Epidemiologic Assessment of Concussions in an NCAA Division I Women's Soccer Team

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Background: Among collegiate sports, ice hockey and wrestling have been reported to have the highest rates of concussion injury. Recent literature has shown that among all sports, female soccer players had the highest rate of concussion injury at the high school level. Sport-specific analysis will increase our knowledge of epidemiologic characteristics of this serious injury in young soccer players, where "heading" is commonly involved during participation.

Hypothesis: Heading during soccer will be associated with increased frequency of concussion injury in collegiate female players compared with other mechanisms of injury, and concussion injury mechanism and rates will differ by setting of injury (practice or match) and player position.

Study Design: Descriptive epidemiologic study.

Methods: This was a retrospective review and epidemiologic analysis of all concussions documented from a single National Collegiate Athletic Association (NCAA) Division I female collegiate soccer team between 2004 and 2017. A total of 381 participants were reviewed, and concussion injury mechanism, setting (practice or match), player position, and number of games and practices missed due to injury were analyzed.

Results: Overall, 25 concussions in 22 players from the 2004 to 2017 seasons were identified, for an annual rate of 1.79 concussions per year. Collisions (36%) followed by headers (20%) were the most common mechanisms. Forwards sustained the most concussions (32%). Injuries were more common in games (56%) than practice (40%). Of note, the most common cause of concussion during practice was headers (40%). Of the concussions documented, 20 (91%) were the player's first concussion. On average, each concussion resulted in a player missing 3.96 games and 12.46 practices.

Conclusion: Our results demonstrate that concussion rates in female NCAA soccer players vary by position and occur with different frequencies and mechanisms in practice and games. Interventions for concussion avoidance should aim to limit exposure to high-risk activity, including player-to-player contact in games and headers in practice. Although gameplay and collisions can be unpredictable and difficult to control, practice settings can be modified in an attempt to decrease risk.

Keywords: concussion; head injury; risk factors; epidemiology; soccer

Soccer is the world's most popular sport, played by more than 250 million players internationally.[17,20] In the United States (US), soccer is one of the most commonly played sports by female participants and is steadily increasing in popularity. The US has more registered female soccer players than all other countries combined, including youth, collegiate, and professional athletes.[10,15] There are 959 National Collegiate Athletic Association (NCAA) women's soccer programs, 159 more than men's programs.[2]

Approximately 2.5 million people in the US sustain a traumatic brain injury (TBI) annually, of which 75% to 95% are mild.[1,9] However, mild TBIs, or concussions, are projected to have a much higher incidence rate given that many cases go unrecognized or unreported.[14,21] Concussion rates are highest in adolescents and young adults, with a significant portion of concussions occurring secondary to athletics. One study reported the annual incidence of sports-related concussion in the US to be 1.6 to 3.8 million, with as many as 20% of contact sport athletes experiencing a concussion each season.[18]

Interestingly, the literature suggests that female athletes sustain more concussions with elevated rates and severity of symptoms compared with male athletes playing the same sport with the same rules.[12] Studies have provided evidence for these findings in lacrosse, basketball, and soccer.[4,5,7,11,16] Current hypotheses for the greater concussion rates in female athletes include differences in hormone balance, neck strength, style of play, coaching, or

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rates of reporting symptoms.[12] Covassin et al[4] found a significantly increased rate of concussion in collegiate female soccer players compared with male players. Female soccer players sustain these concussions given the nature of the play as well as the large number of participants.[19]

Previous studies have investigated the epidemiologic characteristics of sport-related concussion in student athletes.[3,4] Zuckerman et al,[22] in a sport-specific analysis using the NCAA Injury Surveillance Program database, found that men's wrestling and ice hockey had the largest concussion rates among the 25 sports analyzed. The same authors reported a 6.31% overall concussion rate in women's soccer. However, a recent database study assessing concussions in US high school sports between 2005 and 2014 highlighted that female soccer players have a greater risk for sustaining a concussion than all other sports.[19] To shed light on the epidemiologic characteristics of concussion injuries in young soccer players, sport-specific analysis is necessary.

