Association of Y Balance Test Reach Asymmetry and Injury in Division I Athletes

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ABSTRACT

SMITH, C. A., N. J. CHIMERA, and M. WARREN. Association of Y Balance Test Reach Asymmetry and Injury in Division I Athletes. *Med. Sci. Sports Exerc.*, Vol. 47, No. 1, pp. 136–141, 2015. **Purpose**: The Y balance test (YBT) is a screen of dynamic balance requiring stance leg balance while the contralateral leg reaches in anterior (ANT), posteromedial (PM), and posterolateral (PL) directions. YBT has been proposed as a screen for injury risk; however, limited research has examined the association between YBT and injury. The purpose of this study was to examine the association between YBT (asymmetry and composite score (CS)) and noncontact injury in a sample of Division I (DI) college athletes from multiple sports. **Methods**: DI college athletes were screened with the YBT during the preparticipation examination to determine asymmetry (absolute difference between legs in ANT, PL, and PM) and CS (summed average of right/left ANT, PL, and PM normalized to leg length). Participants were followed throughout the sport season, and noncontact injuries requiring athletic training staff intervention were recorded for analysis. Demographic variables between injured and uninjured athletes were assessed with independent *t*-tests. Receiver operating characteristic (ROC) curves determined optimal cut points for predicting injury on the basis of CS and asymmetry. CS was analyzed as a continuous variable, as ROC curves were unable to maximize sensitivity and specificity. Logistic regression models adjusted for sport and previous injury determined the odds of injury on the basis of asymmetry and CS. **Results**: One hundred and eighty-four participants were included in analysis; 81 were injured. ROC curves determined asymmetry >4 cm (sensitivity, 59%; specificity, 72%) as the optimal cut point for predicting injury. Only ANT asymmetry was significantly associated with noncontact injury (odds ratio, 2.33; 95% confidence interval, 1.15–4.76). **Conclusions**: ANT asymmetry >4 cm was associated with increased risk of noncontact injury. CS in this sample of DI athletes was not associated with increased risk of injury. **Key Words:** NEUROMUSCULAR CONTROL, MOVEMENT PATTERN, STAR EXCURSION BALANCE TEST, YBT

The National College Athletic Association Injury Surveillance System recorded more than 33,000 total injuries in Division I (DI) athletes in 15 sports over a 16-yr interval (16). While contact mechanisms were most common, noncontact mechanisms accounted for 17.7% and 36.8% of injuries during competition and practice, respectively (16). The cumulative incidence of injuries at the 2011 International Association of Athletics Federation World Championships was 134.5 injuries per 1000 registered athletes, 59% of which were caused by overuse mechanisms (1). Furthermore, according to Hewett et al. (14), approximately 70% of all anterior cruciate ligament injuries are noncontact in nature. Analysis of injury determined that noncontact and overuse mechanisms, unlike contact mechanisms, could not be effectively addressed through rules related to the sport and protective equipment (16). For example, ocular damage by contact from stick or puck can be reduced by regulation requiring protective face shields in hockey (19). Therefore, effective reduction in noncontact injury requires identification of modifiable risk factors and implementation of targeted interventions.

Several studies have proposed neuromuscular control as a possible modifiable injury risk factor (14,18,25,31,35). The relation between deficient neuromuscular control and risk of future injury has been assessed using jumping–landing tasks (28), single-leg balance tests (25,31), and movement pattern assessment (5,18). Despite support for these different assessment tools within the literature, barriers to widespread use during the preparticipation examination include the length of time for screening (11,18,21), the availability of equipment (15), and the specificity to certain populations and pathologies (28,29). Integration of screening within existing preparticipation examination requires an efficient, reliable, and affordable tool. Currently, no consensus for preparticipation screening for neuromuscular control has been established; however, several authors have outlined possible methods (6,7,13,21), each emphasizing the need to analyze athlete movement. Thus, more research to identify deficient neuromuscular control as a risk of injury is needed in athletic populations before sport participation.

