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Do Youth American Football Players Intentionally Use Their Heads For High-Magnitude Impacts?

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Abstract

Background—Concern for head injuries is wide spread and has been reported by the media to be the number one cause of decreased participation in the youth American football population. Identifying player mechanisms associated with intentional, or purposeful, head impacts should provide critical data for rule modifications, educational programs, and equipment design.

Purpose—To investigate the frequency of intentional and non-intentional head impacts and to examine the player mechanisms associated with intentional high-magnitude head impacts by comparing the impact mechanism distributions among session type, player position, and ball possession.

Study Design—Cross-sectional research study.

Methods—Head impact sensors and video footage of 68 players were used to analyze and classify 1,319 high-magnitude impacts recorded over one season of youth football.

Results—80 % of the high magnitude head impacts were classified as being caused by the intentional use of the head. Head-to-Head impact was the primary impact mechanism (n = 868, 82.7 %) within the 1,050 intentional high-magnitude impacts, with classifiable mechanisms,

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Conflict of Interest: Jonathan G. Beckwith, Richard M. Greenwald, and Joseph J. Crisco have a financial interest in the instruments (HIT System, Sideline Response System, Riddell, Inc.) that were used to collect the biomechanical data reported in this study.

Study Sites
Brown University and Virginia Tech

Teaser
In a study of four youth American football teams we found that the vast majority of high magnitude head impacts were caused by the intentional use of the helmet. This finding suggests that there is a large potential for intervention by rule changes and training to drastically reduce head impact exposures in youth football.

followed by Head-to-Body (n = 139, 13.2 %), Head-to-Ground (n = 34, 3.2 %), and Head-to-Equipment (n = 9, 0.9 %). Head-to-Head impacts also accounted for a greater proportion of impacts during practices (n = 625, 88.9 %) than games, for linemen (n = 585, 90.3 %) than perimeters and backs, and for ball carriers (n = 72, 81.8 %) than tacklers.

Conclusion—Overall, the majority of high-magnitude head impacts were intentional and resulted from Head-to-Head contact. The proportion of Head-to-Head contact was significantly higher for practices than games, linemen than backs and perimeter players, and ball carriers than tacklers.

Clinical Relevance—These findings suggest that rule changes and educational approaches designed to reduce the intentional use of the head for contact would substantially decrease the number of high magnitude head impact exposures for players and, accordingly, the injury risks associated with head impacts.

Keywords

Head; impact; mechanism; intentional; football; youth players

Introduction

A growing body of research associating repetitive head trauma to neurocognitive deficits has elicited concern for sports-related brain injury in athletes.[3,31,49] American football is at the forefront of this widespread public health concern because the sport accounts for the highest incidence of concussion.[17,20,22,45] While researchers have primarily quantified head impact exposure in professional, collegiate, and high school football, the investigation of the youth population under the age of 14, who account for more than 70 % of the 5 million American football participants, has only recently garnered more traction among researchers.[8–11,18,48]

At every level of play, there are efforts to reduce head impact exposures and the risk of brain injury. The approaches to these efforts have focused mainly on education, rule changes and improvement in performance of helmets. In standardize laboratory impact testing, it has been reported that a specific helmet model significantly reduced peak accelerations when compared to another model by the same manufacturer.[39,46] Importantly, in subsequent field studies of collegiate and high school football players, this same specific helmet model was reported to reduce the risk of concussion by 31 %,[12] 54 %,[42] and 85 %,[40] demonstrating that the mechanical performance of a helmet, as measured by standardized lab tests, can play a role in reducing the relative rates concussions. These studies examined players up until the 2011 season. However, concussion rates have continued to rise,[21] suggesting that improved helmet performance alone may not substantially reduce the risk of concussion in helmeted sports such as football. Thus, we have previously proposed that decreasing head impact exposure by implementing rule changes and educational programs is the best approach to reducing head injuries and promoting players safety.[14]