The purpose of this study was to provide a comprehensive epidemiologic assessment of concussions in a single NCAA Division I female soccer team. We hypothesized that the act of heading would be associated with increased frequency of concussion injury in these athletes compared with other mechanisms of injury and that concussion injury mechanism and rates would differ by setting of injury (practice or match) and player position.

TABLE 1
Diagnostic Criteria for Concussion

Clinical Findings	Physical Examination Findings
Dizziness	Neck pain
Headache	Slowed reaction time
Nausea	Loss of consciousness
Vomiting	Disequilibrium
Lack of coordination	Incoordination
Visual problems	Deficits in recall
Fatigue	Deficits in concentration
Sensitivity to light or sound	Difficulty with speech
Somnolence	Loss of strength in upper or lower extremities
Numbness or tingling	Loss of sensation in upper or lower extremities
Mental slowness	Impaired vestibular function
Disorientation	Impaired ocular motor function
Difficulty with concentration or memory	Loss of balance
Slowed or incoherent speech	
Behavioral changes	
Drowsiness	

METHODS

Study Design

We conducted a retrospective review of prospectively collected data regarding all head or neurologic injuries that occurred on a single NCAA Division I collegiate women's soccer team between 2004 and 2017. All data were entered by the team's board-certified athletic trainer after consultation with the head orthopaedic team physician. This study was approved by the University of Southern California Health Sciences Institutional Review Board.

Inclusion Criteria and Diagnosis

Patients were included in the study if they had been diagnosed by a team physician with a concussion (based on the 2017 Concussion in Sport Group consensus statement[13]) that resulted in the cessation of athletic activity. Diagnoses were made from clinical findings and physical examination, objective assessment scores, and medical judgment. Athletes were given the Post Concussion Symptom Scale, Standardized Assessment of Concussion, Balance Error Scoring System, and a computerized neuropsychological assessment at the beginning of the year to establish a baseline for comparison during presentation. The athlete's history of prior symptoms, level of consciousness, and performance scores assisted in retrospective grading of the severity of injury. The complete list of clinical and physical examination findings indicative of concussion is provided in Table 1.

After the patients with diagnosed concussions were identified, all patient characteristics and injury profiles were assessed. Athlete variables that we examined included player position and year of participation at time of injury. To characterize the injuries in these athletes, the mechanism of injury and setting (ie, practice vs game vs conditioning) were recorded and later analyzed. Mechanisms for head injury were divided into whether they occurred during a header, collision, fall to the ground, or unspecified direct contact. We defined all header concussions as secondary to the head striking the ball or involving a heading attempt,

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Ethical approval for this study was obtained from the University of Southern California Health Sciences Institutional Review Board (proposal No. HS-15-00565).

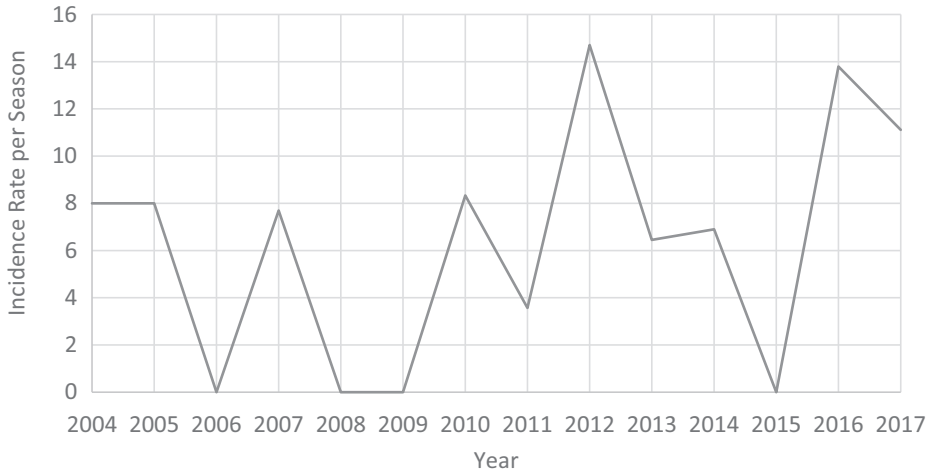

Figure 1. Trends of concussion incidence rates per season by year.

with person-to-person contact (but without a heading attempt) categorized as a collision. Outcomes assessed included the number of games and practices missed as a result of these injuries.