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In DI collegiate athletics, preparticipation screening often involves athletic training staff. Work–family conflict has been well documented in athletic training staff (22–24), contributing to burnout and dissatisfaction with work. Minimizing the time commitment of preparticipation screening for injury risk may reduce the risk of burnout and job dissatisfaction. Thus, a single test that can be used across multiple sports and sexes would be valuable for the athletes to prevent injury without overly burdening staff. The modified Star Excursion Balance Test (SEBT) and an instrumented version of the modified SEBT, the Y balance test (YBT), have been purported as screening tools to predict injury due to aberrant neuromuscular control (31). Originally described with eight reach directions (10), analyses found significant redundancy in the reach directions of the SEBT (11,12,17). In an attempt to gather the most valuable information efficiently, the modified SEBT was created using three reach directions. The YBT was developed to improve reliability and standardize performance of the modified SEBT (30). The YBT assesses performance during single-leg balance with reaching task in anterior (ANT), posteromedial (PM), and posterolateral (PL) directions (30) to determine lower extremity movement asymmetry and balance deficits (11,31). From these reach distances, asymmetries and the composite score (CS) (an overall measurement summing right and left reach directions normalized to leg length) are calculated.

Although the YBT and modified SEBT assess similar movements, significant differences exist in protocol (11) and instrumentation (8), limiting the generalizability of previous research focused on the SEBT to the YBT. The SEBT protocol requires the foot of the stance leg to remain in complete contact during the reach attempt (11). The YBT protocol allows the athlete to lift the heel of the stance leg during a reach because this modification increased overall reliability (30). The heel lift can affect reach distance and motor control strategy of the participant (8). Plisky et al. (31) found that normalized composite right reach distance lower than 94% with the modified SEBT was associated with noncontact lower extremity injury in high school–age basketball players. A recent publication examining a cohort of college football players and YBT determined that a cut point below 89.6% CS increased odds of noncontact injury by 250% (3). To date, this is the only study to prospectively investigate injury risk and YBT performance. Previous research has found that ANT asymmetry greater than or equal to 4 cm had significantly greater odds of injury (odds ratio (OR), 2.7; 95% confidence interval (CI), 1.4–5.3) (31). Differences in protocol, instrumentation, and limited overall research with YBT necessitate further research to support YBT use for injury prediction in collegiate athletic populations.

The purpose of this study was to examine the association between YBT and noncontact in-season injury in a large sample of DI college athletes from multiple sports. It was hypothesized that asymmetrical reach distance in the ANT direction would be related to increased odds of injury. Secondly, it was hypothesized that a lower YBT CS would be associated with higher odds of noncontact in-season injury in a sample of DI collegiate athletes from multiple sports.

METHODS

Study design. This study was a prospective cohort study approved by the institutional review boards of the Northern Arizona University and Daemen College. Athletes received a complete explanation of the procedure and the benefits and risks of the screening process and were given an opportunity to ask questions about the study. Individuals willing to participate provided an informed written consent. After the consent was provided, a health history questionnaire was completed. Data collection of the YBT occurred in conjunction with the preparticipation examination before the sport season. All personnel (e.g., strength and conditioning coach, sport coach, athletic trainer) and participants were blinded to the YBT score. Participants were followed during one competitive sport season. Acute noncontact or overuse musculoskeletal injuries were abstracted from the certified athletic trainers or the team physician's documentation.

Subjects. Two hundred athletes, 18–24 yr inclusive, from a DI collegiate athletics program volunteered to participate in the current study. Athletes were excluded if a current injury that limited the athlete's ability to participate in testing as determined by a physical therapist or athletic trainer was reported in a health history questionnaire.

Procedures. Participants performed dynamic balance using the YBT (Move2Perform, Evansville, IN). All raters (M. W., N. C., and C. A. S.) completed an online certification through the Web site www.move2perform.com, and performed several YBT as a group to ensure consistency. The protocol used instructions from the Move2Perform Web site (27). Participants watched an instructional video that explained and demonstrated the testing procedures. Participants were then asked to remove their shoes and socks and place the most distal end of the longest toe of the right stance leg at the red line on the platform on the test kit. Before the first practice attempt, participants were told that attempts would not count if the following infractions were committed: loss of balance on the stance leg that resulted in movement off the platform or touchdown by the contralateral leg, loss of contact with the reach indicator during a reach attempt, failure to return to starting position without loss of balance, pushing or kicking the indicator to increase distance, and foot placement with the reaching leg on top of the reach indicator. Four to six practice trials were performed in the ANT direction. Then, the participant switched to the left foot on the platform. Once again, four to six trials were performed. This was repeated again for PM, alternating right and left, followed by PL. Research assessing the learning curve during the YBT practice trials have shown an increase in distance followed by a plateau when the longest reach distance is attained (26,32). Rather than requiring all participants to perform six practice trials with each leg in ANT, PM, and PL directions, four to six supervised attempts were allowed. Robinson and Gribble (32) found that

