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RESEARCH ARTICLE

Comparison of Head Impact Magnitudes and Frequencies Between Intercollegiate Male and Female Lacrosse Players

Elizabeth Daidone Yates, MS, ATC[1], Katelyn Nelson, ATC[1], Debbie A. Bradney, DPE, ATC[1], Katherine M. Breedlove, PhD, ATC[2,3] and Thomas G. Bowman, PhD, ATC[1]*

[1]*Department of Athletic Training, University of Lynchburg, Lynchburg, VA, USA*

[2]*Center for Clinical Spectroscopy, Brigham and Women's Hospital, Boston, MA, USA*

[3]*Department of Radiology, Harvard Medical School, Boston, MA, USA*

***Corresponding author:** *Thomas G. Bowman, Department of Athletic Training, University of Lynchburg, 1501 Lakeside Drive, Lynchburg, VA 24501, USA, Tel: (434) 544-8869*

Abstract

Context: Research studies have examined effects of player position and type of play on head impacts in intercollegiate football players, but there is little available information on head impacts in lacrosse players.

Objective: Compare magnitude and frequency of head impacts between lacrosse players based on player position and type of play.

Design: Descriptive epidemiology study.

Setting: Lacrosse fields.

Participants: Thirty one National Collegiate Athletic Association (NCAA) Division III lacrosse players, 15 women (19.93 ± 1.03 years old, 65.13 ± 2.06 cm, 64.07 ± 16.74 kg) and 16 men (20.81 ± 1.10 years old, 70.75 ± 2.29 cm, 80.71 ± 13.95 kg).

Interventions: Participants wore xPatch sensors (X2 Biosystems, Seattle, WA) for every game and practice. Sex, player position, and type of play (offense, defense, transition, man-up, man-down) were the independent variables.

Main Outcome Measures: The frequencies and magnitudes (linear and rotational accelerations) of head impacts were measured.

Results: We found sex, position, and type of play altered the combined dependent variables ($F_{8,1776}$ = 2.171, P = 0.027, η^2 = 0.019). In women, defensive plays had the highest number of impacts (IR = 142.20, CI=106.44-162.67) while in men, offensive plays had the highest number of impacts (IR = 236.79, CI = 207.50-266.09; IRR = 1.66, CI = 1.31-2.11). Based on player position, women's lacrosse defenders were most likely to sustain a head impact (IR = 174.31, CI = 142.31-206.31) and in men, midfielders were most likely to endure head impacts (IR = 382.08, CI = 344.86-419.29; IRR = 2.19, CI = 1.78-2.69).

Conclusion: Identifying player positions and activities during sports that are prone to high frequency of head impacts may allow more effective implementation of strategies to reduce head impacts and improve player safety.

Keywords

Head impact biomechanics, Incident rates, xPatch

Introduction

An estimation of between 1.6 and 3.8 million concussions happen every year in the United States during sports or recreational activities [1]. A concussion is a mild traumatic brain injury that is thought to result from neuronal shearing, which then creates a metabolic cascade [2] and changes in ionic balance and metabolism [3]. Concussions can have cognitive and emotional effects as well as physical signs and symptoms such as confusion, vomiting, headaches, and depression [1]. Concussions are becoming a popular topic in sports, but the biomechanics of sub concussive impacts remain not fully understood.

A concussion is caused by an acceleration to the head after a direct or indirect impact [4]. There are two types of accelerations to the head, linear and rotational.

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Linear acceleration summarizes the movement of the head that is occurring in a linear plane while rotational or angular acceleration occurs when the head rotates around the axis of the neck [5]. The impacts that occur in sports result in both linear and rotational accelerations, but rotational accelerations are thought to be more damaging due to the shearing effect caused by the rotation of the head [6]. Therefore, while looking at concussive head impacts is useful, it is also important to examine the daily sub concussive head impacts since each impact has the ability to cause potentially damaging shearing and potential decline in cognitive functions later in life [7]. Previous studies [1,8-12] have looked at impacts during football participation due to its popularity, but research on head impacts in collegiate lacrosse players is limited [13-15]. It is important to look at lacrosse players because lacrosse is one of the fastest-growing sports in North America [16], and viable information on head impacts for this sport could give insight for the future.

