



## Original research

## Y-balance test performance and BMI are associated with ankle sprain injury in collegiate male athletes

Emily M. Hartley<sup>a,\*</sup>, Matthew C. Hoch<sup>b</sup>, Michelle C. Boling<sup>c</sup><sup>a</sup> School of Physical Therapy and Athletic Training, Old Dominion University, United States<sup>b</sup> Division of Athletic Training, University of Kentucky, United States<sup>c</sup> Clinical and Applied Movement Sciences, University of North Florida, United States

## ARTICLE INFO

## Article history:

Received 2 August 2017

Received in revised form

13 September 2017

Accepted 10 October 2017

Available online 6 November 2017

## Keywords:

Ankle

Postural control

Balance

Injury prevention

BMI

## ABSTRACT

**Objectives:** To determine if static balance, dynamic balance, ankle range of motion, body mass index (BMI), or history of an ankle sprain were associated with ankle sprain injuries within male and female collegiate athletes.

**Design:** Prospective cohort.

**Methods:** Three hundred and eighty-four male (age = 19.79 ± 1.80 years, height = 178.02 ± 10.39 cm, mass = 85.71 ± 17.59 kg) and one hundred and sixty seven female (age = 19.80 ± 1.52 years, height = 165.61 ± 7.08 cm, mass = 66.16 ± 10.53 kg) collegiate athletes involved in a variety of sports at a NCAA Division II or NAIA institution participated. Baseline measures of the Y-Balance (YBT), modified Balance Error Scoring System (mBESS), weight-bearing lunge test (WBLT), BMI, and history of ankle sprain were recorded. Participants were followed prospectively for two years and incidence of ankle sprain injury was documented. The average of the WBLT, mBESS, and YBT measures were used for analysis. Male and female participants were analyzed separately. Mann–Whitney U tests were utilized to identify variables which may be significantly associated with ankle sprain injury for logistic regression analysis.

**Results:** A total of 59 (38 males and 21 females) individuals sustained an ankle sprain during the follow up period. The binary logistic regression revealed BMI (Nagelkerke  $R^2 = 0.069$ ;  $X^2 = 12.89$ ;  $p < 0.001$ ; OR = 3.85; 95% CI, 1.90–7.79;  $p < 0.001$ ) and anterior reach of the YBT (Nagelkerke  $R^2 = 0.074$ ;  $X^2 = 13.70$ ,  $p < 0.001$ ; OR = 3.64; 95% CI = 1.83–7.23;  $p = 0.01$ ) were significantly associated with ankle sprain injury in male athletes. No variables were associated with ankle sprain injury within female athletes.

**Conclusions:** Male collegiate athletes with greater BMI and lesser YBT anterior reach were at a greater risk of sustaining an ankle sprain injury.

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## 1. Introduction

Ankle sprains are one of the most common injuries among physically active individuals, accounting for 7–14% of all collegiate athletic injuries.<sup>1,2</sup> Many individuals who sustain an ankle sprain experience recurrent ankle sprains, develop chronic ankle instability,<sup>3</sup> and suffer long term consequences such as osteoarthritis,<sup>4</sup> and a decreased health-related quality of life.<sup>5,6</sup> Based on these long term consequences, it is important to increase efforts to prevent ankle sprain injuries.<sup>7</sup>

An important step in preventing ankle sprain injuries is to identify modifiable risk factors. Commonly reported risk factors for

ankle sprain injuries include a previous history of ankle sprain and increased body mass index (BMI).<sup>8–10</sup> Individuals with a history of ankle sprain are reported to have up to a 6 times greater risk of sustaining another ankle sprain when compared to those with no history of ankle sprain injury.<sup>9</sup> A recent study identified high school and collegiate football athletes with an elevated BMI are more likely to sustain a lateral ankle sprain.<sup>11</sup> Research further supports that individuals who have a high BMI and a previous history of ankle sprain injury are 19 times more likely to sustain a subsequent ankle sprain injury.<sup>9</sup> Based on these findings, an elevated BMI and a previous history of ankle injury should be considered risk factors for an ankle sprain injury.

