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Frequency and Location of Head Impact Exposures in Individual Collegiate Football Players

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Context: Measuring head impact exposure is a critical step toward understanding the mechanism and prevention of sport-related mild traumatic brain (concussion) injury, as well as the possible effects of repeated subconcussive impacts.

Objective: To quantify the frequency and location of head impacts that individual players received in 1 season among 3 collegiate teams, between practice and game sessions, and among player positions.

Design: Cohort study.

Setting: Collegiate football field.

Patients or Other Participants: One hundred eighty-eight players from 3 National Collegiate Athletic Association football teams.

Intervention(s): Participants wore football helmets instrumented with an accelerometer-based system during the 2007 fall season.

Main Outcome Measure(s): The number of head impacts greater than 10*g* and location of the impacts on the player's helmet were recorded and analyzed for trends and interactions among teams (A, B, or C), session types, and player positions using Kaplan-Meier survival curves.

Results: The total number of impacts players received was nonnormally distributed and varied by team, session type, and player position. The maximum number of head impacts for a single player on each team was 1022 (team A), 1412 (team B), and 1444 (team C). The median number of head impacts on each team was 4.8 (team A), 7.5 (team B), and 6.6 (team C) impacts per practice and 12.1 (team A), 14.6 (team B), and 16.3 (team C) impacts per game. Linemen and linebackers had the largest number of impacts per practice and per game. Offensive linemen had a higher percentage of impacts to the front than to the back of the helmet, whereas quarterbacks had a higher percentage to the back than to the front of the helmet.

Conclusions: The frequency of head impacts and the location on the helmet where the impacts occur are functions of player position and session type. These data provide a basis for quantifying specific head impact exposure for studies related to understanding the biomechanics and clinical aspects of concussion injury, as well as the possible effects of repeated subconcussive impacts in football.

Key Words: biomechanics, concussions, accelerometers

Key Points

- Players received up to 1444 head impacts in 1 season, with an average of 6.3 impacts per practice and 14.3 impacts per game.
- Impact frequency and location differed among player positions, with linemen and linebackers having the largest numbers of impacts per practice and per game.
- The offensive linemen had the largest percentage of impacts to the front of the helmet.
- Most impacts occurred to the front of the helmet for all player positions except for quarterbacks, who received the most impacts to the back of the helmet.

Concussion injuries, which are most often due to head impacts, are a growing concern in sports.[1–6] However, the biomechanical factors that relate a particular impact or a series of impacts to the clinical signs and symptoms of concussion injury, second-impact syndrome, or delayed cognitive sequelae have not been established. Using animal models, several researchers have suggested that repeated impacts[7,8] and direction of impact or head rotation[9–12] influence clinical and pathophysiologic consequences of injury. To investigate these relationships and the many factors potentially involved in acute and chronic effects of head impact, numerous researchers have used sports fields as laboratories. Quantifying events occurring in the experimental environment of the sport field is important for understanding the factors relevant to impacts that result in acute symptoms and for understanding whether repeated impacts might have subacute or long-term effects when no immediate symptoms are apparent.

In a study of collegiate sports injuries by the National Collegiate Athletic Association (NCAA),[13] exposure to the risk of injury was measured as an athlete-exposure (A-E), which was defined as "1 student-athlete participating in 1 practice or competition in which he or she was exposed to the possibility of athletic injury, regardless of the time associated with that participation." The measure of A-E does not account for the magnitude or frequency of head impacts to individual players. For example, 2 athletes who participate in the same game, both of whom would have experienced 1 A-E, might experience a different number of head impacts with very different magnitudes and at different locations. Because traumatic brain injuries are likely to occur along a broad continuum, to be cumulative, and to involve pathophysiologic events that might occur without evidence of acute injury symptoms, the concept of *exposure* needs to incorporate these elements to best understand individual player risk and potential prevention.

We propose to define *head impact exposure* as a broad term that incorporates multiple variables. Multiple measures of head impact exposure are critical because the specific variable or combination of variables that correlates with the risk of head injury has not been determined. The first important variable of head impact exposure is A-E,[13] which is well suited for understanding the overall risk of head injury per session of participation. A more complete understanding of the risk of head injury requires additional quantifiable variables that we propose include the magnitude of the head impact, the number or frequency of head impacts, the location of the head impact, and cumulative measures of head impacts.