Factors important to consider when studying head impacts include player position and type of play. In a study completed by Mihalik, et al. [11] on positional and event type differences in Division I football players, they determined that positional variations did make a significant difference on the magnitude of head impacts. Wilcox [4] discovered that head impact exposure was different based on sex, but was not different based on player position in men's and women's ice hockey. Player position is also important to examine because in lacrosse, midfielders may play offense and defense, whereas in a sport like football, players are typically either playing defense or offense, not both. It is important to note that both men and women are required to wear a full protective helmet during ice hockey participation; whereas in lacrosse, only men wear full protective helmets. In women's lacrosse, direct checking is prohibited, partly because the players are only required to wear protective goggles. Therefore, the purpose of our study was to compare the magnitude and frequency of head impacts between men and women intercollegiate lacrosse players based on player position and type of play (offensive, transition, defensive, man-up, or man-down).

Methods

Participants

Thirty one National Collegiate Athletic Association (NCAA) Division III lacrosse players, 15 women (age = 19.93 ± 1.03 years, height = 65.13 ± 2.06 cm, mass = 64.07 ± 16.74 kg) and 16 men (age = 20.81 ± 1.10 years old, height = 70.75 ± 2.29 cm, mass = 80.71 ± 13.95 kg), volunteered to participate in our study after informed consent was obtained. For males, there were 3 attackers, 7 midfielders, and 6 defenders. For females, there were 2 attackers, 6 midfielders, and 8 defenders. We collapsed all short stick midfielders into one category called midfielders and all long stick midfielders and goalies into the defense group.

Instruments

We used xPatch sensors (X2 Biosystems, Seattle, WA) to collect our data.The sensors continually measured full 6 degrees of freedom for linear (*g*) and rotational (deg/s^2) impacts. We set the threshold for impacts at 10 *g*; impacts below 10 *g* did not register as an impact. We set this threshold because head accelerations for activities of daily living, like walking, running, or similar activities, are normally under 10 *g* [17]. Although the sensors have been shown to be appropriate when making comparisons between two groups who are both wearing the xPatch, it has also been shown that the linear and rotational acceleration measurements are inflated [18,19]. Each practice was filmed with a Canon Vixia HF R600 (Canon, Melville, NY) video camera by a research team member. After every event, the impacts on the sensors were uploaded to a computer using the X2 Impact Monitoring System (X2 Biosystems) software and then recharged overnight.

Procedures

The study was approved by the Institutional Review Board at the host institution before recruitment began. We recruited participants via emails to the active rosters of each team. Players opted in by responding to the email and providing informed consent. Before every practice and game, participants had the xPatch applied over their right mastoid process by a research team member. The application area was first sprayed with Cavilon (3M, St. Paul, MN) to help reduce skin irritation due to the adhesive. The sensors were then attached to an adhesive patch (provided from X2 Biosystems), and then applied to their skin directly over the right mastoid process. We kept an athlete-exposure sheet where we documented who wore the sensors each day and what time the event started. At the end of the season, date and time stamped video of each session (practice or game) was reviewed by the research team and the impacts were verified by a coding structure [20] for player position and type of play. For this study, a verified impact consisted of an impact that was visible and could correctly be identified by type of play (Table 1).

Statistical analysis

We used a MANOVA to examine the effects of sex, player position, and type of play across the combined dependent variables using the Statistical Package for the Social Sciences (Version 26, IBM, Arnonk, NY). We calculated Incidence Rates (IR) per 1000 exposures and Incident Rate Ratios (IRR) with corresponding 95% Confidence Intervals (CI) to examine the frequency of head impacts with Microsoft Excel (Microsoft Corporation, Redmond, WA) [21]. We set our alpha level *a priori* to .05.

