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**Research Article**

# ANKLE FLEXIBILITY ASYMMETRY AS A PREDICTOR OF ANKLE INJURY IN COLLEGE SOCCER PLAYERS: A PROSPECTIVE COHORT STUDY

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**Abstract**

**Background:** Ankle injuries represent a significant burden in soccer, with intrinsic risk factors including proprioception, flexibility, and body mass index (BMI) potentially contributing to long-term disability. Understanding these factors is crucial for injury prevention strategies. **Objectives:** To determine the association of intrinsic risk factors (flexibility, proprioception, and BMI) with ankle injuries in college soccer players. **Methods:** This prospective cohort study included 62 male college soccer players aged 18-25 years. Baseline assessments included BMI measurement, ankle flexibility using the Weight-Bearing Lunge Test (WBLT), and proprioception using the Star Excursion Balance Test (SEBT). Participants were followed up monthly for six months, with ankle injuries being recorded using a standardised injury report form. Binary logistic regression analysis was performed using SPSS. **Results:** During the six-month follow-up period, 12 participants (19.4%) sustained ankle injuries. Binary logistic regression revealed that flexibility asymmetry was a significant predictor of ankle injury ($p=0.045$, OR=0.000164, 95% CI: 0-0.811). Proprioception showed borderline significance ($p=0.051$, OR=2.18, 95% CI: 0.998-4.761). BMI was not significantly associated with ankle injuries ($p=0.082$). Independent t-tests demonstrated significant differences in flexibility between injured and non-injured players for both right ($p<0.001$) and left ($p<0.001$) ankles. **Conclusion:** Flexibility and proprioception asymmetries at the ankle joint are significant predictors of ankle injuries in college soccer players. These findings support the implementation of flexibility training as a preventive measure in this population.

**Keywords:** Ankle injury, Body mass index, Flexibility, Proprioception, Risk factors, Soccer.

## INTRODUCTION

Soccer is a dynamic sport characterised by rapid directional changes, pivoting, jumping, kicking, and cutting movements that impose high loads on the ankle joint, making it a common injury site [1]. Ankle injuries account for 17-20% of all soccer-related injuries, with an incidence rate ranging from 1.7 to 4.5 injuries per 1000 hours of exposure [2,3]. Among these injuries, ankle sprains represent the most common pathology, accounting for up to 67% of all soccer-related ankle injuries [4]. Risk factors for ankle injuries are classified as either extrinsic or intrinsic [5,6]. Extrinsic factors include inadequate warm-up, direct contact with other players, inappropriate footwear, and playing surface characteristics [7]. Intrinsic risk factors encompass flexibility [8,9], joint position sense [10], balance and postural control [11], gait mechanics [12] previous ankle sprains [13], increased body weight, BMI [14,15], and ankle instability [16]. Previous research has demonstrated that 71% of ankle injuries may be related to identifiable risk factors, with only 29% attributed to chance [6]. Evidence suggests that intrinsic risk factors are more prevalent in athletes with a history of recurrent lateral ankle sprains [17]. However, the literature presents conflicting results regarding specific risk factors. Some studies have identified BMI as a predictor of ankle sprain injury risk in youth football players [15,18], while others found no such association [19]. Similarly, research on flexibility has shown associations between reduced ankle dorsiflexion and increased injury risk [8,9,20], though the relationship between multiple intrinsic factors remains unclear.

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Non-contact ankle injuries, which occur through mechanisms such as improper landing or cutting maneuvers, are particularly concerning as they may be preventable through targeted interventions [21]. Most soccer players sustaining injuries are above 18 years of age [22], highlighting the importance of studying this population. While individual risk factors have been investigated in isolation, few studies have examined the interrelationships between flexibility, proprioception, and BMI in predicting ankle injuries among soccer players. Early identification and intervention targeting modifiable intrinsic risk factors represent the most effective approach to injury prevention. Understanding the specific risk factors associated with ankle injuries in college soccer players can inform evidence-based preventive strategies for coaches, trainers, and athletes. Therefore, this prospective cohort study aimed to determine the association between intrinsic risk factors (flexibility, proprioception, and BMI) and ankle injuries in college soccer players over a six-month period.

## METHODS

### Study Design and Setting

This prospective cohort study was conducted over six months among college soccer players. The study protocol was approved by the Institutional Human Ethics Committee, and written informed consent were obtained from all participants.

### Participants

Male college soccer players aged 18-25 years were recruited using convenience sampling. The target sample size of 62 participants was calculated based on a reported ankle joint laxity proportion of 37.3% and an odds ratio of 3.38, with 90% power and 5% alpha error.