Several studies have attempted to identify variables related to dynamic balance, static balance, and ankle range of motion (ROM) to predict lower extremity injuries in physically active populations. The Y-Balance Test (YBT) is a clinical measure utilized to evalu-

\* Corresponding author.

E-mail address: [ehartley@odu.edu](mailto:ehartley@odu.edu) (E.M. Hartley).

ate dynamic balance. Asymmetries between limbs in the anterior direction have been associated with over 2 times increased risk of lower extremity injury.<sup>12</sup> Static balance measured by a single limb balance test has been associated with 2.5 times greater risk of lower extremity injury in high school, collegiate, and physically active athletes.<sup>13,14</sup> Additionally, a deficit in dorsiflexion ROM has previously been linked with an increased risk of lower extremity injury.<sup>14–16</sup> The above mentioned factors have all been associated with an increased risk of lower extremity injury, but have not been investigated collectively to predict ankle sprain injuries.

A recent study<sup>11</sup> investigated the association between BMI, previous history of ankle sprain, and performance on the Star Excursion Balance Test (SEBT) and ankle sprain injury occurrence in high school and collegiate male football athletes. The results indicated the most prominent predictor of ankle sprain was poor performance on the anterior reach of the SEBT while BMI was also a significant predictor of ankle sprain injury. Although this study indicates that dynamic balance and BMI are important factors for understanding ankle sprain risk, it is unknown whether these results can be generalized among male and female athletes who participate in a variety of sports. An additional study utilized both male and female collegiate athletes and found no correlation between performance on the YBT and subsequent lower extremity injury occurrence.<sup>17</sup> Stiffler et al.<sup>18</sup> found an asymmetry in the anterior direction of the SEBT to be predictive of lower extremity injury when controlling for sport, sex, and athletic position. There is a possibility that injury risk prediction for certain variables is specific to demographic variables such as gender.

Gaining a better understanding of the modifiable risk factors associated with increased risk of ankle sprain injury is needed to develop effective injury prevention strategies. There is a lack of prospective studies investigating a multitude of risk factors for ankle sprain injury at the collegiate level within a variety of sports. Additionally, there is a lack of studies investigating injury prediction for males and females separately. Therefore, the purpose of this study was to determine if performance on the YBT, static balance, dorsiflexion ROM, BMI, and history of previous ankle sprain are associated with ankle sprain injury in collegiate athletes within each gender. We hypothesized that poor performance on the YBT, an increased asymmetry between limbs on the YBT, poor static balance, poor dorsiflexion ROM, elevated BMI, and history of previous ankle sprain will be associated with ankle sprain injury within male and female collegiate athletes.

## 2. Methods

A prospective cohort design was used to determine the risk factors for ankle sprain injury. Three hundred and eighty-four males (age = 19.79 ± 1.80 years, height = 178.02 ± 10.39 cm, mass = 85.71 ± 17.59 kg) and one hundred and sixty-seven females (age = 19.80 ± 1.52 years, height = 165.61 ± 7.08 cm, mass = 66.16 ± 10.53 kg) volunteered to participate. Participants were collegiate athletes involved in a variety of sports at a Division II (n = 69) and National Association of Intercollegiate Athletics (n = 482) school (Table 1). All participants were recruited during pre-participation physical exams. Participants were included if they intended to participate in a sport at either of the two institutions. Participants were excluded if they had a current injury or disease that prevented them from completing any of the baseline ROM and balance measures. This study was approved by the IRB of all involved institutions.

Participants signed an informed consent document, completed an injury history questionnaire, and had their height and weight measured (Health O Meter<sup>®</sup> with Height Rod, Bedford Heights, OH) to calculate BMI prior to performing the baseline measures. The

**Table 1**  
Subject sport and frequency of ankle sprain.

Sport	Injured (%)	Uninjured	Total
Baseball	3 (6)	51	54
Men's basketball	6 (9)	61	67
Women's basketball	6 (17)	29	35
Football	24 (15)	137	161
Men's lacrosse	0 (0)	19	19
Men's soccer	3 (5)	59	62
Women's soccer	6 (13)	42	48
Softball	2 (7)	28	30
Men's tennis	2 (20)	8	10
Volleyball	6 (20)	24	30
Men's other	0 (0)	11	11
Women's other	1 (4)	23	24
Total	59 (11%)	492	551

injury history questionnaire assessed previous history of injuries to the ankle, knee, and hip. Limb length was measured from the ASIS to the medial malleolus (cm). The order of the functional tests (YBT, single limb balance, and weight-bearing lunge test (WBLT)) and limb tested first during each test were counterbalanced. All investigators were Athletic Trainers who were trained by the principal investigator to collect the functional measures. Standard operating procedures were utilized for each test to ensure uniformity with the administration of the test.