Results

We found that sex, player position, and type of play altered the combined dependent variables ($F_{8,1776}$ = 2.171, P = 0.027, η^2 = 0.019). We also found significant two-way interactions between type of play and player position ($F_{16,1776}$ = 1.790, P = 0.027, η^2 = 0.031) and player position and sex ($F_{4,1776}$ = 2.381, P = 0.050, η^2 = 0.011). We also had a main effect for type of play ($F_{12, 1776}$ = 6.939, P < 0.01, η = 0.088). No other main effects or two-way interactions were significant (P > 0.05). When we explored significances with ANOVA, we only found type of play affected linear acceleration ($F_{6, 889}$ = 7.343 P < 0.001, ω^2 = 0.041). We found no pairwise differences among the linear accelerations for type of play levels. All other ANOVA results were non-significant (P > 0.05). Men's and women's linear and rotational accelerations and standard deviations can be seen in Figure 1 and Figure 2.

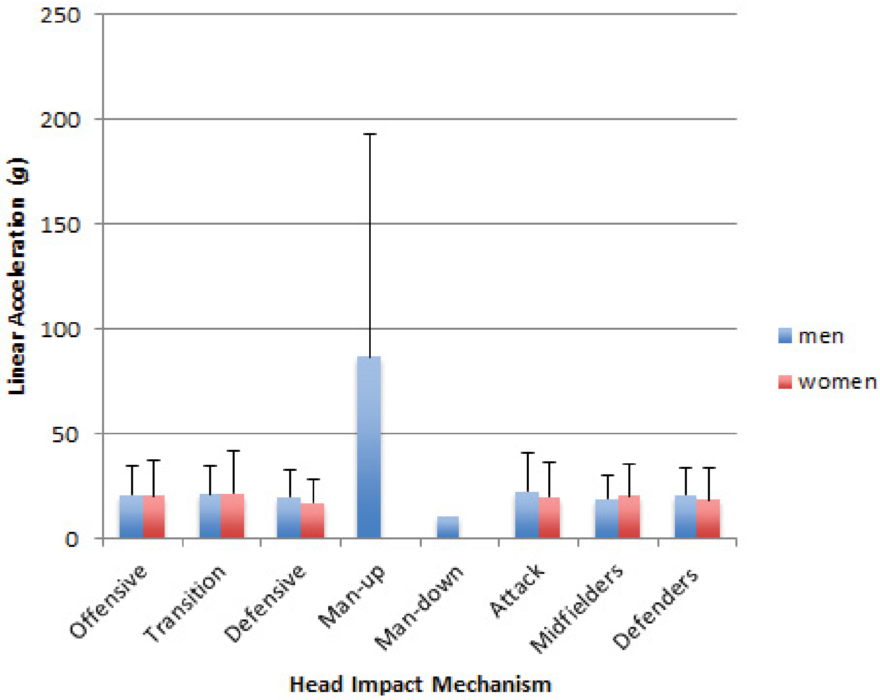

Figure 1: Linear accelerations and standard deviations for head impacts.

