Original Article

Increased Risk of Fracture, Dislocation, and Hospitalization Are Associated With Collision in Contact Sports

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Purpose: To quantitatively determine whether there is an added risk of orthopaedic injury attributable to the collision forces that athletes participating in collision-contact (CC) sports regularly encounter. **Methods:** The National Electronic Injury Surveillance System was used to collect data on patients presenting to an emergency department with a contact sports-related injury between 2014 and 2020. Select contact sports were classified as either belonging to a CC or noncollision-contact (NCC) sports group based on involvement of frequent and intentional player-to-player collisions. **Results:** From 2014 to 2020, 25,784 patients with team-based sports related injuries presented to an emergency department, of whom 7,591 sustained an injury during a CC sport and 18,193 during a NCC sport. The CC group was associated with significantly increased odds of sustaining at least 1 fracture (odds ratio [OR] 1.4, 95% confidence interval [CI] 1.35-1.52) ($P < .001$), dislocation (OR 1.2, 95 % CI 1.06-1.33) ($P < .001$), and being admitted into the hospital (OR 1.6, 95% CI 1.34-1.86) ($P < .001$), compared with the NCC group. **Conclusions:** We found that frequent and intentional high-energy collisions associated with CC sports significantly increase the risk of sustaining fractures and dislocations. Furthermore, we found that that the injuries sustained by players engaging in CC sports required hospitalization at a significantly greater rate than those sustained in contact sports that do not involve frequent and intentional player-to-player collisions. **Level of Evidence:** Level III, prognostic (retrospective cohort study).

The subject of sports injuries is continually growing in scope in the literature, as increasing emphasis is now being placed on making contact sports safer for athletes.[1-6] A foundational epidemiologic understanding of the orthopaedic injuries occurring in contact sports is helpful for clinicians, sideline health care providers, and athletes in mitigating the risks of their occurrence. Currently, a substantial body of epidemiologic literature exists to describe orthopaedic injuries occurring within individual sports[7-9] and across different sports.[10,11] However, there are limited studies that have investigated the effect of collision on the pattern and incidence of orthopaedic injuries occurring in contact sports that routinely involve high-speed, intentional collision between athletes.

The term "contact sport" refers to a sport in which athletes legally come into contact with one another. This term is traditionally used to describe many different sports that exist on a wide spectrum of contact levels, i.e., from limited-contact sports like basketball, to moderate contact sports like soccer, to collision-contact (CC) sports like football, ice hockey, and so forth. Given the substantial differences in the mechanism, frequency, and magnitude of contact among "contact" sports, it is apparent that additional classification is required to sufficiently investigate the effect of intentional player-to-player collision (e.g., tackling, body checking, etc.) on the frequency and patterns of orthopaedic injuries occurring in contact sports.

Herein, the term CC sport is used as a further subclassification of contact sports to describe sports in which high-velocity collision between athletes is both necessary and encouraged during competition

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(e.g., football, ice hockey, rugby). Employing this term allows for the systematic exclusion of limited- and moderate-contact sports from epidemiologic analysis of orthopaedic injuries sustained by athletes while engaged in CC sports.

The isolation of orthopaedic sports injuries from CC sports into one epidemiologic out-grouping allows for the direct comparison of CC sports with other contact sports, referred to here as "noncollision contact" (NCC) sports, which do not routinely involve purposeful and legal player-to-player collisions. Studying CC sports as a separate out-grouping also may elucidate patterns of injury that are associated with CC sports, which could inform future injury prevention strategies and improve clinical preparedness when injury does occur. The purpose of this investigation was to quantitatively determine whether there is an added risk of orthopaedic injury attributable to the collision forces that athletes participating in CC sports regularly encounter. We hypothesized that the increased frequency of player-to-player collisions, and the uniquely high energy forces involved in these collisions, in CC sorts would be associated with and increased frequency of high-energy orthopaedic injuries, as well as an increased risk of severe injury and hospitalization.

