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ORIGINAL RESEARCH

# ACUTE LATERAL ANKLE SPRAIN PREDICTION IN COLLEGIATE WOMEN'S SOCCER PLAYERS

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## ABSTRACT

***Background:*** Women's soccer has among the highest injury rates in collegiate sports, and lateral ankle sprains (LAS) are among the most commonly occurring injuries in that athletic population. However, no established LAS prediction model exists for collegiate women's soccer players.

The purpose of this study was to develop a prediction model for acute LAS injuries in collegiate women's soccer players utilizing previous ankle sprain history, height, mass, and BMI as potential predictors.

The authors' hypothesized that collegiate women's soccer players with greater height, mass, and body mass index (BMI), as well as a previous history of ankle sprain would have greater odds of sustaining a LAS.

***Study Design*:** Prospective cohort study.

***Methods*:** Forty-three NCAA Division I women's soccer players' (19.7 ± 1.1yrs, 166.8 ± 3.7cm, 60.8 ± 4.4kg) height, mass, and BMI were measured one week before beginning preseason practices. Additionally, participants reported whether or not they had sustained a previous ankle sprain. The team athletic trainer tracked LASs over the competitive season. Independent t-tests, binary logistic regression analyses, receiver operating characteristic (ROC) curves, and diagnostic statistics assessed the ability of the variables to differentiate between those that did and did not sustain a LAS.

***Results*:** Participants that sustained a LAS (n = 8) were significantly taller than those that did not sustain a LAS (n = 35) ($t_{41}$ = -2.87, p = 0.01, *d* = 0.83[0.03,1.60]). A logistic regression analysis (odds ratio = 1.30[1.00,1.70]) and area under the ROC curve analysis (AUROC = 0.73[0.58,0.89], p = 0.04) further exhibited predictive value of height. A height cutoff score of 167.6cm demonstrated excellent sensitivity (0.88), moderate specificity (0.51), and a favorable diagnostic odds ratio (7.5). A logistic regression analysis (odds ratio = 1.87[1.22,1.98]) exhibited predictive value of previous ankle sprain history. That variable was also associated with good sensitivity (0.75) and specificity (0.71) within the model, as well as a favorable DOR (7.37). Mass and BMI demonstrated no predictive value for LAS.

***Conclusion*:** Taller collegiate women's soccer players and those with previous ankle sprain history may have a greater predisposition to LAS.

***Level of evidence*:** 1b

***Key words*:** Ankle sprain, injury prediction, women's soccer

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## INTRODUCTION

Over 488,000 student-athletes participated in National Collegiate Athletic Association (NCAA) sponsored sports during the 2014-2015 academic year, approximately 43% of which were females.[1] While the NCAA's participation rate has risen annually, sport-related injury rates have remained steady,[2] likely leading to a greater total number of injuries. Across all collegiate women's sports, soccer has the highest overall injury rate during competition,[3] with the lower extremity accounting for approximately 70% of the total injuries.[2] Soccer also has the highest ankle sprain rate among all collegiate women's sports, with a combined practice and competition rate of 1.3 ankle sprains per 1,000 athlete-exposures.[3] Lateral ankle sprain (LAS) is the most commonly reported injury resulting in 10 or more days of activity loss in collegiate women's soccer.[2] Along with time loss, there is added concern for recurrent injury,[4] impaired neuromuscular control,[5-7] decreased physical activity,[7,8] decreased health-related quality of life,[8] and post-traumatic osteoarthritis[9] in individuals with a history of LAS.

Prevention of LAS and subsequent long-term consequences may be accomplished through training programs designed to enhance neuromuscular control. Specifically in athletic populations, the use of neuromuscular training protocols has previously demonstrated effectiveness for preventing LASs.[10] However, a numbers needed to treat analysis performed by McKeon and Hertel[11] found that up to 44 athletes were required to undergo training in order to prevent one LAS. While successful injury prevention is likely achievable, prospective determination of which participants are at greater risk for an acute lower extremity injury likely enhances the efficiency of neuromuscular training protocols, as those at greater risk may have a greater degree of responsiveness.[12] Furthermore, risk assessment will perhaps identify individuals' specific impairments, which clinicians can target through neuromuscular training interventions.