Heads Up Football, developed by USA Football, is one of numerous educational programs dedicated to making player safety a priority within the youth and high school football population. Initiatives within this program range from concussion recognition to proper equipment fitting. A major initiative is teaching a shoulder-tackling technique, in which players are instructed to track the opponent's hip and maintain leverage with their shoulder while keeping their heads up and removed from the impact.[26] In addition, the Pop Warner youth football programs have restricted the amount of contact time in practice and banned certain drills. For example, linemen are prohibited from lining up farther than 3 yards apart and players are not allowed to run straight at each other at full-speed. While there have been studies describing specific practice drills, a player's role within the impact, and the positions on the field prone to increased head impact exposure, there is limited information on the mechanisms associated with head impacts in youth football.[8,9,25] Kontos et al.[29] analyzed the mechanism of 20 concussions that occurred during play over a 2011 youth football season and determined that Head-to-Head contact was the leading cause of concussions. While these findings are important, this research is biased towards a small subset of concussion-causing impacts. It is important to evaluate a larger scope of impacts because neurocognitive changes occur even in the absence of a diagnosed concussion.[3,19,44] Other researchers have quantified the magnitude and frequency of head impact mechanisms in a Pop Warner youth football team.[48] Wong et al. found a significant difference in hits per player during games versus practices but did not find any statistical evidence within their subgroup analysis of player position, type of hit, and presence of Head-to-Head contact. However, the sample size was small, including only 22 youth players, and the data was collected over only eleven play sessions.

Implicit in these rule changes and education is that players' intentional behavior can be restricted or modified, but such interventions are likely to be effective only if they address the issue from a systems approach.[30] What is currently lacking is an understanding of the role of intentional behavior in head impact mechanisms. Several sports including rugby, hockey, and soccer have characterized head impact mechanisms through video review.[2,16,28,47] However, to our knowledge, no study to date has examined the role of intention in head impacts, especially in the youth football population. The specific aims of this study were to first determine whether high-magnitude head impacts were non-intentional or intentional. The second specific aim was to determine the mechanism of the intentional high-magnitude impacts, as well as to ascertain if there were distinct distributions of impact mechanisms associated with session type, player position, and ball possession. We hypothesized that Head-to-Head contact would be the highest percentage of intentional impacts and that the percentage of these impacts would be greater in practice than in games and greater in lineman than other positions.

Methods

Following the approval of both Virginia Tech University and Rhode Island Hospital Institutional Review Boards (IRB), head impact data was collected from 68 youth football players over 153 sessions throughout the 2017 football season. Sessions were determined to be either competitions (games) or practices for the season of 2017. Data was collected from a total of 119 practices and 34 games. The 68 players, with a mean age of 12.6 ± 1.3 years and a mean body mass of 54.5 ± 16.3 kg, were recruited from four youth football teams after informed assent and written consent was obtained from the participants and their parents or guardians, respectively.

Study participants received either the Riddell Revolution, Speed, or SpeedFlex (Riddell, Chicago, IL) football helmets that were instrumented with the Head Impact Telemetry (HIT) System (Simbex, Lebanon, NH) that is part of the Sideline Response System (SRS; Riddell, Elyria, OH). The HIT System measures linear acceleration of the center of gravity of the head, estimates rotational acceleration at the center of gravity, and impact location on the helmet. The HIT system includes a sideline receiver unit, laptop with a radio receiver and sensor unit for each helmet. The sensor unit is comprised of an array of nonorthogonal single-axis accelerometers, and when a single accelerometer exceeds 9.6 g during an impact, the data is recorded over a 40-ms duration, including 8 ms of pre-trigger data. The HIT system has been validated, and the errors associated with the system have been reported extensively.[5,18,37,41] Standard video analysis included deeming impacts valid if they occurred during organized team sessions (games or practices) and invalid if they occurred during water breaks or outside organized team sessions.

All validated impacts with a peak linear acceleration equal to or exceeding a threshold of 40 g were classified as high magnitude impacts and thus included in the analysis for this study. Selecting a threshold for analysis was motivated from several perspectives. Single-video camera setups were used in all practices and most games. As impact magnitudes decreases it becomes more difficult to discern contact on video. At lower contact levels, consensus on intent becomes less reliable due to limited viewing capability, especially when this type of contact occurs away from the ball and thus is likely to be missed on video. Selecting a threshold on high-magnitude impacts balanced clinical relevance (i.e., inclusive of concussion risk) and practicality of video review (i.e., reduced dataset by 92%).

Video footage was used to process each of these impacts into five categories of impacts using a coding matrix based on the definitions (Table 1) developed from templates used in previous studies.[9,16,29,33,34,48] Video analysis was performed by two authors at each of the two institutions and the protocol for analyzing the videos was developed in collaboration. Example videos were identified for training. Each analyzer independently completed an analysis, the results were reconciled, and reviewed to ensure all analyzers were in agreement. Agreement of the final categorization was then verified by the first author. We note that in the database of analyzed high magnitude impacts, all impacts involved contact with at least one player’s helmet.

