Pediatric Concussions in Female Contact Sports: A 10-year Analysis of Mechanisms and Associated Symptoms

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BACKGROUND: The increased popularity of female athletics has led to an increased incidence of sports-related injuries in women. Concussions comprise a significant proportion of sports injuries and are associated with immediate and long-term consequences for youth athletes. However, despite the increasing participation of women in contact sports, there is relatively little research on sex-specific characteristics in concussions. The objective of this study is to describe the characteristics, mechanisms of injury (MOI), and associated symptoms of pediatric female patients diagnosed with concussions from contact sports.
METHODS: The National Electronic Injury Surveillance System (NEISS) database of the US Consumer Product Safety Commission was queried from 2012-2021 for concussions evaluated in emergency departments (EDs) sustained by athletes aged 4 to 18. The contact sports analyzed included basketball, cheerleading, gymnastics, hockey, lacrosse, soccer, softball, and volleyball. Demographics, incidence rates, mechanism of injury, and associated symptoms were analyzed for each sport and stratified by age during the study period.
RESULTS: There were 3,906 female athletes who sustained concussions from 2012-2021 from contact sports. Most sports-related concussions were treated in the outpatient setting (97.4%). Soccer had the greatest number of concussions at 34.1%, followed by basketball at 21%, and softball 14.1%. The most common MOI was player-to-player contact (1214, 31%) and head-to-ground impact (1103, 28.2%). MOI was sport and age-specific with basketball and cheerleading having the highest proportion of player-to-player injuries in older athletes (15-18) while younger athletes (4-9) suffered concussions via head-to-ground injury. Loss of consciousness (LOC) was reported in 5.5% of concussions with older athletes having significantly more LOC concussions than younger athletes (P= 0.02). The most frequently reported associated symptoms were headache/head pain (41.1%), dizziness (28.12%), and confusion (9.2%).
CONCLUSION: Concussions are a common injury among youth female athletes, with soccer, basketball, and softball being the sports with the highest number of concussions. MOI of injury in female concussions is sport-specific with high rates of player-to-player and player-to-ground injuries that differ with age. There is an increased prevalence of head-to-ground concussions in younger athletes and an increased prevalence of player-to-player concussions in older athletes. LOC was significantly higher in older athletes while other symptoms including headache, and dizziness were similar across all age groups. Athletes, coaches, and physicians' awareness of common symptoms and mechanisms of injury for each sport can better develop preventative strategies and improve patient care for concussions in female contact sports.

INTRODUCTION

An increase in the popularity and accessibility of female athletics has led to an increased incidence of sports-related injuries.[1,2] Concussions make up a significant proportion of contact sports injuries and are associated with immediate and long-term consequences for youth athletes.[3] Concussions are mild brain injuries that can be described as traumatically induced transient disturbances of brain function.[4] The CDC reported in 2020 that 6.8%

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of children under the age of 17 experienced symptoms of a concussion or brain injury.[5,6]

Sports-related concussion rates widely vary as concussion prevalence is associated with each individual sport and its inherent type of play.[3,4] In comparable sports, female athletes have higher concussion rates than male athletes.[3,7,8] Research conducted on athletes in the NCAA, found that female athletes have higher rates of concussions than males in softball, soccer, basketball, and baseball.[9] Furthermore, females suffer more severe concussions with increased complaints of migraine, headache, dizziness, fatigue, concentration, and sleep deviations.[9] Other studies found increased severity of concussions in female athletes with greater post-concussive symptom scores, longer return to play time, cognitive decline, and prolonged recovery time.[10,11]

The reasons for the greater severity of concussions in females are not yet fully understood, but it has been proposed that a variety of factors may contribute, including the effects of hormones, gender normative behavior, underdiagnosis, and increased removal latency from the onset of concussion symptoms.[10] Several hypotheses have been proposed to explain the increased concussion rates in female athletes, including reduced neck strength, increased head acceleration, increased ball-to-head concussions, differences in hormones, differences in brain structure/function, and reduced visual awareness. However, there remains a scarcity of studies with high-level evidence to support these theories. Without supporting evidence to guide injury prevention through rule changes or promotion of protective equipment, female contact athletes remain at risk for concussions.[12]

Despite the increasing participation in female contact sports and higher concussion rates, there is relatively little research on sex-specific characteristics in concussions. One study highlighted that past research on concussions focused predominantly on male participants, while 40.4% of studies did not include females at all.[13] There is limited investigation into the current literature regarding why females may be predisposed to more severe outcomes following a concussion injury.[10] The objective of this study is to describe the characteristics, mechanisms of injury (MOI), and associated symptoms of pediatric female patients diagnosed with concussions from contact sports.