Dynamic balance was assessed using the YBT (Perform Better; Warwick, RI). While barefoot, participants balanced on the center board of the YBT instrument. They were instructed to keep their hands on their hips and reach as far as possible by pushing a board into the anterior, posteromedial, and posterolateral directions. Four practice trials in each direction were followed by three test trials for each direction. YBT reach distances were normalized to leg length (%). Between-limbs symmetry was calculated as the absolute difference between limbs for each direction. The YBT has previously been determined to have good intrarater (ICC = 0.85–0.91) and interrater (ICC = 0.99–1) reliability.<sup>19</sup>

Static balance was measured using the single limb stable surface condition of the Balance Error Scoring System (BESS).<sup>20</sup> This test was performed barefoot utilizing a single limb stance on a stable surface with the eyes closed. The participant maintained balance on a single limb with their eyes closed for 20 seconds while the rater recorded errors. Each participant performed one test trial on each limb with a maximal score of 10 errors recorded. This stance of the BESS has good intrarater (ICC = 0.88–0.99) and interrater (ICC = 0.83–0.98) reliability.<sup>21,22</sup>

Dorsiflexion ROM was measured using the WBLT. To complete the WBLT, participants performed a forward lunge towards a wall allowing the knee to contact the wall. The foot was progressively moved backwards until maximum dorsiflexion was reached while the knee maintained contact with the wall and the heel remained planted on the floor. The distance from the great toe to the wall was recorded and measured in cm. Three practice trials followed by three test trials were recorded for each limb. The WBLT has good interrater (ICC = 0.80–0.99) and intrarater (ICC = 0.65–0.99) reliability.<sup>23</sup>

During the injury surveillance period, ankle sprain injuries were recorded by Athletic Trainers at each institution utilizing an electronic medical record system. An ankle sprain was classified as an injury if there was damage to any of the ankle ligaments and the injury limited athletic participation for at least 1 day. The involved limb, mechanism of injury, and date of injury were recorded by the Athletic Trainer and this information was provided to the principal investigator. Participants were followed for incident ankle sprain injury for up to two years or as long as they remained a student athlete.

**Table 2**  
Male and female descriptive statistics for the dependent variables in the injured and uninjured groups.

Variable	Injured (Mean ± SD)	Uninjured (Mean ± SD)	P-value
<b>Males</b>			
Anterior reach (%)	55.61 ± 6.70	58.24 ± 6.78	0.01
Posteromedial reach (%)	106.37 ± 8.06	105.63 ± 10.25	0.65
Posterolateral reach (%)	99.21 ± 9.26	100.67 ± 11.33	0.42
Anterior asymmetry (cm)	3.74 ± 2.92	3.47 ± 2.77	0.61
Posteromedial asymmetry (cm)	4.05 ± 3.69	5.70 ± 5.14	0.06
Posterolateral asymmetry (cm)	5.62 ± 5.62	5.81 ± 4.79	0.38
mBESS	4.75 ± 3.13	3.79 ± 2.73	0.10
WBLT (cm)	8.19 ± 3.24	8.51 ± 3.60	0.58
BMI	28.87 ± 5.09	26.78 ± 5.88	0.00
Previous ankle sprain	19 (n=39)	156 (n=342)	0.60
<b>Females</b>			
Anterior reach (%)	62.02 ± 7.71	62.86 ± 6.12	0.76
Posteromedial reach (%)	109.36 ± 10.72	105.17 ± 8.89	0.18
Posterolateral reach (%)	105.65 ± 13.47	100.65 ± 10.41	0.18
Anterior asymmetry (cm)	3.50 ± 2.85	3.69 ± 3.16	0.96
Posteromedial asymmetry (cm)	3.86 ± 5.06	5.03 ± 3.86	0.03
Posterolateral asymmetry (cm)	4.06 ± 3.17	5.38 ± 4.20	0.25
mBESS	3.41 ± 2.48	3.65 ± 2.49	0.72
WBLT (cm)	9.44 ± 2.79	9.06 ± 3.36	0.48
BMI	23.12 ± 2.32	24.27 ± 3.56	0.23
Previous ankle sprain	8 (n=21)	72 (n=145)	0.36

All values included are the Mean ± SD except for previous history of ankle sprain in which the frequency is presented.