Methods

Data Sources

This descriptive epidemiological study used the National Electronic Injury Surveillance System (NEISS), a database maintained by the U.S. Consumer Product Safety Commission. NEISS collects injury data from a cohort of 65 hospital emergency departments (EDs) in the United States. Each participating NEISS ED is weighted to provide an accurate representation of the number of national cases. Although the main purpose of the NEISS database is to track injuries associated with consumer products, 65 of the 100 existing NEISS-associated hospital EDs collect information pertaining to a broader range of injuries, including sports injuries. These hospitals record the date of treatment, age, sex, and race of the patients involved, as well as the activity or consumer product involved in the injury. The location of injury, disposition of the patient, and a brief description of the mechanism of injury are also recorded. This information is then uploaded daily into the database by the U.S. Consumer Product Safety Commission.

Institutional Review Board

Institutional review board approval was not required by our institution for this retrospective study based on publicly available and deidentified NEISS population data.

Data Collection

The study population consisted of all patients presenting to the ED for evaluation and management of a sports-related injury, identified by the code SPORTS and RECREATION EQUIPMENT. From this query of 42 variables, we selected 6 sports: football, ice hockey, rugby, basketball, soccer, and baseball. Football, ice hockey, and rugby were assigned to the CC sport group because in each sport CC (checking, tackling) between athletes is legal, and often encouraged, within the rules of these sports. These were the only CC sports with information available in the database, apart from lacrosse. Lacrosse was excluded due to the dramatic difference in rules between men's and women's lacrosse: CC is prohibited in the latter.

Conversely, the same potential for confounding is minimized in the study of men's and women's ice hockey, as several studies report that collision between players and surfaces still routinely occurs in women's hockey and significantly contributes to player injury.[12-14] This is despite the fact that player collision (i.e., "checking") in women's ice hockey is illegal at all levels of play. Soccer, basketball, and baseball were assigned to the NCC sport group, which served as a control group consisting of sports in which contact occurs, but intentional collisions between athletes is illegal and does not occur routinely. The 3 sports included in the NCC group were chosen with the intention of including contact sports that, on average, range from a low to high degree of contact based on previous studies.[15-19] The inclusion of baseball serves the NCC group as a contact sport with a low degree and frequency of contact[15,19-21]; basketball serves as a contact sport with an intermediate degree of contact[15,19]; soccer serves as a contact sport with a high degree and frequency of contact, but wherein collision between players is prohibited.[16,17] Notably, all the sports included in the sample are team-based sports with a high frequency of injuries due to falls or incidental contact with other players and/or the sporting equipment (balls, pucks, sticks, etc.).[22,23]

Subject Selection

Included in this study were consecutive cases of patients 13 years and older presenting to the ED for injuries associated with the designated sports from the start of 2014 through 2019. Patients younger than 13 years of age or who did not present to the ED with a designated sport-related injury were excluded from the study.

The decision to exclude data pertaining to patients younger than 13 years of age was made for 2 distinct reasons. First, important rule changes occur at this age, as Bantam Hockey begins at age 13 years, where body checking (involving collision) is legal for boys. Second, this was done out of consideration for epidemiologic data that suggest that injuries, especially fracture, become most common in youth contact sports, especially football, around the age of 13 years, and become more likely with increasing age.[24,25] Some parallel data, albeit limited, exists to support a similar conclusion for the analysis of rugby injuries.[26]

Statistical Analysis

Descriptive statistics and statistical analysis were performed using RStudio with the "plyr" and "tidyverse" packages. All participants were initially grouped based on their participation in a CC sport or NCC sport. Median and standard deviation were used to report the descriptive statistics for continuous variables in the study: the age of participants. Because the distribution of age was positively skewed for both the CC and NCC groups, a Mann–Whitney *U* test was used to detect differences in median age between the CC and NCC groups. Outcomes of interest included the diagnosis and location of injury for CC and NCC groups. Differences in the outcome frequency between the CC and NCC of categorical data was analyzed with a χ^2 test. Odds ratios (ORs) were calculated as stated by Tenny and Hoffman.[27] Statistical significance was defined as $P < .05$.

Results

Overall Characteristics

In total, 183,713 patients from the NEISS database were initially assessed for eligibility. Of these patients, 35,932 patients presented with an injury after participation in hockey, football, and rugby (CC sports) or soccer, basketball, and lacrosse (NCC sports). Patients younger than 13 years of age or who did not present to the ED with a designated sport-related injury were excluded from the study, resulting in a study size of 25,784 (Table 1). There were no missing data for the outcomes of interest in the study.