METHODS

All data were collected using The United States Consumer Product Safety Commission (CPSC) National Electronic Injury Surveillance System (NEISS) from January 2012 to December 2021. The NEISS database is a nationally representative probability sample of approximately 100 emergency departments (EDs) in the United States (U.S.) and its territories. All participating NEISS hospitals have at least 6 beds and a 24-hour ED where information on demographics, injury, and treatment information is collected. From the data collected by the NEISS hospitals, national estimates are made of the total of product-related injuries treated in U.S. emergency departments. National estimates can be calculated by summing the number of cases that present to each NEISS ED after using a multiplier based on the size of the hospital and the number of hospitals similarly sized across the United States.[14]

The NEISS database was queried for all female concussions (injury code: 52, location code: 75) in athletes aged 4-17 years old related to team contact sports including basketball, soccer, softball, and volleyball. Athletes ages 4-17 years old were included to cover the full scope of pediatric concussions with organized team sports beginning as early as age four. Information on demographics, injury characteristics, diagnosis, and narrative details describing MOI and how the patient presented to the ED was collected. Our analysis included variables covering mechanism of injury (MOI) and other associated symptoms collected from the narrative section. All injuries were filtered based on location. Only injuries that occurred at school or a place of recreation were included to capture injuries sustained in an organized sports setting.

Data Analysis

Descriptive analysis was performed for each year, stratified by sport. Differences in MOI were stratified based on the five mechanisms of injury: 1. Player-to-Player; 2. Head-to-Ball; 3. Head-to-Ground; 4. Head-to-Other Object; 5. Unspecified in report. Chi-square analysis comparing the proportion of loss of consciousness (LOC) and associated symptoms were performed based on the narrative provided. Analysis of the severity of the injury was completed based on the number of concussions that presented with LOC and the number of injuries that required hospitalization.[14,15] Differences in the number of concussions sustained

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by year and sport, MOI, the severity of the injury, and associated symptoms, were compared using chi-square tests with an alpha of 0.05 indicating statistical significance. In further analysis, athletes were stratified into the following age groups: 4-10, 11-14, 15-17 and differences in LOC, hospital admittance rates, and MOI were assessed among the different age groups. All statistical analyses were performed using R Studio Version 4.01 (Boston, MA).

RESULTS

The total number of cases from 2012-2021 in female contact sports was 3,906 (National Estimate [NE] = 87,468) for athletes aged 4-17 years. The mean age was 13.8 ± 2.3 years across all sports with lacrosse having the oldest athletes (14.6±1.8) and gymnastics having the youngest (11.8±2.9). (See Table 1) No trends in the incidence of concussion from 2012 through 2019 were observed, but 2020-2021 showed significant decreases in concussions across all contact sports. ($p<0.001$). (Figure 1)

Among all the contact sports analyzed, soccer made up the greatest number of concussions with a total of 1332 (NE=32,061) ($p<0.001$). The next most common was basketball (NE=16,595), followed by softball (NE=15,360), and cheerleading (NE=10,135). Lacrosse (NE=2,468) and Hockey (NE=1,094) had the fewest number of concussions. (See Table 1 for all sports).

Table 1. Demographic, incidence, and mechanisms of injury stratified by sport for pediatric female concussions in contact sports from 2012-2021.