For all limb specific data (YBT, BESS, WBLT), the average values for each limb were pooled. All analyses were completed for males and females separately. Due to non-normally distributed data, Mann–Whitney U tests were used to identify differences between the injured and uninjured groups which may be significantly associated with ankle sprain injury for additional analysis (BMI, YBT, BESS, and WBLT). A chi-square analysis was used to detect differences between the injured and uninjured groups for the variable of previous ankle sprain injury history. For significant variables, receiver operator characteristic (ROC) curves determined a cutoff score that would maximize both sensitivity and specificity. Chi-square analyses were then used to determine the strength of the cutoff score to predict injury occurrence. Binary logistic regression was utilized to determine the strength of group identification using the significant variables from the chi-square analyses. Odds ratios and associated 95% confidence intervals were calculated to determine the strength of the model. Alpha was set at  $p < 0.05$  for all analyses.

### 3. Results

There were a total of 59 (38 male and 21 female/11%) athletes who suffered an ankle sprain during the injury surveillance period. The means and standard deviations for all variables in the male and female groups can be found in [Table 2](#).

Within the male participants, the injured group performed significantly worse on the YBT anterior direction (injured = 55.61 ± 6.70%, uninjured = 58.24 ± 6.78,  $p = 0.01$ ) and had a significantly higher BMI (injured = 28.87 ± 5.09, uninjured = 26.78 ± 5.88,  $p = 0.007$ ) compared to the uninjured group. There were no significant group differences for any other variables ( $p > 0.05$ ). ROC curve analysis for the YBT anterior reach revealed mild C-statistics (0.625; 95% CI: 0.524–0.725;  $p = 0.012$ ) with a cutoff score of 54.4%. ROC curve analysis for BMI revealed mild C-statistics (0.632; 95% CI: 0.537–0.727;  $p = 0.007$ ) with a cutoff score of 30.2. Chi-square analyses confirmed the strength of the cutoff score for the YBT anterior reach ( $X^2 = 6.97$ ,  $P = 0.014$ ) and BMI ( $X^2 = 16.04$ ,  $p < 0.001$ ) to predict ankle sprain injury

**Table 3**  
Chi-square analyses for anterior reach of YBT and BMI.

Variable	Injured	Uninjured	P-value	Sensitivity	Specificity
Anterior reach of YBT			0.008	0.61	0.62
>54.4%	15	209			
<54.4%	23	130			
Body mass index			<0.001	0.42	0.84
>30.2	16	54			
<30.2	22	291			

([Table 3](#)). Separate binary logistic regression models revealed BMI (Nagelkerke  $R^2 = 0.069$ ;  $X^2 = 12.89$ ;  $p < 0.001$ ; OR = 3.85; 95% CI, 1.90–7.79) and YBT anterior reach (Nagelkerke  $R^2 = 0.074$ ;  $X^2 = 13.70$ ,  $p < 0.001$ ; OR = 3.64; 95% CI = 1.83–7.23;  $p = 0.01$ ) were significantly associated with ankle sprain injury. Individuals who had a BMI above the cutoff score and a YBT anterior reach below the cutoff score were at 4.84 greater odds of sustaining an ankle sprain when compared to those with either one factor or neither factors (Nagelkerke  $R^2 = 0.078$ ;  $X^2 = 14.48$ ,  $p < 0.001$ ; OR = 4.84; 95% CI = 2.26–10.35;  $p = 0.01$ ).

Within female participants, the individuals who sustained an ankle sprain had significantly less posteromedial asymmetry on the YBT when compared to the uninjured group (injured: 3.86 ± 5.06 cm; uninjured: 5.03 ± 3.86 cm;  $p = 0.03$ ). No other significant differences were identified between the injured and uninjured groups. The difference in posteromedial asymmetry was contradictory to what is hypothesized to associate with injury. Therefore, additional statistics were not performed.