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longest reaches plateaued at four trials, but six trials were allowed if participants requested more practice or if large improvements in distances on the fourth attempt were noted to ensure the learning plateau (26). After all practice trials were performed, right leg length was measured in centimeters from the inferior aspect of the anterior superior iliac spine to the distal medial malleolus while standing with weight evenly distributed between the right and left legs. Finally, the participants completed three attempts, following the same protocol from the practice trials. The maximal reach distance of these three trials was recorded for analysis. Reaches during the final three attempts were discarded and repeated if any of the aforementioned infractions were committed.

The health history questionnaire was administered to determine previous injuries and exclusion of participants who currently have musculoskeletal injuries. The presence of previous injuries was included as a covariate in multivariable models. The questionnaire was developed by one of the authors (N. C.) in collaboration with researchers who have published in the field of injury; however, it has not been validated. The questionnaire has been used in previous research on collegiate athletes (4).

Injury data. Throughout the competitive season for each sport, athletic trainers recorded injuries for all participants on an electronic medical record database (HealtheAthlete; Cerner Corp., Kansas City, MO) or a written medical documentation that recorded the type of complaint and injury mechanism. The difficulty in clearly defining what constituted an injury has been reported previously in the literature (9,20). Considering staff burden, a clinically meaningful definition of injury was determined as any that caused resource use and consequently increased workload. Therefore, injury was defined as the first musculoskeletal problem with a noncontact mechanism that caused the participant to report to the athletic training room and required intervention by an athletic trainer (2). Injury with contact mechanisms was excluded from this analysis. After all sport seasons, the data were abstracted by two of the investigators (M. S. and C. A. S.) for analysis.

Statistical analysis. Asymmetry was calculated by the absolute difference in centimeters between right and left leg reach distance in ANT, PM, and PL. CS was determined by summing the average of right and left maximum reach distances in each direction, dividing by 3 times the leg length, and multiplying by 100 to obtain a percentage. With type one error for two-sided tests set at 0.05, power analysis showed that 184 participants would have 94% power to detect an OR of 2.7 for noncontact injury between those with ANT asymmetry greater than or equal to 4 cm compared with those with ANT asymmetry less than 4 cm. This hypothesized OR was reported in a previous study on SEBT and injury in high school athletes (31).

Descriptive statistics were calculated as means (SD). Differences with demographic variables between those injured and not injured were assessed with independent *t*-tests. Receiver operating characteristic (ROC) curves were calculated to determine the optimal CS and asymmetry for predicting injury. Sensitivity and specificity at different cut points were calculated for CS (89%, 94%, 98%, 101%, 104%, and 106%) and asymmetry (1, 2, 3, 4, and ≥5 cm). Because the ROC curves were unable to maximize sensitivity and specificity for CS, further analysis was completed with CS as a continuous variable. The optimal cut point for asymmetry was determined to be 4 cm. Logistic regression models were used to determine the odds of injury with CS and asymmetry. For these analyses, injury (yes/no) was the dependent variable. The independent variables included continuous CS and presence or absence of asymmetry for ANT, PM, and PL (difference of greater than or equal to 4 cm in each direction signified asymmetry, and difference of less than 4 cm between sides signified no asymmetry). Potential covariates (history of previous injury, sex, and sport) were assessed; sport and previous injuries were included in the final models. An alpha level of <0.05 was used to determine statistical significance. All data were analyzed using SAS version 9.3 (SAS Institute, Inc., Cary, NC).