**Inclusion criteria:**

- Male soccer players aged 18-25 years
- Active participation in training activities include running, jumping, pivoting, and kicking
- Minimum of six months of sport-specific training under a professional trainer

**Exclusion criteria:**

- Previous reconstructive ankle surgery
- Leg length discrepancy
- Current musculoskeletal conditions
- Neurological disorders
- Cardiovascular problems
- Other pathological abnormalities

**Baseline Assessments**

All baseline assessments were conducted by a single trained examiner to minimise inter-rater variability. Prior to testing, participants performed a 10–15-minute warm-up including dynamic stretching of lower extremity muscles. Each participant was familiarised with testing procedures and allowed three practice repetitions for each test, with the best performance recorded for analysis.

**Body Mass Index (BMI)**

Height was measured to the nearest 0.1 cm using a standard measuring tape with participants standing barefoot against a wall. Weight was measured to the nearest 0.1 kg using a calibrated digital weighing scale. BMI was calculated using the formula: BMI = weight (kg) / height $(m)^2$. BMI categories were defined according to WHO recommendations for Asian populations [23].

**Ankle Flexibility - Weight-Bearing Lunge Test (WBLT)**

The WBLT was performed with participants in a standing lunge position facing a wall [24]. The participant's foot was positioned perpendicular to the wall with the great toe initially 10 cm from the wall. While maintaining heel contact with the ground and the knee aligned with the second toe, participants lunged forward until the knee touched the wall. The foot was progressively moved away from the wall in 1 cm increments until maximum dorsiflexion was achieved without heel lift. The distance from the great toe to the wall was measured to the nearest 0.1 cm using a standard measuring tape. Three trials were performed for each ankle, with the maximum distance recorded.

**Proprioception - Star Excursion Balance Test (SEBT)**

The SEBT was performed using a standardised grid constructed with 3-inch adhesive tape on a hard floor surface [25]. The grid consisted of eight lines extending from a center point at 45-degree intervals, labeled as anterior (A), anterolateral (AL), lateral (L), posterolateral (PL), posterior (P), posteromedial (PM), medial (M), and anteromedial (AM). Participants stood on one leg at the center of the grid and reached as far as possible along each direction with the contralateral leg, lightly touching the line with the reach foot while maintaining balance. The reach distance was measured from the center to the touch point using a measuring tape. Three reaches in each direction were performed, with 15 seconds rest between trials. The maximum reach distance for each direction was normalized to leg length and expressed as a percentage: (reach distance / leg length) × 100. The composite score was calculated as the average of all eight directions.

**Follow-up and Injury Surveillance**

Participants were followed prospectively for six months through monthly visits (every 30 days) and telephone contacts. Ankle injuries were documented using a standardised injury report form based on the consensus statement by Fuller et al. [26]. An ankle injury was defined as any traumatic incident involving the ankle joint during training or competition that caused the player to miss at least one subsequent training session or match.

For each injury, the following information was recorded:

- Date and time of injury
- Mechanism of injury (contact vs. non-contact)
- injured side (right or left)
- Activity at time of injury (training or match)
- Pain severity using Visual Analog Scale (VAS)

**Statistical Analysis**

Data was analysed using SPSS. Descriptive statistics included means and standard deviations for continuous variables and frequencies for categorical variables. Independent t-tests were used to compare baseline characteristics between injured and non-injured groups. Binary logistic regression was performed to identify significant predictors of ankle injury, with odds ratios (OR) and 95% confidence intervals (CI) calculated. Statistical significance was set at $p<0.05$.

## RESULTS

**Participant Characteristics**

A total of 62 male college soccer players (mean age 21.73 ± 1.65 years) completed the six-month follow- up period. During this time, 12 participants (19.4%) sustained ankle injuries, while 50 participants (80.6%) remained injury-free. Baseline characteristics of the study population are presented in Table 1.

**Comparison Between Injured and Non-Injured Players**

Significant differences were observed between injured and non-injured players for ankle flexibility on both sides ($p<0.001$). The non-injured group demonstrated greater flexibility compared to the injured group (right: 13.98 cm vs. 11.49 cm; left: 13.53 cm vs. 11.64 cm). Right ankle proprioception was significantly higher in the injured group (90.33% vs. 89.54%, $p=0.036$), while left ankle proprioception showed a non-significant trend toward higher values in the injured group ($p=0.065$). No significant difference in BMI was observed between groups ($p=0.074$).