Of these patients, 7,591 patients presented to the ED after injury sustained in a CC sport, compared with 18,193 patients who were injured in a NCC sport. Table 1 reports demographic and injury data for the CC and NCC groups. The CC group was significantly younger than the NCC group, with a median age of 15 years (interquartile range, 14-18) ($P = .001$). Female patients comprised only 6.2% of the CC group, compared with 19.6% in the NCC group ($P = .001$). The ankle (23.5%), finger (10.4%), and knee (10.2%) were the most common sites of injury for the NC group.

Table 1. Demographic, Diagnosis, and Anatomic Injury Location Data for Collision-Contact and Noncollision-Contact Groups

	Collision-Contact 7,591	Noncollision-Contact 18,193	*P* Value
Age, y, median [IQR]	15.00 [14.00, 18.00]	16.00 [14.00, 21.00]	<.001
Hospitalized (%)	242 (3.2)	370 (2.0)	<.001
Female (%)	470 (6.2)	3,558 (19.6)	<.001
Body part (%)			<.001
Shoulder	927 (12.2)	894 (4.9)	
Elbow	161 (2.1)	332 (1.8)	
Lower arm	406 (5.3)	506 (2.8)	
Wrist	434 (5.7)	965 (5.3)	
Knee	627 (8.3)	1,847 (10.2)	
Lower leg	383 (5.0)	1,006 (5.5)	
Ankle	751 (9.9)	4,279 (23.5)	
Head	969 (12.8)	1,557 (8.6)	
Face	315 (4.1)	1,467 (8.1)	
Eyeball	21 (0.3)	173 (1.0)	
Lower trunk	278 (3.7)	612 (3.4)	
Upper arm	76 (1.0)	74 (0.4)	
Upper leg	122 (1.6)	197 (1.1)	
Hand	288 (3.8)	502 (2.8)	
Foot	180 (2.4)	705 (3.9)	
Neck	132 (1.7)	110 (0.6)	
Finger	1,075 (14.2)	1,899 (10.4)	
Toe	79 (1.0)	273 (1.5)	
Diagnosis (%)			<.001
Concussion	760 (10.0)	1,018 (5.6)	
Contusions/abrasions	997 (13.1)	2,217 (12.2)	
Dislocation	470 (6.2)	953 (5.2)	
Fracture	2,328 (30.7)	4,282 (23.5)	
Hematoma	47 (0.6)	105 (0.6)	
Laceration	393 (5.2)	1,412 (7.8)	
Strain/sprain	2,358 (31.1)	7,682 (42.2)	

IQR, interquartile range.

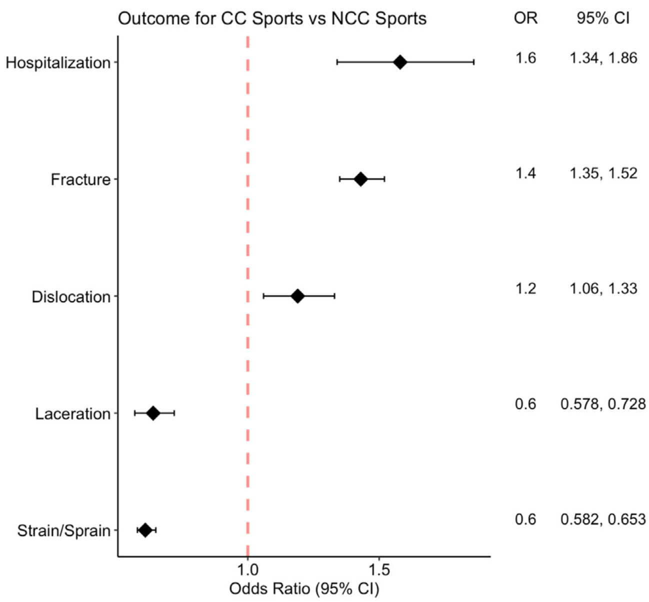

Fig 1. Injury outcomes for collision-contact (CC) sports versus noncollision-contact (NCC) sports. CC sports injuries were associated with a significantly increased risk of hospitalization, fracture, and dislocation compared with NCC sports injuries. (95% CI, 95% confidence interval; OR, odds ratio.)

In the CC group, the finger (14.2%), head (12.8%), and shoulder (12.2%) were the most common sites of injury.