### 4. Discussion

The main finding of this study was male collegiate athletes who sustained an ankle sprain injury performed significantly worse on the anterior reach of the YBT and had significantly higher BMI at baseline compared to athletes who did not sustain an ankle sprain. The odds of sustaining an ankle sprain of male athletes who had a normalized anterior reach of ≤54.4% on the YBT were 3.64 times greater than athletes who had normalized reaches >54.4%. Additionally, the odds of a male athlete sustaining an ankle sprain who had a BMI ≥30.2 was 3.85 times greater than male athletes who had a BMI <30.2. Additionally, those who had both an elevated BMI and decreased anterior reach distance were at a 4.84 greater odd of sustaining an ankle sprain than those who had either condition or neither of the conditions. However, none of the other factors collected in this study including previous ankle sprain history were significantly associated with injury within males. Despite the findings in male athletes, no variables were able to stratify injury risk in female athletes who sustained an ankle sprain injury. Overall, these findings suggest that BMI and anterior reach of the YBT may be useful variables to help guide injury prevention in male athletes, but other variable should be explored for female athletes.

The results of our study indicate greater BMI and shorter YBT anterior reach were significantly associated with ankle sprain injury within male collegiate athletes. Similarly, Gribble et al.<sup>11</sup> determined poor performance on the anterior reach of the SEBT was a significant predictor of ankle sprain injury in high school and collegiate football athletes. Individuals who fell below the cutoff score were at 2.8 times greater odds of sustaining an ankle sprain than those who were above the cutoff score. The results of our study aligned well with other literature that determined the YBT and SEBT to be predictors of lower extremity injury occurrence.

Similar to the results of our study, several other studies have found BMI as a significant predictor of injury occurrence.<sup>11,24</sup> Most notably of these was a study which investigated the use of several variables as a predictor for ankle sprain injury within male high

school and collegiate football athletes. BMI was a significant predictor of ankle sprain injury within this cohort utilizing a cutoff score of 26.69. Those who had a BMI greater than the cutoff score were at a 2 times greater odds of sustaining an ankle sprain injury.<sup>11</sup> The results of our study were similar to those of this study resulting in a 3.85 times greater odds of sustaining an ankle sprain injury in those who had a BMI above the cutoff score of 30.2. The cutoff score within Gribble's study aligned with a classification of overweight (25.0–29.9)<sup>25</sup> to obese (above 30.0)<sup>25</sup> while the cutoff score within our study only included those who fell within the obese (above 30.0)<sup>25</sup> category. BMI may be better utilized as a predictor of ankle sprain within male athletes.

Asymmetry on all reaches of the YBT was not a significantly associated with ankle sprain injury within our study except for the posteromedial direction within the female participants. However, the posteromedial asymmetry was greater in the females who did not sustain an ankle sprain injury. Additionally, the male participants who did not sustain an ankle sprain also had increased posteromedial asymmetry although not statistically significant. These results are surprising as previous research has indicated an increased asymmetry is associated with injury. A potential explanation for these findings may be the large amount of variability associated with posteromedial reach asymmetry. For this measure, the standard deviation was either comparable or exceeded the mean asymmetry. This is supported by a recent study which indicated the posteromedial measure exhibited high levels of variability over time in collegiate field hockey athletes.<sup>26</sup> Other literature has supported the use of asymmetry between limbs on the YBT. Stiffler et al.<sup>18</sup> found an asymmetry between limbs in the anterior reach of the SEBT to be predictive of lower extremity injury. However, the authors controlled for gender, sport, and player position within the analyses.<sup>18</sup> Plisky et al.<sup>27</sup> determined an asymmetry of more than 4 cm between limbs for the anterior reach of the SEBT within male and female basketball players was a predictor of lower extremity injury. The operational definitions for a lower extremity injury varied within these studies which could have also led to differences in results. There is a potential that asymmetry may be dependent on multiple factors such as gender, sport, player position, and injury definition. Therefore, it may be important to control for these factors when considering asymmetry as a predictor of lower extremity injury.