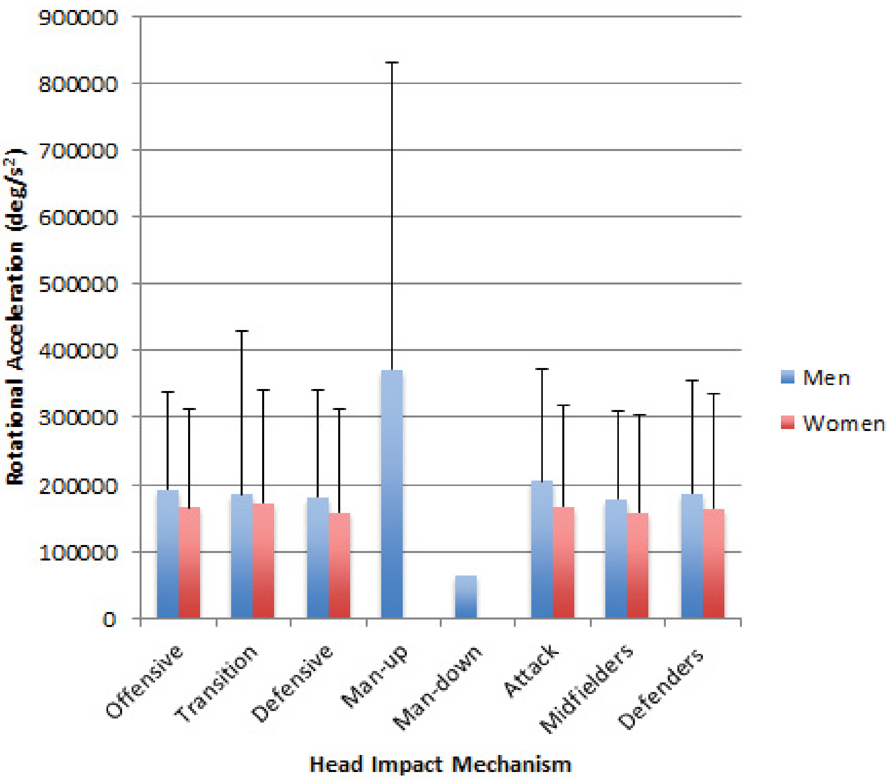

Figure 2: Rotational accelerations and standard deviations of head impacts.

Male lacrosse players (IR = 633.02, 95% CI = 585.12-680.92) were two times more likely to get hit in the head than women (IR = 311.93, 95% CI = 269.12-354.73) when looking at overall impacts (IRR = 2.03, 95% CI = 1.74-2.37). Across the types of play, we found that in women, defensive plays had the highest number of impacts (IR = 142.20, CI = 106.44-162.67) contrary to men, where offensive plays had the highest number of impacts (IR = 236.79, CI = 207.50-266.09; IRR = 1.66, CI = 1.31-2.11). Based on player position, we found that in women's lacrosse, defenders were more likely to sustain a head impact (IR = 174.31, CI = 142.31-206.31) and in men, midfielders were most likely to endure head impacts (IR = 382.08, CI = 344.86-419.29; IRR = 2.19, CI = 1.78-2.69). Results for women's and men's frequencies based on player position and type of play can be seen in Figures 3 through 6.

Table 1: Type of Play.

Code	Description
1	Offense
2	Defense
3	Transition
4	Man Up
5	Man Down
6	Face-off

Discussion

We suspect that the significance in the three-way interaction between sex, player position, and type of play on impact magnitude may be due to rule differences between men's and women's lacrosse. In men's lacrosse, body checking in the front or the side above the waist and below the neck is legal if the opponent has possession of the ball or if they are within 5 yards of