Obtaining detailed information on magnitude and frequency of head impacts to individual players has been challenging. Videotaping of athletic events can provide some insight into injury mechanisms, but it has limited practicality because it has limited ability to continuously track all players, cannot accurately identify all impacts to the helmet, and cannot provide a direct measure of impact magnitude. The challenges associated with using videotapes to study head impacts in football are well illustrated in the studies of professional football players by Pellman et al.[14,15] Despite the prevalence of head impacts and the amount of video coverage, only 31 of 182 known concussive events were available for their analyses because the impacts were required to be in the open field and to be recorded from at least 2 unobstructed views. The magnitudes of the head impacts, which could not be recorded or quantified directly from the videos, were computed by reconstructing the impact scenario in the laboratory using Hybrid III anthropomorphic test devices (General Motors, Detroit, MI).

To measure the specific details of head impact exposure in sport participants, investigators have developed and implemented a variety of systems.[16–18] With early prototypes, players wore obtrusive data-acquisition hardware that required manual data downloading after each activity; consequently, these studies were limited in the number of athletes and session data that were collected. The Head Impact Telemetry (HIT) System technology[19–21] (developed by Simbex, Lebanon, NH, and marketed commercially as the Sideline Response System by Riddell Inc, Elyria, OH) was designed specifically to address these limitations by measuring the biomechanical factors associated with head impacts for a large number of players without interfering with the play of the game. The HIT System is an accelerometer-based system that is mounted inside a football helmet and is able to directly measure head acceleration and location of head impacts.

Investigators have used the HIT System to study head impacts to football players.[22–26] They provided new insights into the biomechanics of head impacts in football by examining the number of impacts and the magnitude of the resulting head accelerations across teams and groups of players. Although the authors of each study reported the total number of impacts per team that were recorded, they did not provide detailed analyses of the head impact exposure for individual players. To increase our understanding of the biomechanics of concussion injuries and the potential cognitive effects related to single or repeated head impacts, we sought to analyze head impact exposures for individual players by focusing on 2 specific measures of exposure. The purpose of our study was to quantify head impact exposure by recording the frequency and location of head impacts that individual players received in 1 season. We tested the hypotheses that head impact frequency and helmet impact locations would differ among 3 collegiate teams, between practice and game sessions, and among player positions.

METHODS

Participants

Players from 3 NCAA football programs (Brown University, Dartmouth College, and Virginia Tech) volunteered to participate in this observational study. Participants gave written informed consent, and the study was approved by the institutional review boards of each institution. Two teams participated in the Ivy League, which is an NCAA Football Championship Subdivision conference that does not allow postseason play, and 1 team participated in the NCAA Football Bowl Subdivision. During this study, all 3 teams participated in approximately the same number of games, but 1 school had almost twice as many practices as the other 2 schools. During the 2007 fall football season, 188 players from the 3 teams, which were denoted arbitrarily as team A (n = 65 players), team B (n = 60 players), and team C (n = 63 players), participated in our study. Each player was assigned a unique identification number and categorized in 1 of 8 position units that were defined by the team staff as the player's primary position: defensive line (DL, n = 29), linebacker (LB, n = 29), defensive back (DB, n = 34), offensive line (OL, n = 46), offensive back (n = 23), wide receiver (WR, n = 16), quarterback (QB, n = 8), or special teams (n = 3).

Instrumentation

All players wore Riddell (Riddell Inc) football helmets instrumented with the HIT System (Figure 1A and B), which is a device capable of recording the acceleration-time history of an impact from 6 linear accelerometers at 1000 Hz. The HIT System continuously samples all 6

