

[Orthopaedic Surgery]

Defending Puts the Anterior Cruciate Ligament at Risk During Soccer: A Gender-Based Analysis

Robert H. Brophy, MD,^{*†} Jeffrey G. Stepan, MD,[‡] Holly J. Silvers, MPT,[§] and Bert R. Mandelbaum, MD^{||}

Background: Soccer athletes are at risk for anterior cruciate ligament (ACL) injury. To date, there are limited studies on the mechanisms of ACL injuries in soccer athletes and no video-based analysis or sex-based comparison of these mechanisms.

Hypothesis: There is no difference in ACL injury mechanisms among soccer athletes by sex.

Study design: Case series.

Level of evidence: Level 4.

Methods: Fifty-five videos of ACL injuries in 32 male and 23 female soccer players were reviewed. Most athletes were professionals (22 males, 4 females) or collegiate players (8 males, 14 females). Visual analysis of each case was performed to describe the injury mechanisms in detail (game situation, player behavior, and lower extremity alignment).

Results: The majority of ACL injuries occurred when the opposing team had the ball and the injured athlete was defending (73%). Females were more likely to be defending when they injured their ACLs (87% vs 63% for males, $P = 0.045$). The most common playing action was tackling (51%), followed by cutting (15%). Most injuries occurred due to a contact mechanism (56%) with no significant difference for sex. Females were more likely to suffer a noncontact injury in their left knee (54%) than males (33%) ($P = 0.05$).

Conclusion: Soccer players are at greatest risk for ACL injury when defending, especially when tackling the opponent in an attempt to win possession of the ball. Females are more likely to injure their ACLs when defending and are at greater risk for noncontact injuries in their left lower extremity.

Clinical Relevance: Soccer ACL injury prevention programs should include proper defending and tackling techniques, particularly for female athletes.

Keywords: soccer; football; anterior cruciate ligament; ACL

Soccer is widely regarded as the most popular sport in the world in terms of both audience and participation. Anterior cruciate ligament (ACL) tears are a common injury in soccer, with serious short- and long-term consequences to both the individual and the team. The incidence of ACL tears in soccer players has been reported to range from 0.06 to 10 injuries per 1000 game hours, with the highest rates reported in

professional players.^{4,12,27} Recovery takes at least 4 months, even with accelerated rehabilitation in professional players, and more typically, lasts 6 to 8 months.^{28,30} The players themselves have at least a 40% risk of suffering long-term sequelae in the form of osteoarthritis in the knee joint.^{18,22} Many players do not return to their sport or to full form because of physical and psychological factors related to their knees.^{20,21}

From [†]Washington University Orthopedics, Chesterfield, Missouri, [‡]Washington University School of Medicine, St Louis, Missouri, [§]Santa Monica Orthopaedic and Sports Medicine Research Foundation, Santa Monica, California, and ^{||}Santa Monica Orthopaedic Group, Santa Monica, California

*Address correspondence to Robert H. Brophy, MD, Washington University Orthopedics, 14532 South Outer Forty Drive, Chesterfield, MO 63017 (e-mail: brophy@wudosis.wustl.edu).

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Figure 1. Example of male soccer player at the moment of anterior cruciate ligament injury.

Studies have shown a 2 to 3 times greater rate of ACL injury in female soccer players.^{7,17,25,31,32} Various factors have been proposed as contributing to this inequity, such as higher valgus stress and loading in females when performing tasks, differences in hamstring/quadriceps strength ratio and vastus lateralis/semitendinosus strength ratio, lateral and posterior hip insufficiencies, and nondominant leg strength differences, which may put females at greater risk for ACL injury.^{8,15,26,32} Understanding the mechanism of injury is important to identify underlying risk factors that may be amenable to prevention efforts. While there have been video analyses of ACL injuries in basketball, handball, Australian football, and most recently, alpine skiing,^{3,11,19,24} there is no such study to date of such injuries in soccer. Epidemiological soccer-specific studies on ACL tears analyzing both biomechanics and game situations to date have relied on patients' memories to secure information, which is a limiting factor to the accuracy of the research.^{4,13,31} No study has directly compared female and male athletes' mechanisms of injury through video analysis, providing more definitive evidence. The purpose of the present study was to analyze videos of ACL tears in soccer players to describe the game situation and biomechanics of the injuries and to test the hypothesis that these variables differ between male and female soccer athletes.

METHODS

Institutional review board approval was obtained in the form of a waiver. Videos of ACL injuries in soccer athletes were collected in several ways, including an Internet search to find video of amateur, collegiate, and professional soccer players in the act of tearing their ACLs. Finally, collegiate soccer coaches were contacted by mail and asked to submit any video of ACL injuries in their possession.

Visual analysis of each case was performed to describe the injury mechanisms in detail (game situation, player behavior, lower extremity alignment, and kinematics). The goal was to identify the most frequent soccer "game situation" in which the injury occurs and to determine the most common mechanisms by which ACL tears occur. This 2-tiered analysis was accomplished in previously published basketball, handball, and Australian football video analyses.^{11,19} Videos had to clearly delineate the position of the injured player on the field along with position of the ball and the events preceding the injury. To be included, the moment of injury had to be readily apparent based on the reaction of the athlete and the subsequent favoring of the injured lower extremity. Videos analyzed for mechanism of injury were of high enough quality to estimate the angles and determine the position of the lower extremity (as described below) along with an unobscured view of the injury.