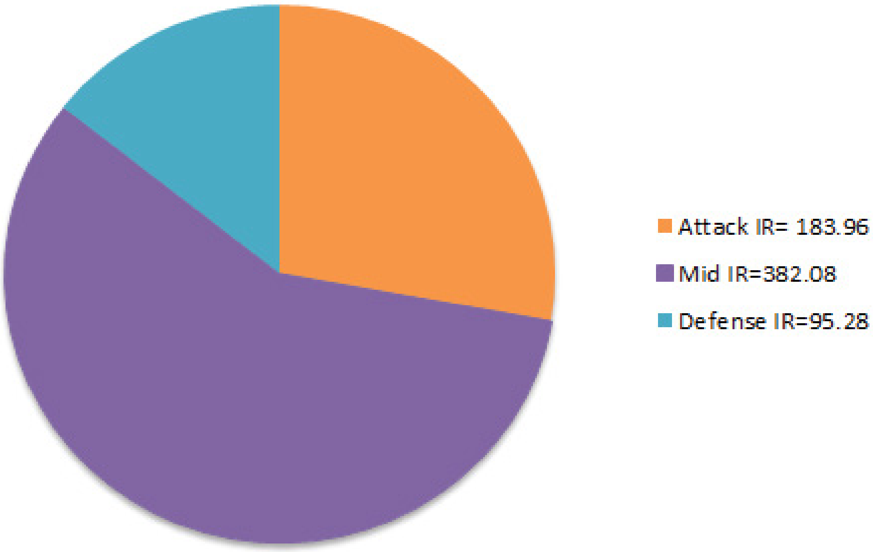

Figure 3: Men's player position frequencies.

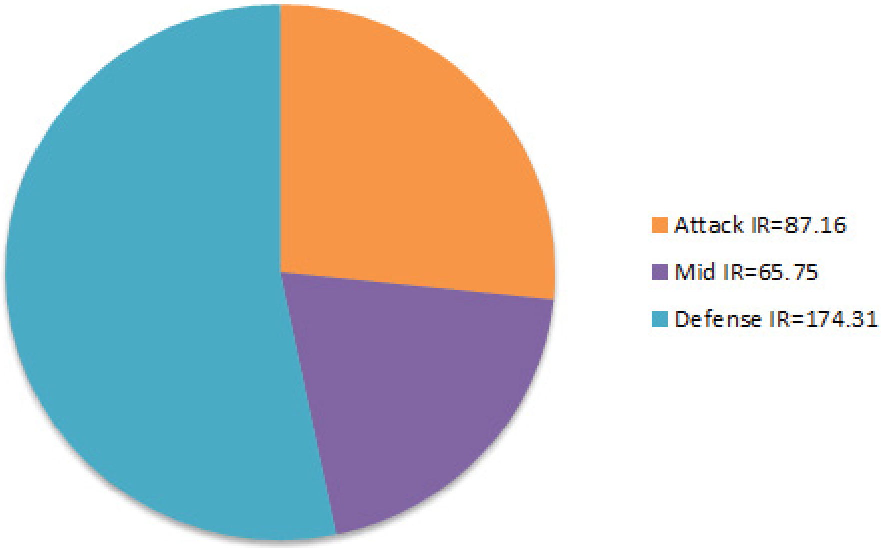

Figure 4: Women's player position frequencies.

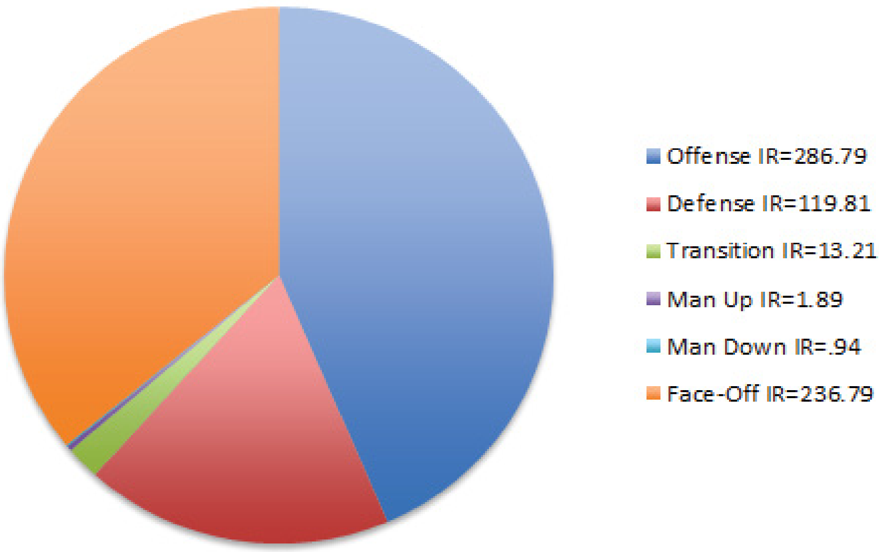

Figure 5: Men's type of play frequencies.