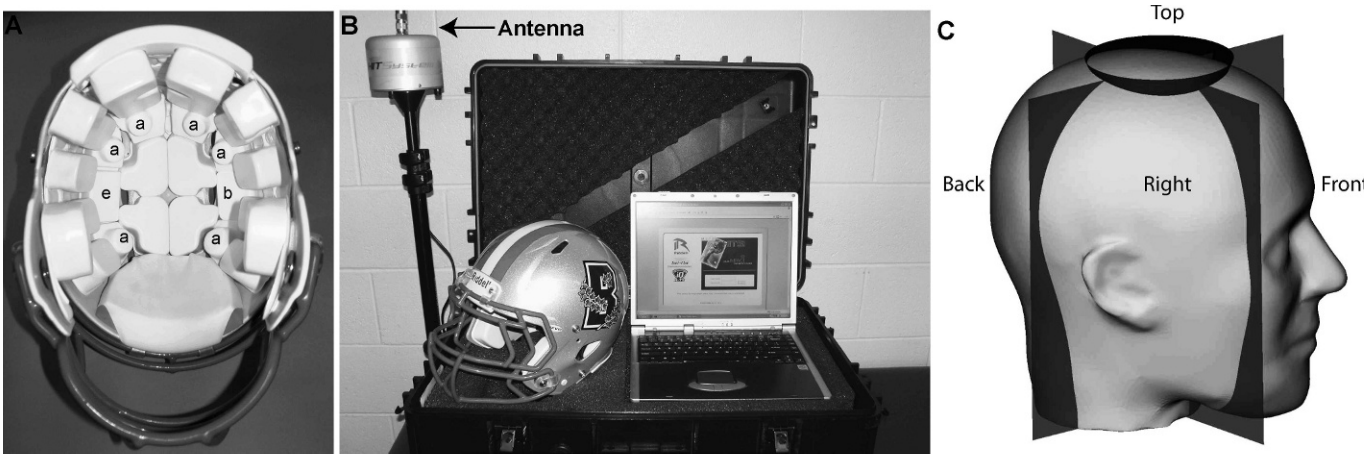

Figure 1. A, Football players wore instrumented helmets during practices and competitions to record the frequency, magnitude, and location of head impacts. These helmets were instrumented with 6 accelerometers (a), telemetry electronics (e), and a battery (b). B, The HIT System (developed by Simbex, Lebanon, NH, and marketed commercially as the Sideline Response System by Riddell Inc, Elyria, OH) comprises an instrumented helmet, a sideline receiver, and a laptop computer. C, The regions that defined the front, right, back, and top impact locations on the helmet and face mask are shown.

accelerometers during play. When a preset threshold for a single accelerometer channel exceeds 14.4*g*, 40 milliseconds of data (8-millisecond pretrigger and 32-millisecond post-trigger) are transmitted to a sideline receiver connected to a laptop computer. From the acceleration-time histories, the severity (magnitude of linear and rotational acceleration) and duration of the head acceleration and the location of the impact on the helmet are computed and stored for future analysis.[19,20] Head impact data from all participating institutions were uploaded to a secure central server with a consolidated database and subsequently exported for statistical analysis (SAS Institute Inc, Cary, NC). Data were reduced in postprocessing to exclude any impact event with a peak resultant linear acceleration less than 10*g* to eliminate events that had been determined during initial system development to be inconsequential, nonimpact events (eg, running, jumping).[24] Any impact event in which the acceleration-time history pattern of the 6 linear accelerometers did not match the theoretical pattern for rigid body-head acceleration,[19] such as a single accelerometer spike that can occur during throwing or kicking a helmet, also was excluded. Finally, all impacts exceeding 125*g* were reviewed visually to verify quality of acceleration data. These methods have been verified by comparing measured impacts with video footage.[23,25]

Definitions and Protocol

A *team session* was defined as a formal practice (players wore protective equipment and had the potential of head contact) or a game (competitions and scrimmages). A *player session* was defined as occurring when at least 1 head impact was recorded during 1 team session because this provided confirmation that the given participant was present and was exposed to impact. Impacts that were recorded outside of the time of the team session, as defined by the team staff, were excluded from the analysis. Head impact data were recorded during 215 team sessions (172 practices and 43 games during the 2007 fall season). The number of sessions that were analyzed for each player ranged from 1 to the maximum number of possible team sessions for his school (Table).

Head impact frequency and the location of the impacts on the helmet were analyzed for each player by team, session, and position. Head impact frequency was quantified using 5 measures: *season impacts*, which indicated the total number of head impacts recorded for a player during all sessions; *practice impacts*, the total number of head impacts recorded for a player during all practices; *game impacts*, the total number of head impacts recorded for a player during all games; *impacts per practice*, the average number of head impacts for a player during practices; and *impacts per game*, the average of the number of head impacts for a player during games. We plotted these data using cumulative histograms and ordinary histograms of impact events sustained by members of each team. Plotting the data as cumulative histograms enables the reporting of values for individual players normalized for the total number of players on each team. For example, if every player on the team received exactly 200 impacts during a season, then the curve would simply be a vertical line at the 200 value on the x-axis.