A previous history of ankle sprain is perhaps the most commonly identified risk factor for LAS in athletes,[13-18] but exploration of other outcomes should continue in order to optimize clinicians' ability to predict LASs. Simple measures of height and mass have demonstrated usefulness in LAS prediction models,[18-23] likely due to their potential influence on LAS mechanisms of injury. Typically, a LAS is sustained when excessive ankle plantar flexion, subtalar inversion, and foot internal rotation are present while decelerating during a functional task.[24-27] These combined movement patterns result in the center of pressure (COP) moving laterally on the plantar aspect of the foot, as well as medially relative to the ankle joint axis of rotation. In this position, an external load can create an external supination moment at the ankle. Greater body mass index (BMI), calculated from height and mass, likely increases the body's moments of inertia and reduces an individual's ability to resist external forces.[22] Due to the potential influence on injury occurrence and simplicity of their measurement, anthropometrics are viable predictor variables for any injury prediction analysis. No previous investigators have developed a model of LAS risk for collegiate women's soccer players specifically, but anthropometrics may possess potential injury prediction value for that population. Therefore, the purpose of this study was to develop a prediction model for acute LAS injuries in collegiate women's soccer players utilizing previous ankle sprain history, height, mass, and BMI as potential predictors. The primary hypothesis was that athletes with a previous ankle sprain history, greater height, mass, and BMI would have greater odds of sustaining a LAS.

## METHODS

### Participants

A convenience sample of 43 NCAA Division I women's soccer players (19.7 ± 1.1 years, 166.8 ± 3.7 cm, 60.8 ± 4.4 kg) volunteered for participation in this prospective cohort study. Inclusion criteria consisted of team membership, full medical clearance for participation in sporting activities. Within one week prior to the beginning of pre-season practices, each participant reported for testing in the university athletic training facility. Each participant reviewed and signed an informed consent document approved by the university institutional review board.

### Procedures

One week before the onset of pre-season practices, each participant's height (cm) and mass (kg) were

**Table 1.** *Comparisons of Anthropometrics between Injured and Uninjured Participants.*

| | Injured (n=8) | Uninjured (n=35) | Independent T-Test | Cohen's *d* (95%CI) |
|---|---|---|---|---|
| Height (cm) | 169.2 ± 2.3 | 166.3 ± 3.7 | $t_{41}$ = -2.87, **p = 0.01** | **0.83 (0.03, 1.60)** |
| Mass (kg) | 60.7 ± 6.1 | 60.6 ± 4.1 | $t_{41}$ = 0.05, p = 0.96 | 0.02 (-0.75, 0.79) |
| BMI (kg/m$^2$) | 21.2 ± 2.2 | 22.0 ± 1.5 | $t_{41}$ = 1.23, p = 0.22 | -0.49 (-1.25, 0.30) |

BMI = body mass index; Bolded data indicate statistically significant differences (p < 0.05).

measured using a standard physician beam scale (Detecto 339 Eye Level Physician Scale; Detecto Scale Company; Webb City, MO) in the school's athletic training facility. Body mass index (BMI) was calculated from height and mass measures (kg/m$^2$). Additionally, participants reported whether or not they had ever sustained a previous ankle sprain of any type (lateral, medial, syndesmotic). Throughout the course of the subsequent soccer season, the certified and licensed athletic trainer responsible for providing care to the team recorded LAS injuries sustained by the participants. A LAS must have 1) occurred during a team practice or competition, 2) required care by medical personnel, and 3) resulted in at least one day of missed soccer activity.

### Statistical Analysis

Independent t-tests and Cohen's *d* effect sizes with 95% confidence intervals (CIs) compared height, mass, and BMI between injured and uninjured participants. Effect sizes were interpreted as small: $d = 0.20 - 0.49$, moderate: $d = 0.50 - 0.79$, and large: $d \geq 0.80$.[28] Separate forward binary logistic regression analyses assessed the influence of each outcome on the estimated odds of sustaining a LAS. A Receiver Operating Characteristic (ROC) curve plotted the predictive utility (sensitivity vs. 1-specificity) of each value observed for each continuous outcome. The ROC curve analysis produced the area under the ROC curve (AUROC), a singular quantitative representation of the overall predictive value of each variable, with 95% confidence intervals. The AUROC can range from 0 to 1, with 0.5 representing an absence of predictive power, and 1 representing perfect predictive power.[29] From ROC curves demonstrating predictive utility, cutoff scores that maximized sensitivity and specificity for the predictor variable were identified. Fisher's exact test to determine the strength of association between the predicted group classification (based on the cutoff score for continuous variables) and the observed injury status. Sensitivity, specificity, positive and negative likelihood ratios (+LR, -LR), and the diagnostic odds ratio (DOR) were calculated from predicted and observed injury status. Statistical significance was set *a priori* at $p<0.05$. All statistical analyses were conducted using IBM SPSS version 22 (IBM Corporation, Armonk, NY).