Statistical Analysis

Descriptive statistics were used to determine the primary impact mechanism of intentional high-magnitude impacts. The impact mechanism of Head-to-Equipment was excluded from further analysis due to its small sample size. Data were analyzed using MATLAB (MathWorks Inc., Natick, MA), and exported to SAS (SAS Institute Inc., Cary, NC) for statistical analysis. Statistical tests were carried out on multivariable interactions using a generalized mixed model (SAS Proc Glimmix) because standard tests of proportions do not account for subject variability. Chi-square (χ^2) test of independence was used to determine if significant differences in the distribution of impact mechanisms were associated with session type, player position, or ball possession and expressed as (χ^2 value and p-value). Confidence intervals for differences between head impact mechanism proportions were used for subgroup analysis to directly compare the proportions across player position, ball possession, and session type and expressed as proportions of each and 95% CI of the difference between proportions. However, since the chi-square test is limited because it only compares the joint effect of all variables, direct comparison of head impact mechanism proportions was also performed for each position group to determine if there was an overall interaction. A bootstrap procedure with each subject as the unit of sampling was used to conduct the subgroup analysis to evaluate differences in proportions. Confidence intervals were constructed based on the upper and lower 2.5 % quantiles of the bootstrap distribution based on 10,000 bootstrap samples. Statistical significance was determined if the difference interval between proportions did not cover zero. Because the aims were primarily descriptive, type 1 error was set at 0.05 for each inference.

Results

A total of 19,325 head impacts were recorded over one season within 153 sessions (119 practices and 34 games). There were 1,598 impacts (8 % of total impacts) that recorded a linear acceleration of 40 g or greater and deemed as high magnitude impacts. Of the 1,598 high-magnitude head impacts, 1,319 impacts were able to be processed by video verification into the classified mechanisms. 279 high magnitude impacts were unable to be processed because of an obstructed view in the video, lack of sufficient light to confirm impact, or the impact occurred out of the field of view of the video.

Approximately 80 % (1050 impacts) of the high magnitude (40 g or greater) head impacts processed were classified as being caused by the intentional use of the head.

Among these intentional high-magnitude impacts, Head-to-Head impacts accounted for the highest proportion (82.7 %) of impacts (Figure 1). Head-to-Head impact mechanism was also the primary impact mechanism for both session types, accounting for 71.9 % of game impacts and 88.9 % of practice impacts (Figure 2A). While Head-to-Head was the predominant mechanism in both session types, there was a significantly greater proportion of Head-to-Head impacts that occurred during practices compared to games (0.89 vs 0.72; 95 % CI of the difference: 0.10 – 0.24). On the contrary, there was a significantly greater proportion of Head-to-Body impacts that occurred in games compared to practices (0.23 vs. 0.09; 95 % CI of the difference: 0.09 – 0.20). There was no significant difference in the proportion of Head-to-Ground impacts that occurred across session types.

The Head-to-Head impact was the primary impact mechanism for each player position, accounting for 90.3 % impacts in linemen, 71.2 % impacts in backs, and 77.4 % impacts in perimeter players (Figure 2B). The linemen did have a significantly greater proportion of Head-to-Head impact mechanisms compared to backs and perimeters but there was no significance in the difference in proportion of Head-to-Head impact mechanism distribution between backs and perimeter players. The proportion of Head-to-Body impacts was significantly greater in backs than in linemen (0.24 vs 0.08; 95 % CI of the difference: 0.09 – 0.22). There were no significant differences in the proportion of Head-to-Ground impacts across player positions.

The ball was directly involved in 27.9 % of the impacts. Within these impacts, Head-to-Head impact was the primary impact mechanism, with 79.1 % experienced by ball carriers and 50.3 % experienced by tacklers (Figure 2C). Ball carriers were more likely (0.79 vs. 0.5; 95 % CI of the difference: 0.15 – 0.39) to experience Head-to-Head impacts, while ball tacklers were more likely (0.46 vs.0.11; 95 % CI of the difference: 0.23 – 0.44) to experience Head-to-Body impacts.

The interaction of the impact mechanisms was found to be a function of ball possession, but not session type or player position. There was an association between impact mechanism and ball possession in terms of ball carrier and tackler ($\chi^2 = 11.5$, $p = 0.003$) but no distinct difference in the impact mechanisms for player position ($\chi^2 = 0.47$, $p = 0.79$) or session type ($\chi^2 = 2.77$, $p = 0.59$).