Postconcussion Return-to-Play Protocol

The return-to-play protocol began with rest until the athlete was symptom-free in activities of daily living. Once the athlete was symptom-free at rest, she followed a gradual progression in noncontact activity, reintroduction to practice, and finally return to competition. An athlete had to be symptom-free to progress from one stage to the next. Although the postconcussion return-to-play protocol was modified according to each player's unique injury, the milestones that the athletes had to achieve in order to return to activity remained the same and were based on the presence of symptoms throughout the study period. There was no minimum time that the athlete was kept from competition.

Statistical Analysis

An epidemiologic analysis was performed to analyze variables, including player position, setting of injury, mechanism of injury, and number of games and practices lost. Chi-square tests were used to compare categorical variables. Significance was set to $P < .05$.

RESULTS

Query of our university's NCAA team database from 2004 to 2017 identified 381 participants for women's soccer, of whom 34 athletes had been diagnosed with a head or neurologic injury. After we excluded all nonconcussion injuries, 25 concussions in 22 athletes remained, for an average of 1.79 diagnosed concussions per year and an average annual incidence rate of 6.56% for the 14-year period. The annual volume and incidence trends remained relatively constant, ranging from 0 to 5 cases and 0% to 14.7%, respectively. The overall trends in concussion incidence rates can be seen in Figure 1. We did not find a significant positive or negative trend over time.

Concussions were reported as occurring during 14 games, 10 practices, and 1 conditioning session throughout the 14-year period. Collisions were the most common documented mechanism of injury (36%), followed by headers (20%). During games, collisions were the most common cause of concussion (57%). However, headers were one of the most documented causes of concussion during practices along with direct contact (also 40%). Unspecified direct contact was the listed cause of concussion for 36% of all concussions, 36% of concussions during games, and 40% of concussions during practices. The full breakdown of mechanism of injury is provided in Table 2.

When we assessed concussions by player position, forwards were found to be the most injured position (32%), followed by defenders (24%). For all positions except for goalkeepers, the majority of concussions occurred during the game setting; for goalkeepers, 75% of concussions were documented as a result of an incident in practice. Further, for all positions aside from midfielders, headers were a minority mechanism of injury for documented concussion, with midfielders having an even split between unspecified direct contact, falls, and headers. A complete breakdown of concussion by position is provided in Table 3.

Games and Practices Missed as a Result of Concussion Injury

On average, each concussion resulted in a player missing 3.96 games and 12.46 practices: This equates to 18.3% of the 21.6-game season average. Of the concussions documented, 20 (91%) were the player's first concussion.

DISCUSSION

In this epidemiologic analysis of concussion events in collegiate female soccer players, the most important finding was

TABLE 2
Mechanism of Injury by Setting[a]

Mechanism	Practice (n = 10; 40%)	Game (n = 14; 56%)	Conditioning (n = 1; 4%)	Total (n = 25)
Header	4 (40.00)	1 (7.14)	0	5 (20)
Collision	1 (10.00)	8 (57.14)	0	9 (36)
Fall	1 (10.00)	0	0	1 (4)
Direct contact	4 (40.00)	5 (35.71)	0	9 (36)
Unknown	0	0	1 (100)	1 (4)

[a]Values are expressed as n (%).

TABLE 3
Number of Concussions by Player Position[a]

Position	Concussions, n (%)	No. per Mechanism	No. per Setting
Forward	8 (32)	4C, 3DC, 1H	6G, 2P
Defender	6 (24)	3C, 1DC, 1U, 1H	3G, 2P, 1Con
Goalkeeper	4 (16)	3DC, 1H	1G, 3P
Midfielder	3 (12)	1DC, 1F, 1H	2G, 1P
Forward/ midfielder	3 (12)	2C, 1H	2G, 1P
Forward/ defender	1 (4)	1DC	1P

[a]C, collisions; Con, conditioning; DC, unspecified direct contact; F, fall; G, games; H, header; P, practice; U, unknown.

the higher risk of concussions during games. In addition, during games, collision was the most commonly recorded mechanism of injury, and the most injuries by position were sustained by forwards, followed by defenders. Our results also showed a relatively high concussion rate related to headers and direct contact in practice. With an annual incidence rate of 6.56% for the 14-year study period, concussions in women soccer players resulted in their missing an average of 3.96 games and 12.46 practices per concussion.