Table. Team and Player Practice and Game Sessions

		Team Sessions		Player Sessions[a]	
Team	No. of Players (N = 188)	Practices (n = 172)	Games (n = 43)	Practices, Maximum (Median)	Games, Maximum (Median)
A	65	76	14	55 (32)	9 (6)
B	60	48	14	48 (28)	12 (6)
C	63	48	15	46 (37)	15 (10)

[a] A *player session* was defined as 1 session (practice or game) in which a player received at least 1 head impact. The maximum number of sessions for an individual player ranged from 1 to the number of team sessions (practices plus games).

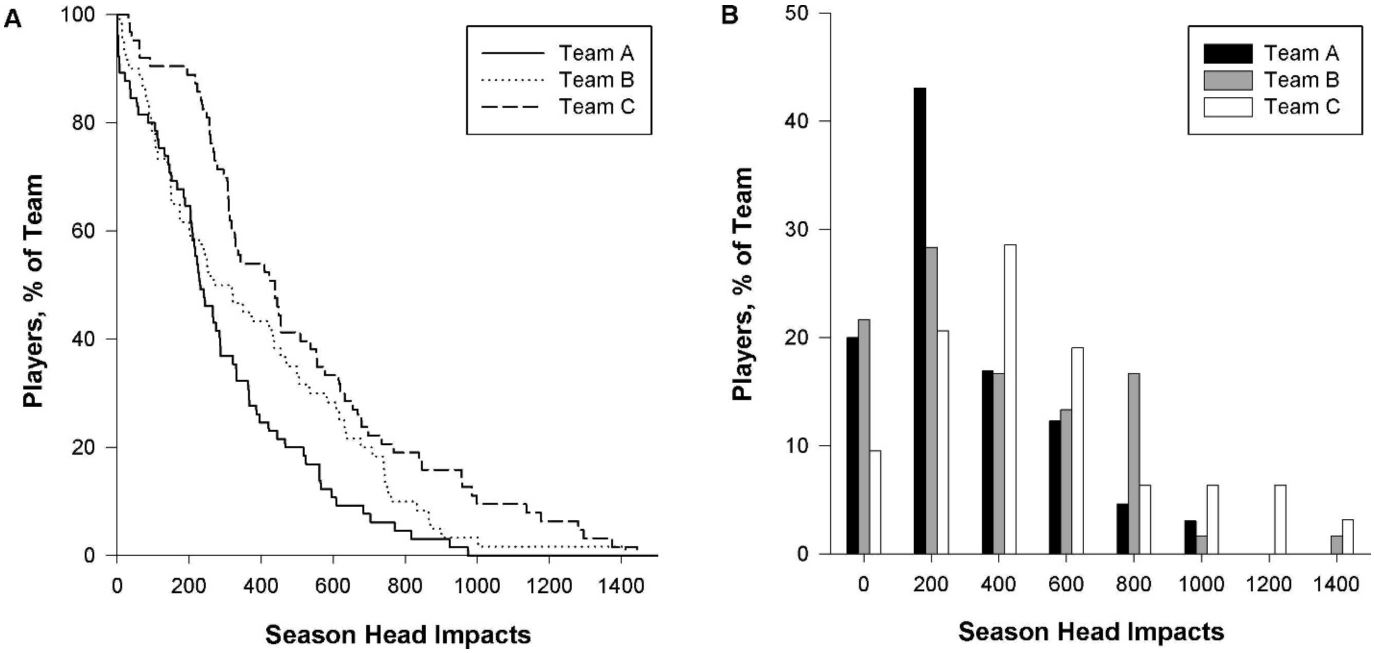

Figure 2. The total number of head impacts for individual players during the season differed with team. A, The complete distribution of the number of season head impacts is plotted as a cumulative histogram for all players of each team. The x-axis shows the number of season impacts, and the y-axis gives the number of players, as a percentage of the team, with the given number of season impacts or greater. B, An ordinary histogram of the same data.

Impact locations to the helmet and face mask were computed as azimuth and elevation angles in an anatomic coordinate system relative to the estimated center of gravity of the head[19] and categorized as front, left, right, back, and top (Figure 1C). Four equally spaced regions centered on the anatomic midsagittal and coronal planes defined the front, left, right, and back impact locations. All impacts occurring above an elevation angle of 65° where *0° elevation* was defined as a horizontal plane through the center of gravity of the head were considered impacts to the top of the helmet.[26]

Statistical Analysis

To determine if season impacts, practice impacts, game impacts, impacts per practice, and impacts per game for individual players were different among teams, we used the Wilcoxon test for comparing Kaplan-Meier survival curves. Comparing the survival curves provided both a compelling visualization and a valid (nonparametric) method for comparisons of the positively skewed data of season impacts, practice impacts, and game impacts. For consistency, we used similar analyses for the rate variables (impacts per practice and impacts per game), but these measures were not skewed. Because only 3 possible post hoc comparisons existed among the 3 teams, α was adjusted using the Bonferroni method to $< .0167$. We used SAS (version 9.2; SAS Institute Inc) for analyses. The relationship between the number of season head impacts that a player received and the number of NCAA-defined A-Es was examined using linear regression (SigmaPlot, Systat Software Inc, San Jose, CA), and the resulting χ^2 and P values are reported.