Despite the association between anterior reach distances and ankle sprain occurrence, other factors which were included such as previous history of an ankle sprain, dorsiflexion ROM, and static balance were not significantly associated with ankle sprain injury in our study. Previous history of an ankle sprain has been thought to be one of the most prominent risk factors for an ankle sprain.<sup>8,9</sup> However, recent literature including our study found history of a previous ankle sprain was not associated with future ankle sprains.<sup>11,28</sup> Researchers have found certain treatment techniques such as balance training and ankle bracing to be effective at preventing future ankle sprains after an initial ankle sprain has occurred.<sup>29,30</sup> It is possible clinicians are utilizing these treatment techniques and rehabilitating ankle sprains more effectively to prevent future ankle sprains from occurring. There is limited research to support the use of a reduction in dorsiflexion ROM and static balance as predictors of injury occurrence.<sup>13</sup> Although these assessments did not contribute to risk of ankle sprain injury in our study, it is possible some of these factors may be better utilized in more homogenous samples which examine associations for other forms of lower extremity injury. Therefore, further research is necessary to determine the association between these factors and ankle sprain injury within different populations.

Although BMI and the anterior reach of the YBT were associated with ankle sprain injury within male collegiate athletes, these variables were not significantly associated with ankle sprain injury

within female collegiate athletes. There is a potential that these tests may help guide injury prevention efforts for male athletes. An additional study identified the use of functional tests to be less effective in the prediction of lower extremity injury when utilizing both male and female participants.<sup>17</sup> One study investigated the association of the YBT and lower extremity injury within collegiate male and female athletes. There was no significant difference in YBT performance between those who sustained a lower extremity injury and those who did not.<sup>17</sup> There is a possibility that specific variables may be more strongly associated with lower extremity injuries within each gender.

There were a few limitations in this study. First, the injury tracking software was setup to track incidence of ankle sprain only. If lower extremity injuries were tracked instead, the results of this study could be different. Future research should investigate the ability of the variables used in this study to predict other lower extremity injuries in addition to ankle sprains. An additional limitation was the injury history data was self-reported. Future research should use injury history that is entered utilizing electronic medical records to ensure the information is accurate. The mode of injury tracking utilized within this study did not allow the researchers to differentiate between contact and non-contact ankle sprain injuries. Additionally, the definition of an ankle sprain injury within this study included injuries in which the athlete was at least limited in athletic participation for a minimum of one day. Therefore, it is possible that the number of reported ankle sprain injuries may have been influenced by the specific definition used within this study. The total amount of time missed from participation was not recorded within this study. Therefore, the severity of ankle sprain and type of ankle sprain (lateral, medial, syndesmotic) were not considered within this study. Future research should stratify the ankle sprain by severity and type to determine if predictive variables are specific to type and severity of ankle sprain injury. Lastly, despite having a higher rate of ankle sprain, the number of male participants included within this study was considerably lower than the number of female participants. The smaller sample size in the female group could have limited the statistical power to identify statistically significant associations with ankle sprain injury.

## 5. Conclusion

Poor performance on the anterior reach of the YBT and increased BMI were associated with an increased risk for sustaining an ankle sprain injury within male collegiate athletes. None of the variables investigated in this study were associated with ankle sprain injury within female collegiate athletes. The results of this study indicate that variables such as the anterior reach of the YBT and BMI should be utilized to guide injury prevention program design. Future research should be performed to determine additional risk factors for ankle sprain injuries, as well as the necessary components of effective injury prevention programs to decrease the risk of ankle sprain injury.

## Practical implications

- The anterior reach of the Y-Balance test and BMI are associated with ankle sprain injury within collegiate male athletes while none of the variables were associated with ankle sprain injury within female collegiate athletes.
- Injury prevention techniques should be utilized within collegiate athletes to reduce the occurrence of ankle sprain injuries.
- BMI and anterior reach of the YBT may be useful variables to help guide injury prevention in male athletes, but other variable should be explored for female athletes.

## Acknowledgement

The authors thank the following individuals for assistance with aspects of the data collection: Samantha Bachman, Kristina Chao, Jordan Olson, Kyle Santo, and other Webber International University Athletic Training Staff members.

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