RESULTS

Two hundred athletes participated in the study. Anthropometric data were not available for four athletes; another eight were excluded because of a lack of proper attire or inadequate time to complete YBT. Injury data were not maintained for the cheer and dance athletes (n = 4) and were excluded from the analysis. The remaining participants (n = 184) were drawn from men's basketball (n = 9), women's basketball (n = 2), men's cross-country running (n = 13), women's cross-country running (n = 17), men's football (n = 68), women's golf (n = 3), men's track and field (n = 7), women's track and field (n = 3), men's tennis (n = 5), women's tennis (n = 5), women's volleyball (n = 8), women's soccer (n = 27), and women's swimming/diving (n = 17). Eighty-one participants experienced a noncontact injury during the competitive season. The mean age, height, mass, reach asymmetry, and CS for injured and uninjured participants are reported in Table 1. The mean CS was not significantly different between those injured (101.3% ± 7.8%) and not injured (101.2% ± 7.1%, P = 0.95). No significant differences in mean ANT, PM, and PL asymmetries were found.

ROC curve analysis determined asymmetry greater than 4 cm (sensitivity, 59%; specificity, 72%) as the cut point for

TABLE 1. Demographic data and YBT ANT, PM, and PL reach asymmetry and CS for injured and uninjured athletes.

Variable	Injured (n = 81), Mean ± SD	Uninjured (n = 103), Mean ± SD
Age (yr)	20.6 ± 1.6	20.0 ± 1.4*
Height (cm)	174.0 ± 0.1	180.3 ± 0.1*
Weight (kg)	73.6 ± 19.6	85.3 ± 20.8*
ANT asymmetry (cm)	3.6 ± 3.9	3.2 ± 3.3
PM asymmetry (cm)	3.9 ± 3.5	3.1 ± 2.7
PL asymmetry (cm)	3.5 ± 2.7	3.7 ± 2.8
CS (%)	101.3 ± 7.8	101.2 ± 7.1

*P < 0.05.

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predicting injury. The association between CS and asymmetry with noncontact injury in participants during competitive season is shown in Table 2. Participants with ANT asymmetry greater than or equal to 4 cm had significantly greater odds of injury (OR, 2.20; 95% CI, 1.09–4.46) compared with those with less-than-4-cm asymmetry with ANT. No significant associations between noncontact injury and CS or asymmetry in PM or PL reach were found.

DISCUSSION

The purpose of this study was to examine the association between YBT CS and asymmetry and noncontact injury during the sport season of a sample of DI college athletes from multiple sports. Only ANT asymmetry was associated with higher odds of injury in the current study, suggesting that imbalance with ANT reach during single-leg stance identified those at elevated risk for injury across multiple sports in a season. Research using the YBT has been limited because this is a relatively new test (30) based on previous findings with the SEBT (11). Initial research comparing the two balance screens demonstrated that differences exist, suggesting that scores on the SEBT are not transferable to the YBT (8). The only study to investigate YBT performance and association with injury (3) found a significantly increased odds of injury with low CS and no association to injury with asymmetry in any reach direction in college football players.

The current study could not determine an optimal cut point to predict injury that maximized sensitivity and specificity for CS. Logistic regression determined no significant association with injury (OR, 1.00; 95% CI, 0.95–1.04) in contrast to Butler et al. (3), who found CS less than 89.6% to increase odds of injury by 3.5 (95% CI, 2.4–5.3). The calculation of CS, the sample under investigation, and the definition of injury may account for the difference in findings. The hypothesis that CS would be associated with injury was originally formed by Plisky et al. (31), who found that normalized composite right reach distance less than 94% on modified SEBT resulted in increased odds of injury in high school basketball players. Plisky et al. (31) and Butler et al. (3) determined normalized CS for the right and left by summing the ANT, PM, and PL reach directions divided by 3 times the leg length, then multiplied by 100. This produced a right and left CS. The current study summed the average of right and left reach directions, normalized to leg length, and multiplied by 100, producing one CS. Because the purpose of CS was to ascertain the overall performance on the YBT, the right and left were not considered separately.

TABLE 2. Association between CS and asymmetry and injury in collegiate athletes during competitive season.