To determine if impacts per game and practice were different among players of the various positions, we used mixed linear models with fixed effects for team, position, and activity and random effects for position and activity within each player. The percentage of impacts at various locations within position (eg, left versus right in WRs) and location differentials between positions (eg, left versus right in WRs compared with QBs) were compared using mixed linear models with fixed effects for team, position, and location and random effects for position and location within each player. The Holm test was used to adjust P values for multiple comparisons because of the large number of comparisons. We used SAS (version 9.2; SAS Institute Inc) for analyses, and the resulting t and P values are reported.

RESULTS

The number of season impacts for players on team C was higher than those for players on team A ($\chi^2_1 = 13.106$, $P < .001$) and tended to be higher than for those on team B ($\chi^2_1 = 5.0830$, $P = .02$; Figure 2). The number of season impacts for players did not differ between teams A and B ($\chi^2_1 = 0.7778$, $P = .38$). The maximum (median) number of season impacts was 1022 (257), 1412 (294), and 1444 (438) among players on teams A, B, and C, respectively. The percentages of players receiving any given number of season impacts are plotted in the cumulative histogram of Figure 2A, whereas the percentages of players receiving season impacts in bins of 200 impacts are plotted in the ordinary histogram of Figure 2B.

Across all players in the study, the number of season impacts increased with A-E ($R^2 = 0.415$, $P < .001$).[13] However, the variability in the number of season impacts for a given A-E increased substantially as the number of A-Es increased (Figure 3). For example, the number of season impacts for players with an A-E value of 50 ranged from 175 to 1405.

The number of practice impacts was less for players on team A than those for players on team C ($\chi^2_1 = 9.405$,

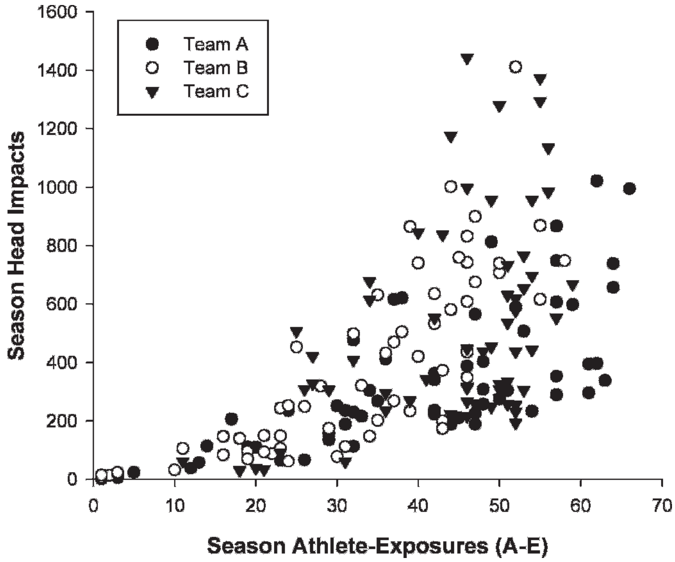

Figure 3. The number of season head impacts increased with athlete-exposures. An *athlete-exposure* was defined as 1 player in 1 session in which he or she is exposed to the possibility of athletic injury.[13] However, athlete-exposure was a poor predictor of the number of season head impacts for any given player.

$P = .002$; Figure 4A and B). We found no differences in the number of practice impacts between players on teams B and C ($\chi^2_1 = 2.0731$, $P = .15$) and between players on teams A and B ($\chi^2_1 = 2.1666$, $P = .14$; Figure 4A). The maximum (median) numbers of practice impacts were 761 (160), 811 (207), and 910 (210) among players on teams A, B, and C, respectively.