Injury Risk and Severity for CC and NCC Sports

The odds of sustaining a fracture were significantly greater for CC sports than for NCC (OR 1.4, confidence interval [CI] 1.35-1.52) ($P < .001$) sports (Fig 1). There were also significantly increased odds of dislocation for CC sports compared with NCC sports (OR 1.2, CI 1.06-1.33) ($P < .001$). CC sports were notably associated with significantly lower odds of laceration (OR 0.6, CI 0.578-0.728) ($P < .001$) and strain/sprains (OR 0.6, CI 0.582-0.653) ($P < .001$) compared with NCC sports.

Injury Severity

Compared with 370 (2.0%) patients in the NCC sports group, 242 (3.2%) patients in the CC sports group were admitted to the hospital ($P = .005$). The odds of being admitted into the hospital for a sports-related injury was 60% greater in the CC sports group versus the NCC sports group (OR 1.6, CI 1.34-1.86) ($P < .001$).

Injury Location for CC Sports Versus NCC Sports

Using data aggregated from the database, differences in injury location between CC and NCC sports for an aggregate of injuries (concussion, contusion, dislocation, fracture, laceration, strain/sprain, and avulsion) were assessed (Fig 2). The odds of sustaining a shoulder injury (OR 2.7, C 2.44-2.96) ($P < .001$) and lower-arm injury (OR 2.0, CI 1.72-2.25) ($P < .001$) were significantly increased for CC sports compared with NCC sports. Furthermore, CC sports were associated with increased odds of injury to the head (OR 1.6, CI 1.43-1.70) ($P < .001$) and neck (OR 2.9, CI 2.25-3.75) ($P < .001$). The odds of sustaining an injury to the knee (OR 0.8, CI 0.724-0.875) ($P < .001$) and ankle (OR 0.4, CI 0.328-0.387) ($P < .001$) were significantly lower in CC sports compared with NCC sports.

Discussion

The most important finding in this study was 2-fold: (1) participation in a CC sport was associated with an increased risk fracture and dislocation; (2) the injuries sustained by athletes in CC sports were significantly more likely to require hospitalization. We validated our hypothesis in that CC sports were associated with an increased injury severity and a greater incidence of high-energy injuries such as dislocation and fracture. We also observed a unique anatomic profile for injuries sustained in CC versus NCC sports and found that injuries of the shoulder, lower arm, head, neck, and hand were at significantly more likely to occur in CC sports compared with NCC sports.

Previous literature has reported an increased risk of fracture associated with high-energy CC sports (football, ice hockey, and rugby).[6,10,11,28,29] Furthermore, studies have also reported a specific association between tackling and an increased risk of shoulder and elbow dislocations due to the kinematics of the commonly used "shoulder tackle," wherein players lead with their shoulder and upper extremity to initiate the collision.[30,31] The intentionality and increased frequency of player-to-player collisions in CC sports may be largely responsible for this observed increased risk of sustaining a fracture or dislocation. It should be noted that a substantial proportion of knee dislocations occur due to a non-contact, rotatory mechanism while stepping or pivoting around a planted foot.[32-34] Overall, we believe that collisions likely represent the chief contributor to the observed risk of fracture and dislocation in CC sports.

Importantly, we found that patients evaluated for injuries sustained in CC sports were significantly more likely to be hospitalized compared with those who sustained injuries in NCC sports. This finding demonstrates the increased average severity of injuries sustained by athletes participating in CC sports and underscores the need for physicians to take great care when evaluating patients who present with injuries sustained while engaged in CC sports.

The anatomical locations at increased risk of injury for players competing in CC sports were also outlined in this study. In general agreement with previous studies,[10,17,18] the present study observed that injury to the shoulder (OR 2.7, CI 2.44-2.96) and lower arm