YBT Variable	OR	95% CI	*P* value
ANT asymmetry (>4-cm reference)	2.20	1.09–4.46	0.03
PM asymmetry (>4-cm reference)	1.15	0.58–2.30	0.69
PL asymmetry (>4-cm reference)	0.57	0.28–1.14	0.11
CS	1.00	0.95–1.04	0.69

The sample of 184 participants included male and female athletes from basketball, cross-country running, football, golf, track and field, tennis, volleyball, soccer, and swimming/diving in a DI collegiate program. In contrast, Butler et al. (3) used a sample of 59 American football participants from a DIII collegiate program. Although the current sample included football participants, the research question under investigation was to determine if YBT performance was associated with injury across multiple sports, which may have contributed to difference in CS score or performance. Another significant difference between these two studies is the definition of injury. Butler et al. (3) defined injury as noncontact lower extremity injury that required medical intervention and time loss of greater than 1 d. The authors of the current study determined a definition of injury that did not include time loss as a criterion. Injury was defined as any musculoskeletal problem that caused the athlete to report to the athletic training room, as evidenced by a medical note by a physician or athletic trainer in the medical record. A meaningful definition to the health care staff in this study was that which requires interaction with an athlete, as this requires time and resources. Therefore, the data with this definition of injury for DI college athletes across multiple sports suggested that the use of an overall CS may not be associated with increased risk.

ANT asymmetry was found to be associated with noncontact injury in support of the second hypothesis, indicating that ANT asymmetry may be an important variable when screening multiple sports in collegiate programs. Butler et al. (3) did not find ANT asymmetry to be associated with injury in collegiate football players, which once again may be due to differences in sample and injury definition. Butler et al. (3) reported neither the mean ANT, PM, and PL asymmetry values nor the cut points under investigation, limiting further analysis. Plisky et al. (31) found that ANT asymmetry greater than 4 cm, with the modified SEBT, was associated with lower extremity injury in high school–age basketball players. Although protocol, administration, and population were different, the findings of this current investigation are similar to those previously reported by Plisky et al. (31). In addition, research on participants performing SEBT and YBT found decreased ANT reach for YBT (8). This indicates that SEBT and YBT ANT asymmetry may be valuable in injury prediction; however, the motor control strategies may be different (8).

The primary limitation of this study was the use of a convenience sample, with greater than 50% composed of football athletes. This was representative of sports participation at the university. This was, to date, the largest study performed with YBT in college athletics. Another possible limitation was the definition of injury; however, the definition was selected to provide clinically relevant information to health care and strength and conditioning professionals. Finally, reliability between raters was not performed; however, the YBT has been shown to be reliable between multiple raters (34). Furthermore, each rater performed certification with the Move2Perform Web site and several YBT screens were performed with all raters present. The strengths of this study were the blinding of results to all coaches, athletes, and medical personnel and the large sample of athletes across multiple sports.

No consensus on which movement screens should be included in preparticipation examination in collegiate athletics exists (36), and the most appropriate testing to reduce risk of injury in athletes has not been determined (33). General examination of injury risk across multiple sports without significant time investment would be an invaluable resource to personnel tasked with the care of large numbers of athletes and finite resources. The results of this study suggest that the YBT ANT asymmetry may be a useful measurement to identify risk for future injury across collegiate athletes participating in multiple sports. Determination of ANT asymmetry is reliable and efficient (30), possibly highlighting athletes that require further testing and intervention. The YBT is a relatively quick screen of injury risk taking approximately 5 min for the rater and elimination of the PM, and PL reach directions would reduce the time investment even further. This would reduce the burden on athletic training staff when compared with other methods of screening (15,18) and could be instituted into existing preparticipation examination with limited resource use. Future investigation of YBT ANT asymmetry is warranted especially in settings with large numbers of athletes and small numbers of athletic training staff.

In summary, YBT ANT asymmetry greater than 4 cm was associated with increased risk of noncontact injury, although sensitivity was low. CS in college-age DI athletes was not associated with increased risk of injury, nor was there a significant difference in YBT performance between those injured and uninjured. The clinical use of the YBT association to injury in multiple athletes across multiple sports is questionable. Future research should incorporate the ANT YBT and investigate additional clinically relevant tests to best determine injury risk. This was the first study to investigate YBT association to noncontact injury in DI collegiate athletes across multiple sports.

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The authors declare no conflict of interest. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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