This study was performed to identify when and how concussions occur in female NCAA Division I soccer players to assist and develop targeted concussion prevention recommendations. It is well documented in the literature that collisions and headers are the most common causes of concussion in soccer players.[8] Zuckerman et al[22] found that in female college soccer players, the largest proportion of concussion occurred due to player (19.9%) or ball (11%) contact while heading the ball. These data are corroborated by a recent analysis of the NCAA Injury Surveillance Program database demonstrating that only 8.2% of soccer injuries were related to ball contact.[6] Of those ball-contact injuries, only 12.8% were headers.

We also performed an analysis of concussions by position. The results of this study suggest that forwards are at the highest risk. These injuries caused the average athlete in this study to miss almost one-fifth of her season. Interestingly, although the general trend was toward concussions being more common in games than practice, 3 of our 4 goalkeeper concussions occurred in practice. However, as goalkeepers who sustained a concussion injury constituted only a small subgroup in our analysis, any conclusion based on our results would be invalid. Thus, this observation may indicate a potential area of future research. Although an understanding of the number of days and games missed is valuable, it is also important to understand that this represents a small portion of the overall impact on the collegiate athlete both athletically and academically. Although not directly examined in this study, the neurocognitive impact of these injuries on the ability of these student-athletes to study, take examinations, and overall excel academically should not be overlooked, because academic demands continue regardless of what occurs in the collegiate athlete's playing career.

We detected a higher rate of concussions during games, with collisions being the most common mechanism of injury. Better refereeing during games, and therefore limitation of the contact between players, could lead to a reduction of concussion events during competition. Another important finding was the relatively high rate of concussions during practice (40%), 40% of which occurred during headers. This indicates that a large portion of these injuries may be prevented by changes in practice regimen. In contrast to the unpredictability of games, activities during practices are more easily controlled. Teams will generally practice headers to improve their shooting, passing, and ball control with their head. This type of volume exposes athletes to repeated microtrauma, which may make them more susceptible to concussion either by lowering their threshold for TBI or through an additive effect from the headers alone. By limiting the athlete's exposure to these microtraumas, it is possible that teams could reduce the concussion incidence. Limiting the overall volume, emphasizing proper technique, using protective headgear, decreasing the force of headers, and using a softer ball material for headers during practice are all potential alternatives being investigated by teams to decrease injury while maintaining skill level. Other considerations include neck strengthening protocols for improved neuromuscular control and the use of impact monitors to evaluate the frequency and strength of forces applied to the head in this controlled environment.

Our study is limited by several factors. We analyzed a relatively small sample size from a single team, which reduced the power of our analysis. The rate of concussion injury might have been underestimated, as we only analyzed the concussion injuries that were documented as resulting in the cessation of the athletic activity. Therefore, some undocumented concussion events were probably missed. In addition, our database relies on accurate diagnosis and documentation of injury. As a clinical diagnosis, the identification of concussion is heavily dependent on a physician's determination of whether a player's constellation of symptoms meets the diagnostic threshold. Although clinical guidelines exist to aid in judgment, diagnosis remains inconsistent given each player's difference in baseline as well as each physician's difference in ability to notice changes from the varying baselines. It is also possible that

players underreported concussive symptoms out of fear of requiring extended time out of competition.

In addition, the lack of an objective clinical, imaging, or laboratory test for concussions makes these limitations inherent to all concussion research. Finally, the definition of *header* when classifying the mechanism of injury in our study involved head-ball contact or a heading attempt. Variation in the literature regarding this definition made it challenging to compare results with those of similar studies.[3] The retrospective nature of the study made it impossible to overcome any issues with documentation, including the description of the header mechanism of injury in detail.

CONCLUSION

Concussions are a serious injury that commonly occur in women's soccer. Our results demonstrate that concussion rates vary by position and that concussions occur with different frequencies and mechanisms in practice and games. Interventions for concussion avoidance should aim to limit exposure to high-risk activity, including player-to-player contact in games, and headers in practice.

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