	Combined	*Basketball*	*Cheerleading*	*Gymnastics*	*Hockey*	*Lacrosse*	*Soccer*	*Softball*	*Volleyball*
Mean Age	13.8 ± 2.3	13.8 ± 2.1	14 ± 2.4	11.8 ± 2.9	13.6 ± 2.6	14.6 ± 1.8	13.8 ± 2.3	14.2 ± 2.1	14.5 ± 1.8
% LOC	5.5%	4.99%	6.5%	4.5%	6.9%	5.5%	5.7%	6.35%	3.24%
% Admitted	2.56%	3.29%	2.18%	4.55%	0.00%	4.48%	2.25%	2.00%	2.06%
National Estimate	87,468	16,595	10,135	3,128	1,094	2,468	32,061	15,360	6,628
Total Injuries	3,906 (100%)	821 (100%)	459 (100%)	198 (100%)	72 (100%)	134 (100%)	1,332 (100%)	551 (100%)	339 (100%)
Mechanisms									
Player-to-player	1,214 (31.1%)	330 (40.2%)	190 (42.4%)	18 (9.1%)	15 (20.8%)	29 (21.6%)	476 (35.7%)	97 (17.6%)	59 (17.4%)
Ball-to-player	1,060 (27.1%)	82 (9.9%)	1 (0.2%)	-	4 (5.6%)	33 (24.6%)	424 (31.8%)	363 (65.9%)	153 (45.1%)
Head-to-ground	1,103 (28.2%)	285 (34.7%)	241 (52.5%)	141 (71.2%)	25 (34.7%)	16 (11.9%)	251 (18.8%)	57 (10.3%)	87 (25.7%)
Head-to-object	144 (3.7%)	22 (9.9%)	8 (1.7%)	22 (11.1%)	13 (18.1%)	24 (17.9%)	30 (2.3%)	15 (2.7%)	10 (2.9%)
Unspecified	385 (9.8%)	102 (12.4%)	19 (4.1%)	17 (8.6%)	15 (20.8%)	32 (23.9%)	151 (11.3%)	19 (3.4%)	30 (8.8%)

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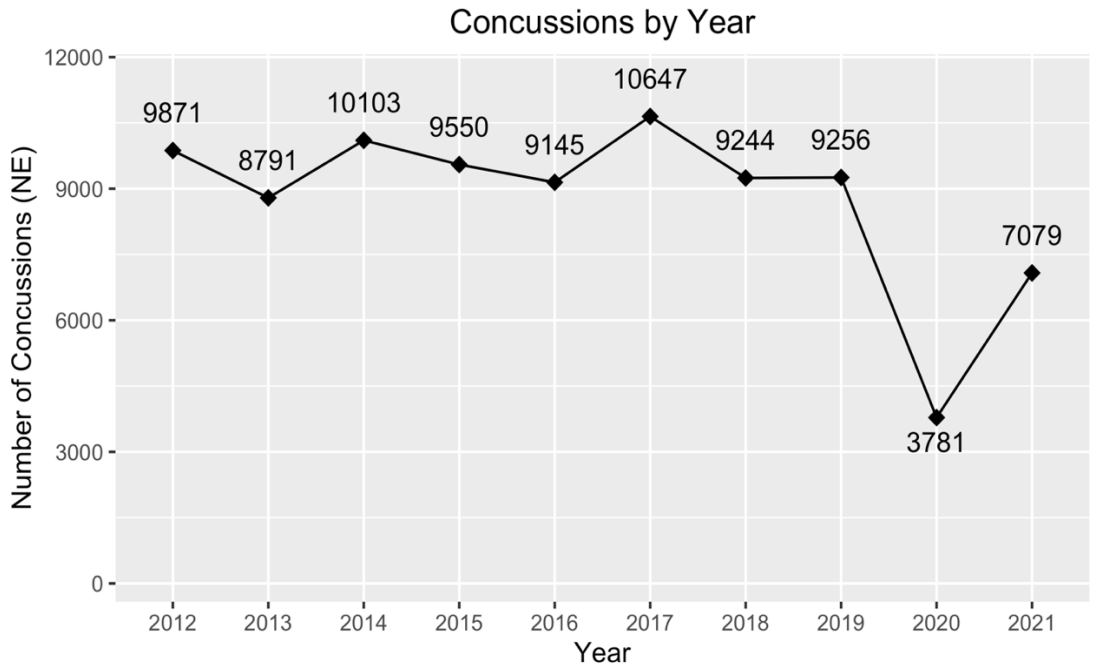

Figure 1. National estimates of female pediatric concussions per year. National estimates are calculated based on NEISS database probability samples.