## RESULTS

During the competitive season, 8/43 (18.6%) participants sustained a LAS. A significant difference on the t-test and large effect size indicated the injured group was taller than the uninjured group (Table 1). No statistically significant group differences existed for mass or BMI. A history of previous ankle sprain was reported by 16/43 (37.2%) participants, with 6/8 (75%) players with a new LAS having a history of previous ankle sprain. Separate binary logistic regression analysis revealed that height and previous ankle sprain history were significant predictors of injury status (Table 2). A ROC curve analysis further demonstrated moderate predictive utility of height (AUROC = 0.73 [0.58, 0.89]; p = 0.04) (Figure 1). The ROC curve analyses further demonstrated poor predictive value for mass (AUROC = 0.52 [0.25, 0.79]; p = 0.84) (Figure 2) and BMI (AUROC = 0.65 [0.38, 0.91]; p = 0.21) (Figure 3). A cutoff score for height that maximized sensitivity and specificity (167.6 cm) within the ROC curve produced a significant Fisher's exact test (p = 0.04) (Table 3). A Fisher's exact test

**Table 2.** *Separate Binary Logistic Regression Analyses.*

| Variables | Odds Ratio (95%CI) | p-Value |
|---|---|---|
| Height | **1.30 (1.00, 1.70)** | **0.05** |
| Mass | 1.00 (0.84, 1.19) | 0.95 |
| BMI | 0.74 (0.46, 1.20) | 0.22 |
| Previous Ankle Sprain History | **1.87 (1.22, 1.98)** | **0.03** |

Bolded data indicate statistically significant differences (p < 0.05).