Fifty-five videos of ACL injuries in 32 male (Figure 1) and 23 female soccer players were reviewed. Most injuries were incurred by professionals (22 males, 4 females) or collegiate-level players (8 males, 14 females), with the remainder occurring in high school and youth players.

Each video was analyzed for the game situation immediately prior or during the occurrence of injury. The analysis for game situation included whether the player was on offense or defense, the action of the player (heading, passing, receiving the ball, tackling, etc), whether the player was in control of the ball, and the location on the field where the injury occurred. Included in the game situation is the action the player was taking with regard to his movement (ie, whether the player was accelerating or decelerating and whether the player was cutting, jumping, or landing in the case of injuries not resulting from a direct blow to the lower extremity).

The mechanics of the ACL injury were studied in a systematic approach. The side of the injury was recorded. Then, it was determined whether the injury was via contact or noncontact. Contact injuries were further divided into 2 separate categories revealing whether the injury was caused by direct contact to the lower extremity or indirect contact to other parts of the body, which influenced the injury. Noncontact injuries were also examined to determine whether there was an opponent or another player in close proximity (within 1 m of the injured player) during the injury.

The alignment of the lower extremity joints was estimated in a qualitative fashion at the time of injury. The sagittal (flexed, neutral, extended) and coronal (abducted, neutral, adducted) position of the hip joint was recorded. The knee flexion-extension angle was estimated as 1 of 3 categories (0°-30°, 30°-60°, 60°-90°), as was utilized by Cochrane et al.¹¹ Coronal plane alignment of the knee was also recorded as abducted, adducted, or in a neutral position. Finally, the nature of foot contact (toe, flat, heel, etc) at the time of injury was determined.

Videos were each independently examined by 2 reviewers. Data were then compared and shown to be in agreement on 99% of data points. Discrepancies were slight and were resolved to complete agreement on mutual review.

Table 1. Playing actions

	Male			Female		
	Contact	Noncontact	Total	Contact	Noncontact	Total
Injured side						
Left	8	5	13	7	5	12
Right	9	10	19	7	4	11
Total	17	15	32	14	9	23
Ball possession						
Yes	7	5	12	1	2	3
No	10	10	20	13	7	20
Mechanism						
Tackling	7	6	13	12	3	15
Being tackled	4	0	4	0	0	0
Cutting	1	3	4	0	4	4
Kicking	1	2	3	1	0	1
Heading	2	1	3	0	0	0
Receiving	1	1	2	0	1	1
Running/jumping	1	1	2	1	1	2
Dribbling	0	1	1	0	0	0

Summary statistics were calculated and compared by sex. Chi-squared tests were used for comparison between males and females for game situations and biomechanical parameters.

RESULTS

Playing Actions

The majority of ACL injuries occurred when the opposing team had the ball and the injured athlete was defending (73%). Females were more likely to be defending when they injured their ACL (87%) than males (63%) ($P = 0.045$) (Table 1). The most common playing action was tackling (51%), followed by cutting (15%). More than half of injuries occurred due to a contact mechanism (56%). There was a trend toward a greater percentage of ACL injuries occurring via contact in females (61%) compared with males (53%) ($P = 0.06$). ACL injuries that occurred when tackling usually involved contact (79%). In females, 80% of ACL injuries while tackling involved contact compared with 54% in males, but the difference was not significant ($P = 0.13$).

For the vast majority of noncontact injuries (83%), an opposing player was within 1 or 2 yards of the injured athlete, but no direct contact occurred. Females (54%) were more likely than males (33%) to suffer a noncontact injury to their left lower extremity ($P = 0.05$).

Biomechanics

Injuries occurred during a variety of motions, including planting, landing, cutting, and decelerating (Table 2). Athletes were usually moving forward or changing direction at the time of injury. The majority of contact injuries occurred with the athlete moving forward (80%). There were no significant differences between male and female athletes.

Noncontact ACL injuries occurred most often with the hip flexed (88%) and abducted (83%) (Table 3), the knee in valgus (58%) and within 30° of full extension (71%) (Table 4), and the foot flat (58%) (Table 5). Similar patterns of joint position were seen with the contact injuries. There were no significant differences between male and female athletes.