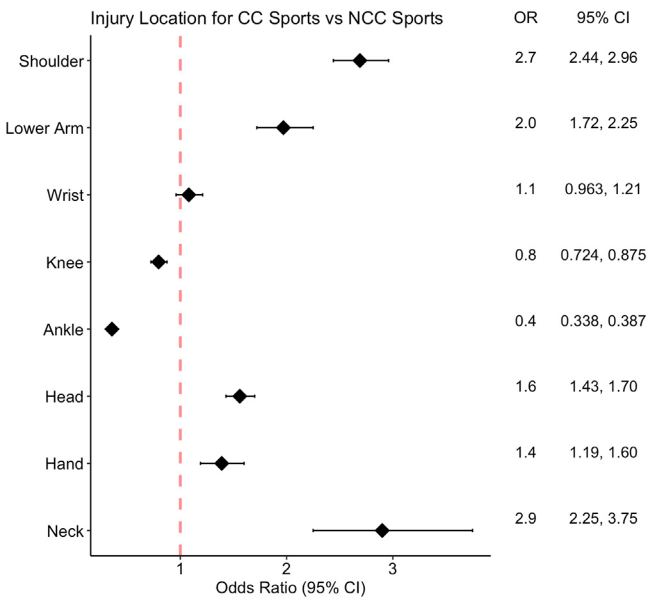

Fig 2. Anatomical location of all recorded injuries (concussion, contusion, dislocation, fracture, laceration, strain/sprain, and avulsion) for collision-contact (CC) sports compared with noncollision-contact (NCC) sports. (95% CI, 95% confidence interval; OR, odds ratio.)

(OR 2.0, CI 1.72-2.25) occurred with significantly increased frequency in CC sports compared to NCC sports. We theorize that the mechanism of tackling or checking in CC sports may account for this increased risk of shoulder injury. Athletes in CC sports are commonly taught to adduct the arm and expose the front side shoulder as a primary point of collision with other players.[9] Notably, the odds of sustaining an injury to the knee (OR 0.8, CI 0.724-0.875) and ankle (OR 0.4, CI 0.328-0.387) were observed to be significantly lower for athletes participating in CC sports compared to those participating in NCC sports. Patellofemoral dislocations, which represent the most common type of knee dislocation, are known to be more common in low-energy, sports-related injuries than tibiofemoral knee dislocations.[22,33] CC sports were also associated with increased risk of injury to the head (OR 1.6, CI 1.43-1.70) and neck (OR 2.9, CI 2.25-3.75). Based on these findings and previous literature, we believe that CC is the primary contributor to the observed increased risk of head and neck injuries in CC sports.[35,36]

We found that frequent, purposeful collisions between players increase the risk of severe orthopaedic injury in contact sports, including hospitalizations, fractures, dislocations and injuries to the head. These results underscore the necessity for focused, evidence-based injury prevention strategies that both aim to reduce the frequency and speed of collisions, while also educating players on proper technique and playing within the rules of the game. Additional strategies for injury reduction may include stricter penalization for illegal plays in CC sports, which represent a preventable cause of serious orthopaedic injury[28,37] and the increased use of properly-fit protective equipment that has been shown to be essential to reducing the risk of severe injury.[38]

Limitations

This study was subject to some limitations. The primary limitation of this study was that the analysis was limited to ED presentations. This patient population represents a limited subset of the overall patient population who sustain sports-related injuries, as many patients may present in other settings such as clinics or an urgent care. Therefore, it is possible that this population self-selects for more severe sports injuries, which limits the generalizability of these findings. Another limitation of this study was that the analysis did not lend itself to stratifying the data based on level of play. Multiple previous single-sport studies have analyzed individual sports at a specific level of play, which allows for more precise analysis based on the style of play, level of physicality and the rules associated with the sport at that age group.

In addition, there exist inherent limitations of large databases. The specific database design and coding of the NEISS database may lead to significant differences in outcomes compared to other national databases, as reported by Salzler et al.[39] Furthermore, data collected by NEISS coders is subject to interpretation by the coders. In the event of a patient who presents to the ED with 2 or more severe injuries, the patient is recorded as having the injury that was determined by the coder to be the most severe. With this being said, NEISS data collection protocols are reported to have an 89% to 98% accuracy, indicating that while the primary diagnosis may not be the only diagnosis, the patients are accurately assigned a primary diagnosis nonetheless.[40]

A final limitation of this paper is that the NEISS database does not record outcomes data for these injuries. Future studies would be needed to group epidemiologic data from CC and NCC sports by level of play for a similar analysis comparing CC and NCC sports at various levels of play to be possible, and also to evaluate outcomes following CC and NCC injuries. In doing so, such studies could identify specific patterns of orthopaedic injury for different levels of play.

Conclusions

We found that frequent and intentional high-energy collisions associated with CC sports significantly increase the risk of sustaining fractures and dislocations. Furthermore, we found that the injuries sustained by players engaging in CC sports required hospitalization at a significantly greater rate than those sustained in contact sports that do not involve frequent and intentional player-to-player collisions.

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