Mechanism of Injury

Overall, the most common MOI was player-to-player contact with 1,214 (31.01%) cases and head-to-ground with 1103 (28.2%) cases. Player-to-player contact was the most frequent MOI in basketball and soccer. (Figure 2) Head-to-ground was the most common MOI in cheerleading, gymnastics, and hockey. Gymnastics had significantly more head-to-ground injuries than all other MOI with 71.2% ($p<0.001$). The head-to-other object was most common in lacrosse and hockey. (Table 1).

Severity of Injury

Overall, 214 (5.5%) concussions led to LOC. Hockey had the highest rate of LOC at 6.9% while volleyball had the lowest rate of LOC at 3.24%. However, overall soccer had the greatest number of cases with LOC. Outpatient treatment was the most common discharge disposition among the athletes (3,806, 97.4%). Severe injuries defined by admittance to the hospital were rare with only 100 (2.6%) concussions requiring hospital admittance. Despite having the lowest rate of LOC, gymnastics had the highest rate of hospital admittance at 4.55%.

Associated Symptoms

The most common associated symptoms reported in female concussions were headache (237, 41.1%) and dizziness (162, 28.1%). Nausea and contusions/bruising were also common symptoms. (See Table 2) Vomiting, blurred vision, altered mental status, and lethargy were also cited as associated symptoms. No differences were noted among the different sports and presentation of symptoms.

Age Stratification

There were significantly more concussions in the 10-14 (52%), and 15-18 (43%) year-old groups, than in the 4-9 year-old group (5%). There was no difference in the rate of hospital admittance between the three groups, but there was a significantly higher rate of LOC in the 15-18 age group than the youngest age group ($p=0.02$). (See Table 3) Further stratifying by sport showed all concussions that occurred in the 4-9 age group occurred exclusively in gymnastics.

Among the different age groups, there were no significant differences in mechanism of injury in softball, volleyball, hockey, and gymnastics. However, mechanisms of injury for basketball and cheerleading indicate that the youngest age group (4-9) were more likely to be injured to have head-to-

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ground injuries in contrast to the oldest age group (15-18) which were more likely to suffer concussions via player-to-player contact. No differences in symptom presentation were found among the different age groups.

Table 2. Combined totals and national estimates of symptoms and loss of consciousness reported with treatment location of all reported concussions.

	Combined	*% of Total*	*National Estimate*
TOTAL	3,906	100%	87,468
DD: Outpatient treatment	3,806	97.4%	86,124
DD: Admitted	100	2.6%	1,344
Loss of Consciousness	214	5.4%	5,683
Symptoms			
Dizziness	162	28.1%	4,166
Headache	237	41.1%	5,932
Nausea	42	7.3%	854
Vomiting	34	5.9%	356
Blurred Vision	19	3.3%	396
Altered Mental Status	18	3.1%	377
Contusion/Bruising	53	9.2%	1,489
Laceration	8	1.4%	176
Tiredness/Lethargy	3	0.5%	35