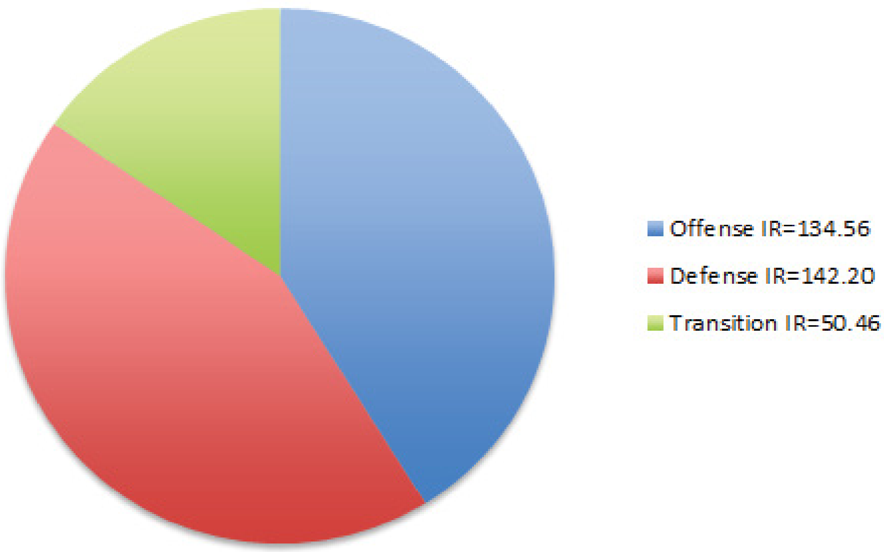

Figure 6: Women's type of play frequencies.

a loose ball [22]. Incidental contact with the head is still common when stick checking or body checking due to the aggressive nature of the game [13,15]. In women's lacrosse, which contains markedly less physical contact, any form of body checking is illegal. Use of the stick to hit, push, or displace the opponent is a foul [23]. The stark contrast in rules is the likely cause for the disparity in head contacts between the sexes.

In addition to checking, other differences in gameplay and rules between the sexes exist. For example, the way the game is started is very different with men's lacrosse starting gameplay with a face-off that requires one player from each team to be down on the ground competing to gain possession of the ball contrasted to the women's game where one player from each team stands and attempts to project the ball into the air to gain possession. When looking at the different starts to the game, it is plausible that men would receive higher magnitude impacts than women. Preliminary evidence has found that face-off players in men's lacrosse receive more frequent impacts but are at a lower magnitude than other positions [24]. This may be because in other positions, the athletes are normally running when an impact occurs, possibly making the magnitudes higher because of the momentum of the body. Similarly, when comparing female attackers to male attackers in offensive plays, it is reasonable that male attacks would have a higher magnitude of impacts based on the fact that they are allowed to hit each other with their sticks in an attempt to gain possession of the ball, although impacts to the head are not legal. The difference in mass and height between men and women may also have an effect on the magnitude of head impacts. Based on the average demographics of our participants, the men had a higher mass and were taller than the women. Therefore, it is possible that the men may check or hit other players with more force than women do, but further research is needed to confirm our hypothesis.

We did not find differences between sexes alone in regards to magnitude, which is different compared to other studies. Le [15] found sex differences in lacrosse players across impact mechanisms. In a study done by Tierney, et al. [25] on head accelerations in female and male soccer players, women had significantly greater head accelerations than men. However, men had significantly higher linear and rotational accelerations than women in ice hockey [4]. Based on these findings from various sports, the effect of sex on head impact biomechanics appears to be sport specific and not fully understood and should be an area of continued investigation.