The number of game impacts was higher for players on team C than for players on team A ($\chi^2_1 = 24.508$, $P < .001$) and for players on team B ($\chi^2_1 = 10.491$, $P = .001$; Figure 4 C and D). Game impacts for individual players on teams A and B did not differ ($\chi^2_1 = 1.9185$, $P = .17$). The maximum (median) numbers of game impacts were 351 (79), 601 (102), and 775 (173) among players on teams A, B, and C, respectively.

The number of head impacts per practice was lower for players on team A than for players on team B ($\chi^2_1 = 18.9576$, $P < .001$) or C ($\chi^2_1 = 11.9123$, $P < .001$; Figure 5A and B). Impacts per practice were not different between teams B and C ($\chi^2_1 = 0.4935$, $P = .48$). The maximum (median) values for the number of impacts per practice were 15.6 (4.8), 18.9 (7.5), and 24 (6.6) among players on teams A, B, and C, respectively. In contrast to practices, the number of head impacts per game did not differ by team ($\chi^2_1 = 0.4921$, $P = .78$; Figure 5C and D). The maximum (median) values for head impacts per game were 58.5 (12.1), 66.8 (14.6), and 86.1 (16.3) among players on teams A, B, and C, respectively.

The number of impacts per practice ranged among positions from 3.2 (QBs) to 11.5 (DLs; Figure 6A). The number of impacts per game ranged from 7.3 (WRs) to 29.8 (DLs; Figure 6B). This increase in the number of head impacts per game compared with head impacts per practice was relatively constant for all positions, with a coefficient of 2.4 times ($r^2 = 0.92$, $P < .001$). In general, DLs, LBs, and OLs had a greater number of impacts per practice and impacts per game than the players at the other positions.

Across all players, the highest percentage of impacts occurred to the front of the helmet (Figure 7). The back of the helmet received the second highest percentage of impacts. When examined by positions, DBs, DLs, LBs, and OLs had higher numbers of impacts to the front than to the back of the helmet (t_{804} range = 8.92–15.23; $P < .001$). The OLs had the highest percentage of impacts to the front of the helmet compared with players at the other positions. Conversely, QBs had a higher percentage of impacts to the back than to the front of the helmet ($t_{804} = 3.19$, $P = .04$). The percentage of impacts to the front and the back was not different for WRs ($t_{804} = 1.89$, $P > .99$). We found no difference between impacts to the left and to the right side at any position (t_{804} range = 0.13–0.97; $P > .99$). Impacts to the top of the helmet occurred more often than impacts to either side but with a difference found only for OLs ($t_{799} = 4.68$, $P < .001$).

DISCUSSION

We sought to quantify head impact frequency and location for individual players on 3 collegiate football teams during a single season. We focused on these 2 measures of head impact exposure because of the lack of data on individual exposures and on concussion injury mechanisms. To date, the only reported exposure measure for individual players is the risk of injury through participation defined using A-E.[13] Although A-E is a useful factor for comparing the risk of injury across sports, sex, and other environmental factors, it has limited applicability to the study of injury mechanisms.

The ability to directly measure head impacts of individual players is critical to establishing the relationship between head impacts and concussion injury and to examining the potential effects of cumulative subconcussive impacts. Only a few of the 188 players enrolled in our study received an impact in all team practices and games. More typically, head impacts occurred in approximately one-half to two-thirds of the team sessions. Head impact frequency recorded over the entire season for practices and games varied by team. This was not unexpected given that players on 1 team had substantially more practice sessions, but this team also had the lowest median number of average impacts per practice. Although the number of team sessions certainly influenced the number of individual head impacts, the structure of the practice plan and the philosophies of the coaching staff also were likely factors that were difficult to quantify. Interestingly, the number of impacts a player received per game did not vary by team. We presume this is because of the controlled and timed nature of football games, which are less dependent on a team's style of play or specific practice tendencies. The total numbers of impacts players received during all practices and all games were comparable (Figure 4); however, after accounting for the number of sessions of each, the number of impacts per game was 2 to 3 times greater than the number of impacts per practice, which was consistent with the reported findings that injury rates are higher in games than in practices.[27] The number of impacts recorded per practice and per game for an individual player reached maximums of 24 and 86.1, respectively. The median values for these players were 6.3 impacts per practice and 14.3 impacts per game. For some individual