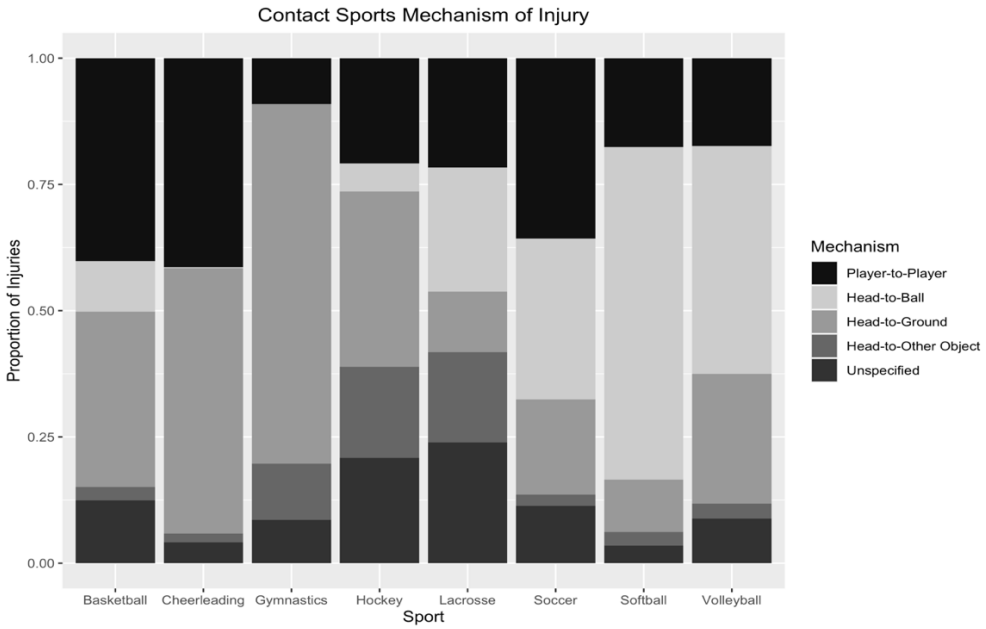

Figure 2. Sport-specific mechanism of injury in female contact sports from 2012-2021

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Table 3. Combined totals and percentage of loss of consciousness and hospital admittance from contact sports concussions stratified by the age groups 4-9, 10-14, and 15-18 years old.

	Age group		
	4-9 years	10-14 years	15-18 years
Total Number (n)	180	2034	1692
National Estimate (n)	3976	43282	40209
Combined Rate LOC	2.78%	6.10%	7.45%
Basketball	-	1.38%	1.36%
Cheerleading	-	0.69%	1.24%
Gymnastics	2.30%	0.25%	0.12%
Hockey	-	0.29%	-
Lacrosse	-	0.25%	0.24%
Soccer	-	2.17%	2.60%
Softball	-	0.74%	1.42%
Volleyball	-	0.34%	0.47%
Combined Rate Admittance	1.67%	2.65%	2.54%
Basketball	-	0.69%	0.77%
Cheerleading	0.56%	0.29%	0.18%
Gymnastics	0.56%	0.34%	0.06%
Hockey	-	-	-
Lacrosse	-	0.20%	0.12%
Soccer	0.56%	0.49%	1.12%
Softball	-	0.39%	0.18%
Volleyball	-	0.25%	0.12%

DISCUSSION

This study analyzes the prevalence, mechanisms, severity, and symptoms of concussion injuries in pediatric female athletes. To our knowledge, there are no studies in the current literature comparing concussion mechanisms and associated characteristics in female youth athletes participating in basketball, cheerleading, gymnastics, hockey, lacrosse, soccer, softball, and volleyball.

We found that soccer, followed by basketball, had the greatest number of concussions. Our findings coincide with other studies which found that soccer and basketball are the most frequent causes of concussions in youth athletes after football.[16-20] The percentage of females participating in sports has continued to rise throughout the years.[21] The increased risk for concussions due to soccer and basketball is likely explained by greater participation in these sports compared to others with potential differences in style of play.[21] Female soccer and basketball have the highest proportion of illegal actions that lead to injury and concussion with a significant portion of these illegal activities being contact with the face and/or head of a player when compared to male sports.[22]

Our results found MOI is sport specific, where softball and volleyball have a higher proportion of

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ball-to-face injuries while gymnastics and cheerleading have a higher proportion of head-to-ground concussions. The current literature highlights player-to-player contact as one of the most common causes of concussions in male and female youth athletes.[20,23,24] Football, dominated by male athletes, is the most common cause of concussion in youth athletes with player-to-player contact being the most common MOI.[25] Our analysis did not include football due to low female participation. An overall similar prevalence of player-to-ground contact (28.2%) and player-to-player contact (31.01%) among all concussions incurred in female athletes. An overall lower prevalence of player-to-player contact in female athletes compared to male athletes may be explained by increased female participation in sports like gymnastics and cheerleading which are dominated by player-to-ground injuries. Stratification of MOI based on age found that younger athletes aged 4-10 were more likely to have head-to-ground injuries in basketball and cheerleading. Older athletes in these sports were more likely to have player-to-player concussions. In developing preventative strategies tailored to female athletes, equal effort should be focused on reducing both player-to-player and player-to-ground contact, especially in younger athletes.