We found that player position had an effect on head impact magnitude only when sex and type of play were included in the model. Our results related to player position varied from results found in American football; however, our results compared to male and female ice hockey were similar. Mihalik, et al. [11] found that in football, player position did make a difference in the magnitude of head impacts. This is most likely due to the fact that offensive lineman explode straight into an opponent to block on most plays, whereas wide receivers generally sustain contact less often but at higher magnitude due to higher speeds. In lacrosse, this is not the case. Similar to Wilcox [4], we did not find any significant differences in player position alone for impact magnitude. This was most likely because in men's lacrosse, body checking happens on almost every play. Checking is how one player gets the opponent to lose possession of the ball. Therefore, regardless of the position, checking happens often although contact with the head is illegal. In women's lacrosse, body checking is completely prohibited and rarely happens regardless of the position.

Our results in regards to frequency were similar to the results of Le [15] in lacrosse athletes and Wilcox [4] and Brainard [26] in ice hockey athletes, which showed that men had a higher frequency of head impacts than women. This is most likely because the rules in ice hockey and lacrosse are similar across sexes. In men's ice hockey, body checking is legal below the neck if the opponent has possession of the puck, as long as it is not a cross-check [26]. In women's ice hockey, similar to women's lacrosse, body checking is illegal in all parts of the ice. Body checking is when a player tries to gain possession of the puck by separating the player from the puck with a definite impact [27].

There was a main effect for type of play in our study. In men's lacrosse, defenders are more likely to check the offensive players since that is how to get the ball out of the opponent's stick to prevent scoring. Thus, offensive plays cause the most amount of impacts in men's lacrosse because the defenders are checking to gain possession of the ball. In women's lacrosse, we were surprised to find most head impacts occurred in defenders. During defensive plays, there may be more head impacts because of the way the attackers or midfielders are following through their shots with their sticks. It may also be due to the way the opponents are trying to maneuver around the defenders to score. More research is needed to determine the exact reasons for the differences we found between the sexes.

It is important to look at overall head impacts for many different reasons. Breedlove, et al. [28] used fMRIs to show that changes in neurophysiology can be attributed to repetitive head impacts in asymptomatic high school football players. In the study by Baugh, et al. [1] on the effects of frequency of head impacts on Division I football players, they determined that football players who had more frequent hits at a lower intensity were more likely to have concussion symptoms, but less diagnosed concussions. Determining the positions and types of play that have the most head impacts allows for coaches and players to recognize it, and find better ways to adjust behavior to minimize the risk of head impacts.

Limitations and Future Directions

There are several limitations in this study that are important to disclose. This study was completed at one institution, and only the men's and women's lacrosse teams from that institution volunteered to participate. Since only one team of each sex was studied, the playing techniques and individual playing styles may have altered the data. We caution against generalizing to a broader population. Another limitation of this study was the disproportionate number of exposures between men and women (1060 to 654, respectively). The men's team went deeper into the playoffs, where the intensity and aggressiveness of plays may have increased. Although we used IRs to normalize the exposures, our results should be interpreted carefully.

Future research should investigate the effects of sex, player position, and type of play on the magnitude and frequency of different levels of play. Our data could be compared to Division I or II lacrosse data or scholastic data. It may also be interesting to compare multiple teams of each sex to determine if playing style or team technique has any effect on head impact biomechanics. Mechanisms of the impacts would also be interesting to determine if certain mechanisms cause a higher magnitude of impacts than others.

Conclusion

Sex, player position, and type of play significantly altered the magnitude of head impacts in lacrosse athletes. Men have a higher likelihood of getting hit in the head than women, especially midfielders while they were involved in offensive types of play. In the women's game, defenders were most likely to get hit in the head while involved in defensive plays. The difference in head impacts between the different sports can likely be attributed to the amount of contact permissible within the rules of each sport and the position specific roles across sports. Identifying player positions and activities during sports that are prone to high frequency and magnitudes of head impacts may allow more effective implementation of strategies to reduce head impacts and improve safety.

Authorship

All authors were fully involved in the study and preparation of the manuscript. All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted. The manuscript, including related data, figures and tables has not been previously published and the manuscript is not under consideration elsewhere.

Conflict of Interest

No authors have any conflicts of interest to disclose.

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