**Table 1. Baseline Characteristics of Study Participants**

| Variable | Total (n=62) | Non-Injured (n=50) | Injured (n=12) | t-value | p-value |
|---|---|---|---|---|---|
| Age (years) | 21.73 ± 1.65 | 21.82 ± 1.70 | 21.42 ± 1.44 | 0.758 | 0.451 |
| BMI (kg/m²) | 22.54 ± 1.03 | 22.66 ± 1.07 | 22.07 ± 0.72 | 1.817 | 0.074 |
| Flexibility Right (cm) | 13.47 ± 1.29 | 13.98 ± 0.88 | 11.49 ± 1.09 | 8.361 | <0.001* |
| Flexibility Left (cm) | 13.17 ± 1.17 | 13.53 ± 0.70 | 11.64 ± 0.88 | 7.963 | <0.001* |
| Proprioception Right (%) | 89.70 ± 1.18 | 89.54 ± 1.17 | 90.33 ± 1.06 | -2.147 | 0.036* |
| Proprioception Left (%) | 89.79 ± 1.15 | 89.65 ± 1.13 | 90.33 ± 1.07 | -1.876 | 0.065 |

*Values are presented as mean ± standard deviation. Statistically significant at p<0.05

**Table 2. Binary Logistic Regression Analysis of Risk Factors for Ankle Injury**

| Risk Factor | Low Risk n(%) | High Risk n(%) | β Coefficient | OR (95% CI) | p-value |
|---|---|---|---|---|---|
| Age (years) | 62 (100) | 0 (0) | -0.152 | 0.859 (0.582-1.268) | 0.445 |
| BMI (kg/m²) | 61 (98.4) | 1 (1.6) | -0.58 | 0.560 (0.291-1.077) | 0.082 |
| Flexibility (cm) | 50 (80.6) | 12 (19.4) | -8.713 | 0.000164 (0-0.811) | 0.045* |
| Proprioception (%) | 61 (98.4) | 1 (1.6) | 0.779 | 2.180 (0.998-4.761) | 0.051 |

*OR: Odds ratio; CI: Confidence interval. Statistically significant at p<0.05

### Risk Factor Analysis

Binary logistic regression analysis identified flexibility as a significant predictor of ankle injury (Table 2). Players with poor flexibility had significantly higher odds of sustaining ankle injuries (OR=0.000164, 95% CI: 0-0.811, p=0.045). Proprioception showed borderline significance as a predictor (OR=2.18, 95% CI: 0.998-4.761, p=0.051). BMI and age were not significant predictors of ankle injury in this cohort.

### Injury Characteristics

The 12 ankle injuries recorded, 8 (66.7%) occurred on the right side and 4 (33.3%) on the left side. All injuries were classified as non-contact, resulting from improper landing or cutting movements during training or match play. The distribution of injuries across the six-month period was relatively uniform, with 2-3 injuries occurring each month (Month 1: n=2, 3.2%; Month 2: n=3, 4.8%; Month 3: n=1, 1.6%; Month 4: n=2, 3.2%; Month 5: n=2, 3.2%; Month 6: n=2, 3.2%).

## DISCUSSION

This prospective cohort study examined the association between intrinsic risk factors (flexibility, proprioception, and BMI) and ankle injuries in college soccer players. The findings of current study demonstrate that flexibility asymmetry is a significant predictor of ankle injury, while proprioception shows borderline significance. BMI was not associated with ankle injury risk in this population.

### Flexibility as a Predictor of Ankle Injury

The present study found that reduced ankle flexibility, measured by the WBLT, was significantly associated with increased risk of ankle injury (OR=0.000164, p=0.045). Players who sustained injuries demonstrated significantly lower dorsiflexion range of motion bilaterally compared to non-injured players (right: 11.49 cm vs. 13.98 cm; left: 11.64 cm vs. 13.53 cm; p<0.001). These findings are consistent with previous research demonstrating associations between restricted ankle dorsiflexion and increased injury risk [8,9,20]. Godinho et al. [27], similarly demonstrated that reduced ankle mobility negatively impacts functional performance and may predispose athletes to injury. The mechanism underlying this association likely involves altered lower extremity landing mechanics. Mason-Mackay et al. [28], conducted a systematic review showing that restricted ankle dorsiflexion modifies landing mechanics in ways that increase injury susceptibility, including increased knee valgus, reduced knee flexion, and altered ground reaction forces. Cejudo et al. [29] noted that flexibility tends to decline with age, suggesting that targeted flexibility training should be emphasized in older adolescent and young adult soccer players. The clinical implication of the present study findings is that screening for ankle flexibility asymmetry may help identify at-risk players. Implementation of structured flexibility programs may serve as an effective preventive strategy.

### Proprioception and Injury Risk

Proprioception, assessed via the SEBT, showed borderline significance as a predictor of ankle injury (OR=2.18, p=0.051). Interestingly, injured players demonstrated slightly higher SEBT scores (90.33%) compared to non-injured players (89.54%), which contrasts with conventional expectations. The SEBT is a dynamic functional test that assesses not only proprioception but also strength, balance, and neuromuscular control [25,30]. Players with higher SEBT scores may compensate for proprioceptive deficits through enhanced muscular strength or alternative movement strategies that do not adequately protect against injury during sport-specific maneuvers. Second, the SEBT is performed in a controlled environment, whereas soccer involves unpredictable, high-velocity movements where proprioceptive demands differ substantially.