Discussion

The purpose of this study was to determine the frequency of non-intentional and intentional head impacts and to characterize the player mechanisms associated with intentional high-magnitude impacts in youth American football players. We achieved this using head impact biomechanics from practice and competition (games) sessions to identify high-magnitude (40 g or greater) impacts and video footage to categorize the player mechanism associated with each impact. Classification of "intentional" is of course subjective, but in reviewing the video footage a player who lowered their head to make contact or had their head up with a purposeful movement to engage in contact were example of clearly intentional impacts. If the player's intent in the video was unclear we erred towards non- intentional classification. Of the high-magnitude impacts that were able to be processed by clear video analysis, 80 % were intentional impacts, and among these intentional impacts, 82.7 % were associated with the Head-to-Head impact mechanism. Head-to-Head impact was also the primary mechanism for both session types, all player positions, and for the ball carrier and tackler when the ball was directly involved in the impact.

Our threshold for the video analysis of impact mechanisms was set at 40 g or greater, a threshold previously used for defining high-magnitude impacts in youth football[8] and a value found to be the 95 % of peak linear acceleration in another previous study of youth football.[18] For perspective, walking generates less than 1g of linear head acceleration,[24] running typically generates less than 2 g of head acceleration,[32] while plopping down in a low-back chair can generate 10 g of linear head acceleration.[1] The severity of impacts associated with concussions vary, but on average for adults are in the range of 100 g.[6,23,35,39,41] In two distinct datasets of adults, the probability of a concussion occurring at 40 g was estimated to be less than 2.5 %.[38] At present the risk of concussion in terms of peak linear acceleration in youth players has not yet been established. We selected 40 g as a threshold to ensure it was above accelerations occurring during daily living activities, and we estimate that impacts above 40 g would be associated with a higher risk of concussion based upon the adult risk function.

Our dataset did not include any diagnosed concussions, but it is noteworthy that other studies have reported Head-to-Head mechanism as the most common mechanism for concussion and the mechanism with the highest linear acceleration.[29,48] A study of a 2011 youth football season identified the mechanisms of 20 concussions that occurred over 11,338 Athletic Exposures. Concussions resulting from Head-to-Head mechanisms accounted for 45 % of the injuries, Head-to-Ground and Head-to-Body mechanisms each accounted for 5 % of the injuries, and the mechanism for the remaining 45 % of concussions were indiscernible.[29] A study conducted by Wong et al. calculated linear acceleration values of impacts over 30 *g* and reported Head-to-Head impact mechanism accumulated the highest linear acceleration for skilled non-line players, in the open field, and players that were tackling.[48]

Session type, player position, and ball possession are a few of the many factors that can influence head impact magnitude, frequency and location. Recent studies have quantified high-magnitude impacts in both practices and games to assess how representative practice activities are of games[8] and have demonstrated varying impact exposures across a wide range of practice drills.[25] Researchers have also found that coaching style and practice intensity are important factors in high-magnitude impact exposure.[8] The current study found that practices accounted for more intentional high-magnitude impacts than games, but we did not analyze different types of practice drills, nor did we have a metric to account for coaching style or their history of education or training in such programs as Heads-Up football. Research into the collegiate and high school levels of football found that although offensive and defensive lines sustained the lowest-magnitude impacts, they did sustain the highest number of impacts.[6,7,10,11,27] Player position has been reported to be a significant factor in head impact exposures at the high school and collegiate levels, [7,13,15,20,36,43] while in the youth population it can be challenging to investigate since youth players play a variety of positions, and often play both offense and defense. Campolettano et al. researched player position in the youth population and found each position group to be associated with a distinct distribution of high-magnitude impacts.[8] In this study, 90 % of all intentional high-magnitude impacts that linemen experienced were associated with Head-to-Head contact. Linemen also experienced significantly greater proportion of intentional high-magnitude impacts compared to other position groups. Although detailed studies have not been previously reported on the role of ball possession in head impacts, we found that when the ball was involved in the tackle there was significant evidence to support a distinct impact mechanism distribution for ball carriers and tacklers. Ball carriers experienced a greater proportion of impacts from Head-to-Head impact mechanism as compared to Head-to-Body (0.79 vs. 0.11). Tacklers, however, experienced approximately equal intentional impacts in Head-to-Head as Head-to-Body mechanisms.