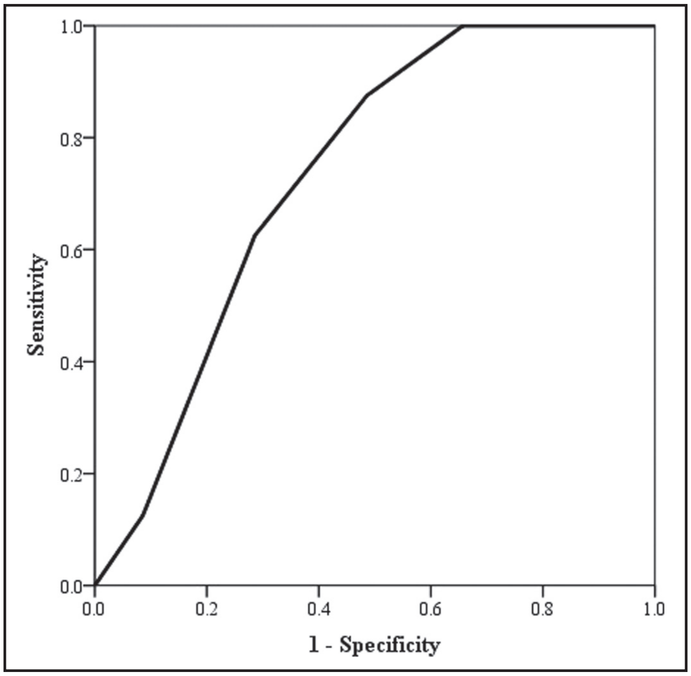


**Figure 1.** *Height Receiver Operating Characteristic (ROC) Curve.*

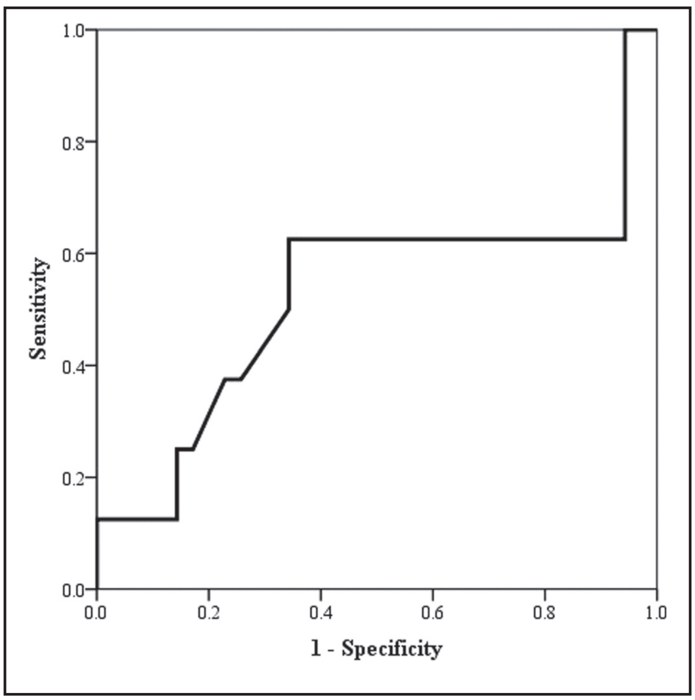


**Figure 2.** *Mass Receiver Operating Characteristic (ROC) Curve.*

also demonstrated a significant association between previous ankle sprain history and sustaining a LAS in the current season (p = 0.02) (Table 4). Associated sensitivity, specificity, +LR, -LR, and DOR calculated from the 2-by-2 contingency tables are in

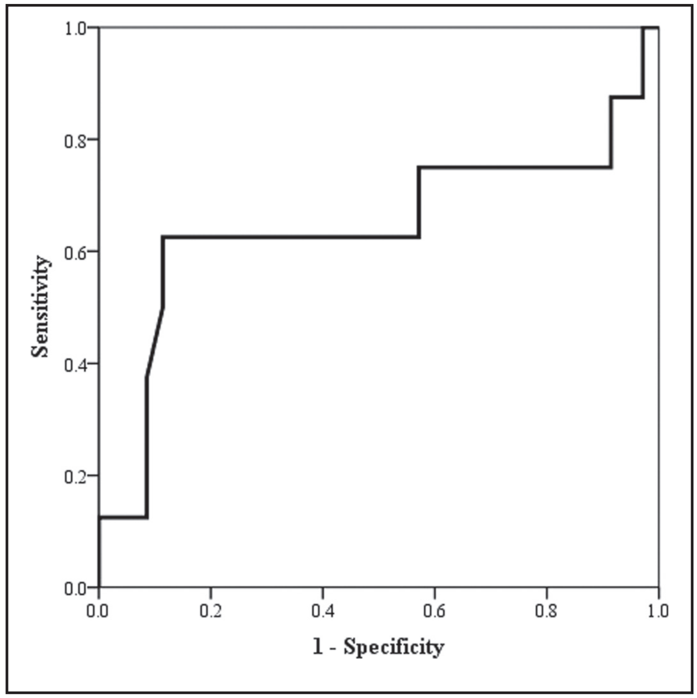


**Figure 3.** *Body Mass Index (BMI) Receiver Operating Characteristic (ROC) Curve.*

**Table 3.** *Fisher's Exact Test for Height.*

| Height (cm) | LAS | No LAS |
|---|---|---|
| ≥ 167.6 | 7 | 17 |
| < 167.6 | 1 | 18 |

LAS = Lateral Ankle Sprain

**Table 4.** *Fisher's Exact Test for Previous Ankle Sprain History*

| Previous Ankle Sprain History | LAS | No LAS |
|---|---|---|
| Yes | 6 | 10 |
| No | 2 | 25 |

LAS = Lateral Ankle Sprain

Table 5. For height, excellent sensitivity (0.88) and moderate specificity (0.51) were identified within the model, as well as a favorable DOR (7.50). For previous ankle sprain history, we identified good sensitivity (0.75) and specificity (0.71) within the model, as well as a favorable DOR (7.37).

## DISCUSSION

The primary finding of this study is that participant height and a history of previous ankle sprain were effective predictors of LAS among collegiate

**Table 5.** *Diagnostic Statistics of Height and Previous Ankle Sprain History*

| Quantities | Formula | Height (167.6 cm) | Previous Ankle Sprain History |
|---|---|---|---|
| Sensitivity | true positive/(true positive + false negative) | 7/8 = 0.88 | 6/8 = 0.75 |
| Specificity | true negative/(true negative + false positive) | 17/35 = 0.51 | 25/35 = 0.71 |
| +LR | sensitivity/(1-specificity) | 0.88/0.49 = 1.80 | 0.75/0.29 = 2.58 |
| -LR | (1-sensitivity)/specificity | 0.12/0.51 = 0.24 | 0.25/0.71 = 0.35 |
| DOR | +LR/-LR | 1.89/0.21 = 7.50 | 2.58/0.35 = 7.37 |