Fousekis et al. [1] similarly found that prospective proprioceptive testing did not predict ankle sprain occurrence in professional soccer players, suggesting that static laboratory assessments may not capture sport-specific proprioceptive demands. However, other studies have demonstrated the effectiveness of proprioceptive training in reducing ankle sprain incidence [31,32]. Schiftan et al. [33] conducted a systematic review and meta-analysis showing that proprioceptive training programs significantly reduce ankle sprain rates in sporting populations (relative risk: 0.65, 95% CI: 0.55-0.77). The discrepancy between baseline proprioceptive assessment and intervention studies suggests that while static proprioception testing may have limited predictive value, dynamic proprioceptive training that incorporates sport-specific movements may still be beneficial for injury prevention. Future research should investigate dynamic proprioceptive assessments that better simulate soccer-specific demands.

### Body Mass Index and Injury Risk

In contrast to some previous studies, [15,18], present study investigation found no significant association between BMI and ankle injury risk (p=0.082). This finding aligns with research conducted by Beynnon et al. [34] and Owoeye et al. [19], who similarly reported no association between BMI and ankle injury in athletic populations. The mean BMI of both injured (22.07 kg/m²) and non-injured (22.66 kg/m²) groups fell within the normal range according to WHO criteria for Asian populations [23]. The lack of association in present study may reflect the relatively homogeneous BMI distribution in this population of trained soccer players. Gribble et al found that BMI was predictive of ankle sprains in American football players, a population with greater BMI variability including many overweight and obese athletes [35]. Tyler et al. demonstrated that the predictive value of BMI was stronger in athletes with previous ankle sprains, suggesting that BMI may interact with injury history [36]. Nikolaidis et al. reported that excess body mass and body fat negatively affect physical fitness in soccer players, which may indirectly influence injury risk through altered movement mechanics or reduced neuromuscular control [37]. However, within the normal BMI range observed in current study population, this factor does not appear to be a primary determinant of ankle injury risk.

### Injury Patterns and Mechanisms

All 12 ankle injuries in current study were classified as non-contact injuries, occurring through mechanisms such as improper landing or cutting movements. This finding is consistent with Wong and Hong's study showing that non-contact injuries are more prevalent than contact injuries in soccer [38]. Fong et al. conducted a systematic review demonstrating that ankle injuries are the most common body site injury across multiple sports, with non-contact mechanisms predominating [39]. The predominance of right-sided injuries (66.7%) in current study may reflect limb dominance effects or sport-specific movement patterns. However, present study was not designed to systematically investigate laterality effects, and this observation warrants further investigation in larger cohorts.

### Clinical Implications

The findings of current study have important implications for injury prevention in college soccer players:

- **Screening protocols**: Baseline assessment of ankle flexibility using the WBLT should be incorporated into pre-season screening programs to identify at-risk players.
- **Targeted interventions**: Players demonstrating reduced ankle dorsiflexion should participate in structured flexibility programs emphasising both static and dynamic stretching of the gastrocnemius-soleus complex.
- **Monitoring and reassessment**: Regular reassessment of ankle flexibility throughout the season may help identify players experiencing progressive restrictions who require intervention.
- **Comprehensive prevention programs**: While flexibility appears most important in sports population, multifaceted programs incorporating strength, balance, and proprioceptive training may provide additional benefits [31-33].

### Strengths and Limitations

Strengths of this study includes its prospective design, standardised assessment protocols, single examiner to minimise measurement variability, and systematic follow-up procedures. The use of validated measurement tools (WBLT and SEBT) and established injury reporting criteria enhances the reliability and generalisability of current findings. There are few limitations of present study. First, the relatively small sample size (n=62) and single-center design limit statistical power and generalisability. Second, the six-month follow-up period captured only 12 injury events, limiting the precision of odds ratio estimates. Third, we did not account for potential confounders such as training load, previous injury history, fatigue, or level of competition. Future research should include larger, multicenter studies with longer follow-up periods to capture more injury events and improve statistical precision. Investigation of additional intrinsic and extrinsic risk factors, examination of interactions between multiple risk factors, and evaluation of the effectiveness of flexibility training interventions in reducing ankle injury incidence are warranted. Additionally, development and validation of dynamic proprioceptive assessments that better reflect sport-specific demands may improve injury risk prediction.

### Conclusion

This prospective cohort study demonstrates that ankle flexibility asymmetry is a significant predictor of ankle injury in college soccer players, while proprioception shows borderline significance. BMI was not associated with ankle injury risk in this population of normally weighted athletes. These findings support the implementation of flexibility screening and targeted flexibility training programs as preventive measures for ankle injuries in college soccer players. Future research should validate these findings in larger cohorts and evaluate the effectiveness of flexibility-focused interventions in reducing ankle injury incidence.

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