The average age of individuals experiencing concussions in our study was 13.8 years with the majority of concussions occurring in high school aged athletes, consistent with prior research.[26,27] Our results showed that athletes age 10-14 suffered the greatest number of concussions while older athletes aged 15-18 had the highest rates of LOC. Higher rates of LOC in older athletes have been highlighted in previous literature and may be due to increased forces in older athletes and differences in style of play.[17,28,29] Athletes participating in lacrosse were the oldest on average, while gymnasts experiencing concussions were the youngest. All concussions with LOC suffered by athletes aged 4-9 were from gymnastics. Further research is needed to identify risks and safety promotion strategies for younger athletes to prevent concussions.[30]

Throughout the 10-years analyzed in this study, there was an overall decline in the incidence of concussion injuries over time. Yet this difference can be isolated to the years of 2020-2021. During this two-year period, the COVID-19 pandemic occurred, resulting in social restrictions that included limitations in athletic events. As a result, emergency departments saw fewer sports-related injuries and concussions during this period as there were likely fewer opportunities for athletes to participate in high-risk situations that could lead to injury.[31-32] Alternatively, people may have been less likely to present to the emergency department for concussion injuries during the pandemic to avoid contracting the COVID-19 virus. In 2021, the number of concussions rose from the previous year but remained lower than the eight years preceding the pandemic, which could be attributed to efforts focused on reestablishing social and athletic gatherings.[32] Prior to the pandemic, there were no significant differences in the number of concussions sustained across all sports in the population, suggesting that injury rates remained consistent throughout these years.

Symptoms resulting from concussions can vary widely depending on the severity of the injury. The current literature is equivocal regarding sex-related differences in symptom presentation.[15,33,34] The most common symptoms observed in this study were headache (237, 41.1%) and dizziness (162, 28.1%). Studies on concussions in the pediatric population have found headaches to be the most commonly associated symptom, which is consistent with our findings.[35,36] Other symptoms that resulted from concussion injuries were nausea, contusions/bruising, vomiting, blurred vision, altered mental status, and lethargy which is also consistent with the symptoms associated with concussions throughout the literature.[35,37-39] LOC can be used to rate the severity of concussions in sports, with male athletes having higher rates of LOC than female athletes.[15,40,41]We found that hockey had the highest rate of LOC at 6.9% while volleyball had the lowest rate at 3.2%. Among all contact sports analyzed, we found the rate of LOC of 5.5% was consistent with the literature. [15,42]

This study helps to identify the most common concussion mechanisms in female athletes across various sports and highlights the associated symptoms and perceived severity of the injuries. However, there are some notable limitations of the current analysis. The population in this study is limited, as we were only able to assess the concussion injuries experienced by patients who presented to the emergency department. Not all patients seek medical care for a concussion, as some patients may present to a provider outside of the emergency department setting. In addition, this is a retrospective study, meaning our analysis relies on self-reports of the injuries so the patient charts may not be inclusive of all situational information

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surrounding the event. Lastly, emergency department providers are not required to complete patient charts in a standardized manner, meaning that not all patient charts will contain the same data points to be analyzed.

CONCLUSION

Concussions are a common injury among youth female athletes, with soccer, basketball, and softball being the sports with the highest number of concussions. MOI in female concussions are sport-specific with high rates of player-to-player and player-to-ground injuries. Furthermore, mechanisms of action also differ based on age, with increased prevalence of head-to-ground concussions in younger athletes and increased prevalence of player-to-player concussions in older athletes. LOC was significantly higher in older athletes while other symptoms including headache, and dizziness were similar across all age groups. Athletes, coaches, and physicians who are aware of the common symptoms and mechanisms of injury for each sport can better develop preventative strategies and improve patient care for concussions in female contact sports.

Conflict of Interest Statement

The authors report no conflict of interest with the contents of this manuscript.

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