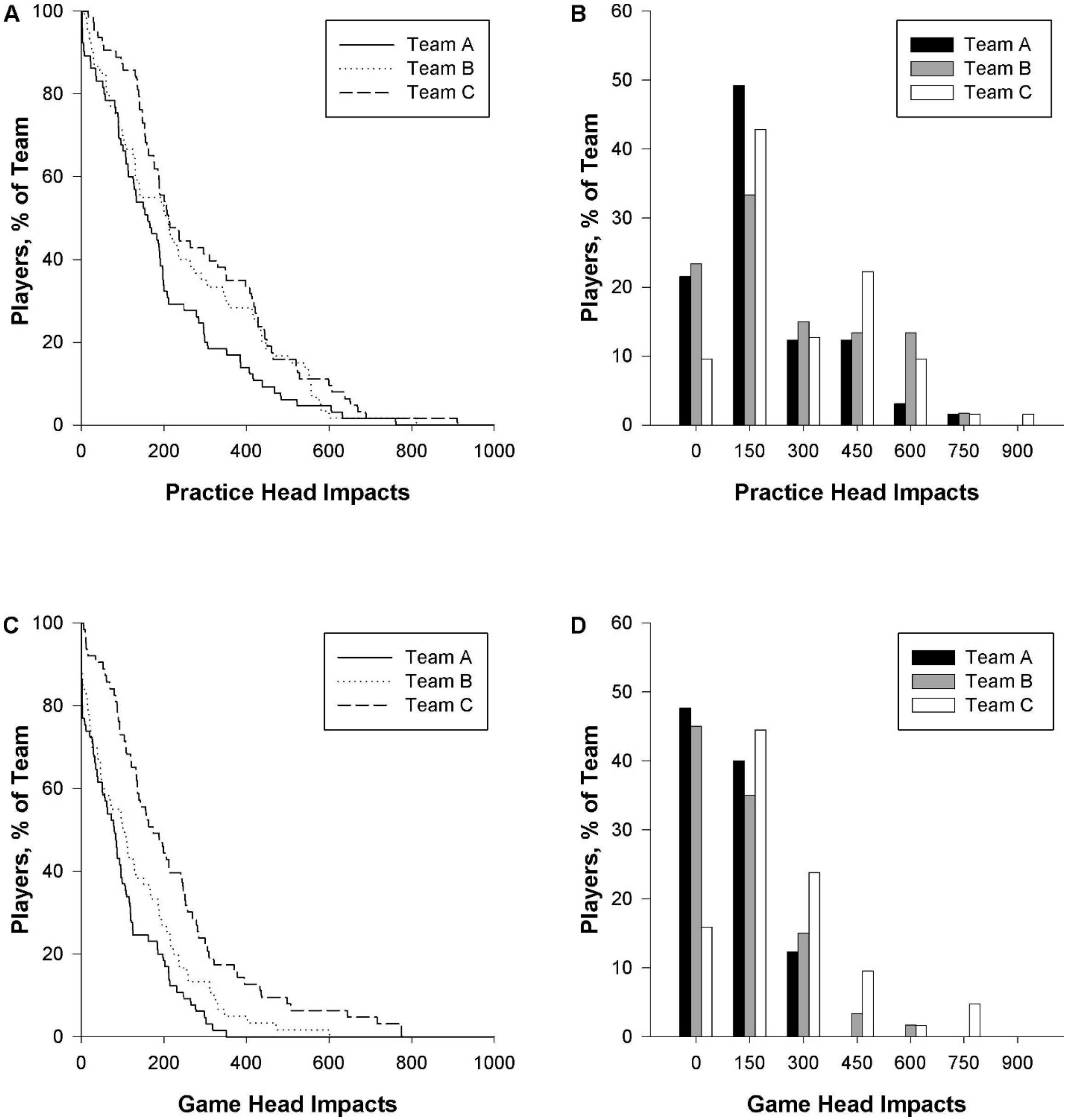

Figure 4. The number of head impacts for individual players of each team during A and B, all practices, and C and D, all games. The data are plotted as a cumulative histogram with the number of A, practice and C, game impacts plotted on the x-axis and the percentage of players on each team with the number of impacts, or greater, plotted on the y-axis. B and D, Ordinary histograms of the same data.

players, the values that we recorded might be underestimates of the actual impacts because a player might have started a practice or game but might not have completed the session and because we were not able to instrument all players on each team.