The high frequency of intentional head impacts we recorded suggests that rule changes and educational programs could have a substantial effect on reducing head impact exposures. Heads Up football promotes shoulder tackling in which tacklers are taught to track the opponent’s hip and maintain contact with the opponents’ thighs using their own shoulder as a point of leverage. Players are taught to keep their heads up and lead with their shoulders.[26] Kerr et al.[27] evaluated the effectiveness of the Heads Up football program by comparing the frequency of impacts measured using xPatch accelerometers (X2 Biosystems, Seattle, WA) in games and practices between leagues that implemented Heads Up football and leagues that did not implement this program. They found that leagues that implemented the Heads

Up program accumulated significantly fewer impacts per practices. Their study examined all impacts over 10 g and 20 g thresholds with categorizing as intentional or not. It remains to be determined if such educational programs can reduce high magnitude intentional head impacts in football. When intervention programs and the study of their effects are being considered, our finding suggest that the largest effect may be associated with lineman and ball carriers, as 90 % and 80 % of their intentional high-magnitude impacts were associated with Head-to-Head impacts.

We were faced with limitations while conducting this study. Variability of impact rates across players and team have been widely documented.[11,15] Variability of impact rates has also been documented among age group, team, and league.[6,7,10,11,27] To minimize these variabilities, we employed a bootstrap procedure in our statistical analysis in which each subject was set as a unit of sampling. Data collection was limited to only four teams over a single season, and we did not examine individual teams as a factor. We did not analyze the data as a function of coaching style or their training. We also did not stratify the analysis by the type of play (e.g. run versus pass) or by offense or defense, since most players play on both squads. 17.5 % of high-magnitude impacts could not be processed. Challenges arose from occluded or dark video footage, impacts occurring with multiple players, or plays occurring outside the video frame. We chose a 40 g threshold for peak linear head acceleration as measured with the HIT system for our data analysis. The accuracy of the impact recording system itself, [4,5] as well as selecting a different impact thresholds for analysis, would certainly affect the portions reported herein. We postulate that the overall conclusion would be similar since our primary outcome measure is impact mechanism as determined from video analysis; however, this remains to be examined.

In 2011, we discussed the need to reduce intentional head impacts in sports, especially in American football.[14] We proposed the adoption of rules, or in some sports, the enforcement of existing rules that penalize intentional head contact. If coupled with additional education and training of both coaches and players, this two-pronged approach has the potential to significantly reduce the incidence and severity of brain injuries, potentially without the need to substantially change the existing play of the game. The findings are indeed limited to the cohort studied, but if these findings can be extrapolated to larger cohorts they clearly indicate that such interventions would have a significant beneficial effect.

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What is known about the subject

Head impact exposures for American football players have been previously documented. This data is critical from multiple perspectives, including concussion etiology, the effects of rule changes, development and assessment of educational programs, and improving helmet performance. What is not known is how many of the high magnitude impacts are intentional. If the percentage is high, this indicates educational and rule changes may be the most effective approach to decrease head impact exposures, and thus the potential for reducing acute and long-term brain injuries.

What this study adds to the existing knowledge

This is the first study to analyze the intentional mechanisms of high magnitude head impacts in youth football.

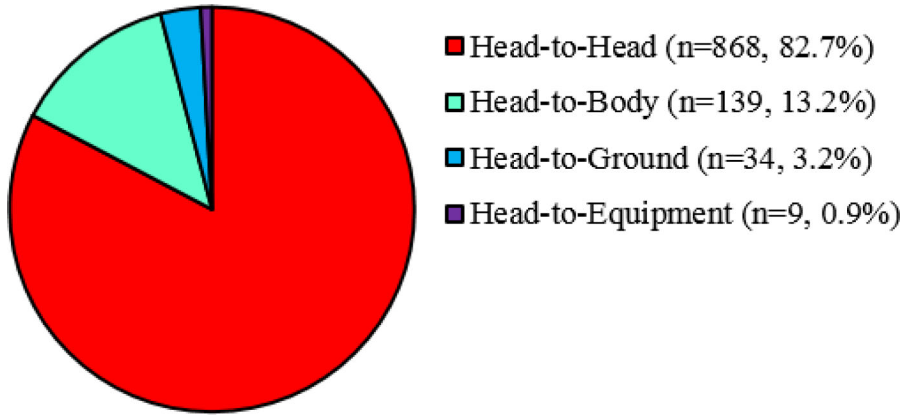

Figure 1:
Distributions of impact mechanisms for the intentional high magnitude head impacts over games and practices.