+LR = positive likelihood ratio; -LR = negative likelihood ratio; DOR = diagnostic odds ratio

women's soccer players. Specifically, those athletes equal to or taller than 167.6 cm in height had 7.5 times greater odds of sustaining a LAS than those below 167.6 cm in height. Within the sample 24/43 (56%) participants were at least 167.6 cm tall, and thus, possessed an elevated predisposition to sustaining a LAS. This finding supports previous studies reporting participant height as an effective predictor of ankle injuries. Waterman et al.[23] reported taller military academy cadets were at greater risk of sustaining an ankle sprain. Similarly, Milgrom et al.[22] found that taller infantry recruits were more prone to LASs. They postulated that taller stature may contribute to larger moments of inertia in the lower extremity.[22] Essentially, longer trunk and extremity segments may reduce the ability of an individual to resist external moments exerted on the body, potentially increasing injury risk.[22] The aforementioned studies only found associations between height and injury in male participants, [22,23] but the current findings suggest height may also be pertinent to LAS risk in females. The average height of the sample was similar to that of 64 Division I collegiate women's soccer players (168.4 $\pm$ 5.9 cm) that underwent testing of physical and physiological performance characteristics,[30] suggesting the results are likely relevant to other collegiate women's soccer teams. Elevated body mass can also increase moments of inertia, but the lack of differences between injured and uninjured participants suggests body mass had little influence over injury risk in this population. Furthermore, the lack of body mass differences likely limited the ability of BMI to differentiate those that did and did not sustain a LAS.

Not surprisingly, previous ankle sprain history was also a significant predictor of LAS. This result is in agreement with a number of other authors who have reported similar findings in soccer players.[13-15] Ekstrand and Gillquist found significantly higher rates of previous LAS in adult soccer players that sustained a LAS during one year of injury surveillance (47%) compared to those that did not sustain a LAS in the same time (25%).[13] Kofotolis et al. also prospectively examined a large cohort of amateur soccer players and determined that those with a previous LAS had nearly two times greater odds of sustaining a LAS during two years of subsequent observation.[15] In another study of amateur male soccer players, previous history of LAS was again the strongest predictor of LAS, increasing the odds of injury approximately 23%.[14] This is the first study to assess the predictive value of previous ankle sprain history in a sample of collegiate women's soccer players.

Clinically, the strength of height and previous ankle sprain history as LAS predictors is their ease of assessment, but they are clearly limited by their lack of modifiability. Although they are not changeable, these simple outcomes may be important catalysts for targeted intervention. For example, preventative measures such as prophylactic ankle supports and postural control training are viable options for LAS prevention,[31,32] and perhaps may be particularly valuable for taller athletes and those with a previous ankle sprain. As a LAS in collegiate women's soccer players occurs through a variety of mechanisms (~35% player contact, ~27% non-contact, ~25% surface contact, ~13% other),[33] postural control training likely should be diversified to include static and dynamic balance exercises, dynamic stability following a landing or cutting task, and external perturbations. Future studies should examine various forms of neuromuscular control training and attempt to find the most effective protocol for LAS prevention in this population. While prophylactic ankle supports and postural control training are associated with significant cost and time demands, respectively, identification of strong risk factors will allow clinicians to allocate preventative resources to those with the greatest predisposition to LAS. While the DORs suggest previous ankle sprain history and height were similar in their ability to predict a LAS, the small sample size inhibited the ability to examine these predictors in a multivariate logistic regression model. Future studies using larger samples should explore whether or not a combination of increased height and previous ankle sprain history can elevate LAS risk even further.

### Limitations

Certain notable limitations are present within this study. First, this study was specific to NCAA Division I women's soccer players and may not be applicable to those participating in other sports and levels of competition. Furthermore, the sample of convenience population was potentially small raising the possibility of type II error during comparisons of body mass and BMI. Lastly, this study focused on a limited collection of potential predictor variables. Future studies should continue to explore LAS prediction in collegiate women's soccer players using a larger sample and other clinical tests that may be relevant to LAS injury mechanisms (i.e. postural control, flexibility, muscular strength, and self-reported function).

## CONCLUSIONS

Participant height and previous ankle sprain history demonstrated predictive value for LAS among collegiate women's soccer players. Longer trunk and segment lengths may impair an athlete's ability to resist external forces, potentially increasing the likelihood of sustaining a LAS. Clinicians should consider collegiate women's soccer players with increased height and previous history of ankle sprain for increased need for interventions designed to prevent LAS.

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