Table 2. Acceleration and direction

	Male			Female		
	Contact	Noncontact	Total	Contact	Noncontact	Total
Acceleration/deceleration						
Planting	4	2	6	1	1	2
Landing	2	4	6	1	2	3
Cutting	3	6	9	1	5	6
Decelerating	0	3	3	7	1	8
Direction						
Forward	12	7	19	12	2	14
Lateral	1	2	3	1	0	1
Changing direction	3	6	9	1	6	7

Table 3. Hip position

	Male		Female	
	Contact	Noncontact	Contact	Noncontact
Sagittal				
Flexed	15	13	12	8
Neutral	1	2	1	1
Extended	1	0	0	0
Coronal				
Abducted	11	13	9	7
Neutral	3	2	4	2
Adducted	2	0	0	0

DISCUSSION

Our analysis demonstrated that soccer players most often injure their ACLs when defending, specifically tackling, and females are more likely to injure their ACLs while defending than are males. Slightly more than half of the injuries occur via a contact mechanism, although a significant proportion of noncontact injuries occur with an opponent in close proximity. Soccer ACL injuries usually occur when the lower extremity is in a position of risk for both contact and noncontact injuries. For noncontact ACL tears, female soccer players are more likely to injure their left knee compared with males.

Our findings that 51% of ACL injuries occurred with tackling (38% males, 60% females) are very similar to those reported by Bjordal et al,⁴ who found that tackling was the cause of 46% of ACL injuries in soccer players (42% males, 58% females). Tackling likely puts soccer athletes at risk for ACL injury for a number of reasons. First, tackling is often a reactive maneuver that can require last-minute adjustments in body position and technique, which may put either lower extremity in the position of risk as the player responds to his opponent's actions. Female athletes with poor neuromuscular control and suboptimal biomechanics may be more likely to react while tackling in a way that puts the ACL at risk for injury. Furthermore, contact is

Table 4. Knee position and mechanics

	Male		Female	
	Contact	Noncontact	Contact	Noncontact
Sagittal, deg				
0-30	15	10	9	7
30-60	1	5	3	2
60-90	0	0	1	0
Coronal				
Valgus	6	10	6	4
Neutral	10	4	7	5
Varus	0	1	0	0

Table 5. Foot position (not always applicable)

	Male		Female	
	Contact	Noncontact	Contact	Noncontact
Flat	8	8	6	6
Medial	3	3	2	2
Lateral	1	1	0	0
Toes	0	1	1	0
Heel	1	1	0	0

inherent in tackling. Although a number of the ACL injuries that occurred during tackling were noncontact, the majority (79%) were contact. Nevertheless, this could be an important finding with regard to potential injury prevention efforts, as proper tackling technique should be addressed during player development and training.

Previous studies have shown that ACL injuries in soccer occur via a contact mechanism in 55% to 80% of cases.^{13,17,21} Studies across different sports, including soccer, report a contact mechanism in 65% to 80%^{2,5,6,11} of ACL tears. However, a large percentage of noncontact injuries did have an opponent in close proximity (82%). Patient self-report of contact versus noncontact mechanism may not be as accurate as previously thought and likely deserves further study.

The higher involvement of the left lower extremity in noncontact ACL injuries among females compared with males is concordant with a previous study demonstrating that the majority of noncontact injuries occur on the nondominant lower extremity of female soccer players.⁷ Seventy-four percent of noncontact ACL

injuries occurred in the dominant limb of male soccer athletes, compared with 32% of females. In a recent study of outcomes from ACL reconstruction in soccer players, females were more likely to be right-foot dominant (96%) than males (74%).¹⁰ Assuming the right lower extremity is the dominant kicking leg, 67% of noncontact ACL injuries occurred in the dominant limb of males compared with 46% of females. The consistency of these data suggests a sex-based difference in the risk for and potentially a contributing mechanism of noncontact ACL injuries among soccer players. Possible factors behind this difference include differences among sexes in kicking⁸ and female side-to-side asymmetries in hip abduction and external rotation strength.⁹

Past studies have pointed to the ACL being most vulnerable and most often injured when the knee is at near extension.^{1,5,23,29} Our data support this conclusion in soccer players as well. Knee rotational moments combined with near knee extension is often described as the most common situation in which ACLs are injured in observational and retrospective analyses.^{5,6,19} Knee abduction has been shown to increase the

risk of injuring the ligament in some studies,^{1,6,16} although 1 study found no relationship between calculated peak knee abduction moment during videotaped drop vertical jump and ACL injury risk.¹⁴ Another important factor in ACL tears is foot position at initial contact and which part of the foot first hits the ground.^{1,6,23} Flat-footed contact may put soccer players at risk for ACL injury, particularly when tackling.

The primary limitation of this study is the relatively low number of injuries analyzed, the lack of sample size estimate, and the resulting lack of power to detect statistically significant differences. There is a bias toward match play versus practice, as matches are more likely to be videotaped than practices. The videos were not randomly or systematically obtained, resulting in selection bias for these cases of ACL injury. There was incomplete information on the athletes with regard to level of play, leg dominance, and any history of previous ACL injury and/or reconstruction. This observational study did not include precise analytical methods with regard to lower extremity position and angulation, raising uncertainty about the reported injury mechanisms. Finally, we do not have specific recommendations in terms of how to improve tackling techniques, an area that warrants further study.

Soccer players are at increased risk for ACL injury when defending and tackling, especially females, with just over half of injuries occurring via a contact mechanism. Females are at greater risk of noncontact injury on the left lower extremity than males. Female soccer players may especially benefit from training focused on safe techniques for defending and tackling.

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