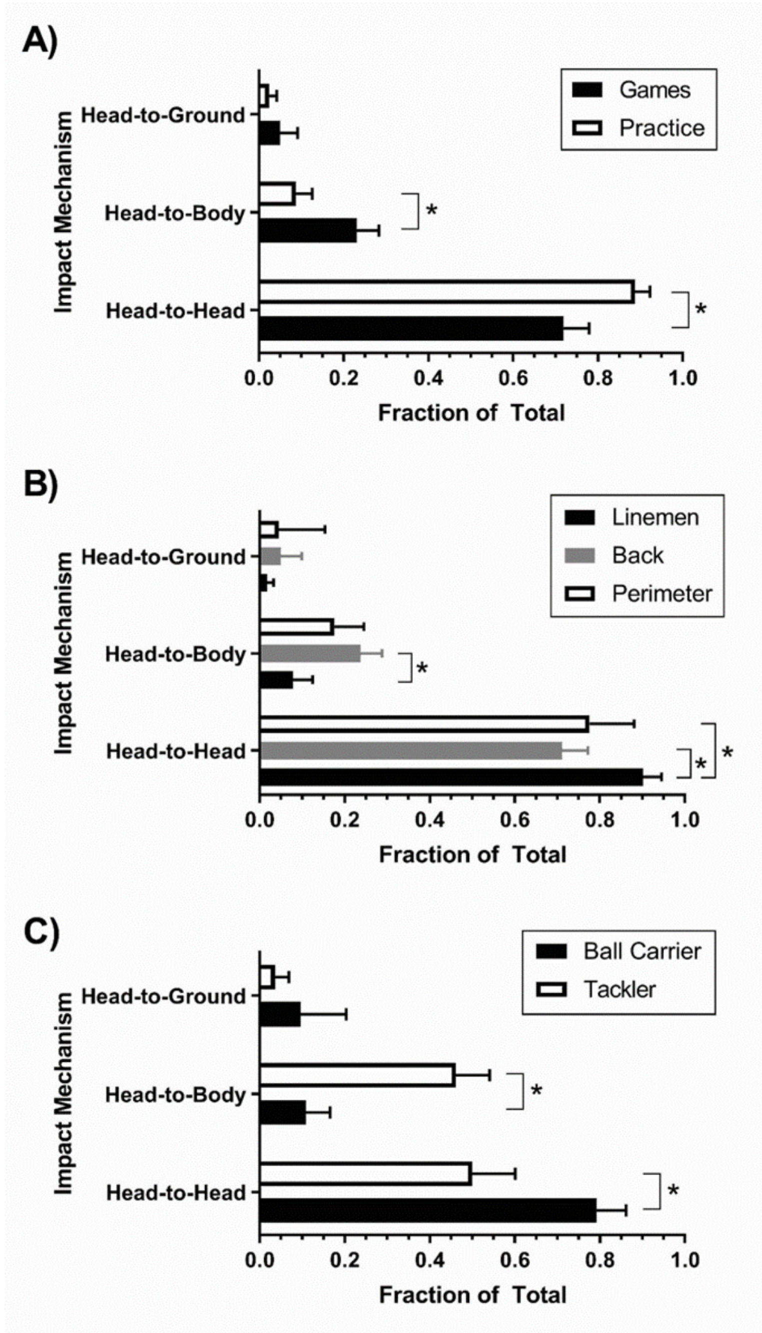

Figure 2:

Distributions of the impact mechanisms for the intentional high magnitude head impacts across sessions (A), player positions (B), and ball possession (C).

Table 1:

Description of Impact Classification, which was performed in a top down approach, as listed in rows below.

Intentional vs Unintentional Impacts	Was the impact purposeful? Did one or more players involved in the impact intend for the impact to occur?
Mechanism[34] - Head-to-Head (contact with another player) - Head-to-Body (contact with another player) - Head-to-Ground (contact with the ground) - Head-to-Equipment (contact that can occur against sleds or sandbags in practice drills or goal posts in game sessions)	Determine the initial contact surfaces of the analyzed impacts in which at least one player made purposeful (intentional) impact.
Ball Involvement - Yes - No	Do either of the players within the impact have the ball?
Ball Possession - Carrier - Tackler	Is the player carrying the ball or tackling for the ball?
Player Position[8] - Back (Quarterbacks, Linebackers, Running backs) - Linemen (Offensive, Defensive line) - Perimeter (Wide receiver, cornerback, safety) - N/A (a player's position may not be defined in a drill)	Position the player was assigned to at the time of the impact.