 25 or higher, and prior precollegiate LE surgery were all significant independent predictors of the number of injuries per AE ($P < .01$).

DISCUSSION

The literature reports conflicting results on whether the YBT-LQ can predict injury and identify potentially correctable functional deficits to reduce injury risk. In our study, ROC analysis found optimal asymmetry cutoff scores of 2 cm, 9 cm, and 3 cm for anterior, PM, and PL reach, respectively. However, all of these potential cutoff scores, along with a cutoff score of 4 cm used by the majority of prior studies,^{2,7,17} were associated with poor sensitivity and specificity. More important, none of the asymmetry cutoff scores were associated with earlier or increased rate of injury in the multivariate analyses. Our study also suggests that laterality of reach asymmetry does not predict the laterality of injury. These findings suggest that the YBT-LQ alone is a poor screening tool for LE injury in the general collegiate athlete population.

Our findings contradict several studies reporting that a reach asymmetry more than 4 cm is associated with increased risk of LE injury.^{7,17,20} In a population of NCAA Division I athletes, Smith et al²⁰ found that anterior asymmetry more than 4 cm (sensitivity, 59%; specificity, 72%) was the optimal cutoff point for predicting injury. Although the sensitivity was poor, the determined cutoff point was in agreement in a study by Plisky et al¹⁷ using the SEBT. However, in studies that compared SEBT to YBT-LQ, participants reached farther in the anterior direction on SEBT than on YBT-LQ.^{4,5} Coughlan et al⁴ concluded that reach values established for the SEBT in athletic, healthy, and injured populations may not be transferrable to YBT-LQ performance. Furthermore, Gonell et al⁷ showed that professional soccer players were 3.86 times more likely to sustain an LE injury with PM asymmetry more than 4 cm on the YBT-LQ, but those investigators found no significant risk in the anterior or PL direction.

Our findings are consistent with 2 other published studies that found no relationship between reach asymmetry and injury risk.^{2,23} Butler et al² found that in 59 college

football players, no particular asymmetry cutoff point was associated with a higher risk for injury. A study of 189 Division I athletes also discovered no particular cutoff point for any reach direction that was associated with increased injury risk.²³ Using our calculated cutoff scores in a multivariate analysis, we found that increased anterior and PL asymmetries were associated with a slightly lower rate of injury per AE, which is contradictory to the purposed role of the YBT-LQ.

Although a weak but significant correlation was found between the left-side CS and the number of left-side LE injuries per AE, we found that CS was a poor predictor of LE/core injury overall. This stands in contrast to other studies,^{2,17} which found that athletes with CS less than a predetermined cutoff score were at increased risk for LE injury. One study found that female high school basketball players with CS cutoff scores 94.0% or lower were 6.5 times more likely to sustain LE injury.¹⁷ Another study found that male college football players with CS cutoff scores lower than 89.6% were 3.5 times more likely to sustain LE injury.² In other studies of NCAA Division I athletes across multiple sports, CS did not predict LE injury.^{20,23} We suspect that this discrepancy may be primarily attributed to confounding variables among the study populations. In our study, we found that female sex, sport type, BMI 25 or higher, and prior precollegiate LE surgery were significant independent predictors of the rate of injury, which is also well documented in the literature.^{1,6,9,14,21} However, previous YBT-LQ studies did not account for most of these factors or for AEs.^{2,7,20,23}

The discrepancies among prior studies may be attributed also to the inconsistent definition of *injury*. For example, Plisky et al¹⁷ and Butler et al² defined injury as restricted participation or inability to participate in the current or next scheduled practice or game. In contrast, Smith et al²⁰ and Wright et al²³ defined injury as any event that caused the athlete to seek care from one of the members of the university-based health care team as evidenced by a medical note by a physician or athletic trainer. In our study, we defined LE injuries as those requiring 7 days or more missed before return to full participation, similar to the definition of significant injury used by NCAA-ISP.¹³ We believe that this definition is appropriate in identifying clinically significant injuries throughout a season. Including injuries that result in fewer than 7 days missed risks counting less significant

injuries that are typically self-limiting and may not as significantly affect an athlete's ability to participate.

This study has several limitations. A large proportion of our athletes (29%) were football players, who on average have higher injury rates.¹³ Furthermore, the classification of sport by contact status may not always reflect injury risk, as some limited-contact sports can be as dangerous as collision or contact sports. However, classification of the sports was needed to perform our statistical analysis. Other factors that may be associated with injury, such as playing surface, rest quality, muscular strength, and dietary habits, were not accounted for in this study because these particular data were not available. Additionally, the data used to determine the ROC cutoff score were used to test the predictive value of the cutoff score in the multivariate model. Using the same data for both analyses is more likely to demonstrate meaningful findings than using cutoff scores determined from a different data set. Practice participation data were not available and therefore were not included in calculation of AEs. However, sports-related injuries have been shown to occur 3.5 times more frequently in games compared with practices and training sessions.¹⁰ Finally, repeated testing of athletes was not performed, so the intra- and interrater reliabilities within our study are not known. Nevertheless, other studies have demonstrated good intra- and interrater reliabilities of the YBT-LQ.¹⁹

In conclusion, YBT-LQ scores do not predict LE injury in the general collegiate athlete population. We found that reach asymmetry and normalized CS on the YBT-LQ were not associated with increased LE injury risk in our population when we controlled for established risk factors such as sex, BMI, prior LE surgery, and sport type. Ultimately, sports medicine professionals should be cautioned against using the YBT-LQ alone to screen for collegiate athletes at high risk for LE injury.

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