Researchers have not reported head impact measures for individual players, so direct comparison with our data is limited but instructive. Using an earlier version of the instrumented helmet technology, Duma et al[25] reported 2114 impacts in 35 practices while monitoring 38 different players (up to 8 players per session), giving a value of approximately 7.6 impacts per player per practice. In 10 games, they recorded 1198 impacts, for an estimated 15.0 impacts per player per game. Brolinson et al[23] recorded 11 604 impacts over 84 sessions of games and practices. During each session, they monitored up to 18 players, with 52 different players wearing the instrumented helmets over the 2-season period. From their results, we estimate that

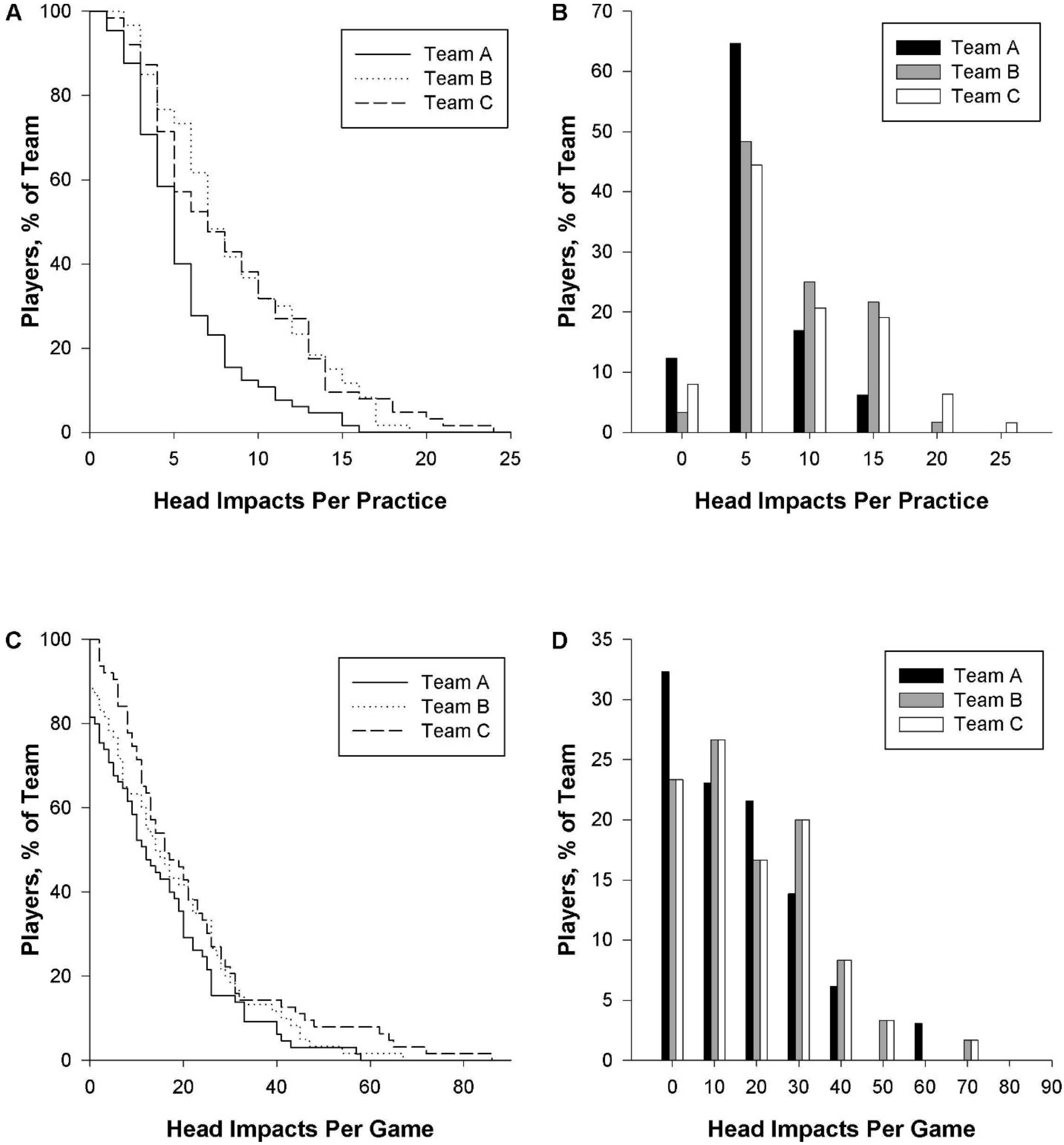

Figure 5. The number of head impacts for individual players A and B, per practice, and C and D, per game for players on each team. The data are plotted as a cumulative histogram with the number of impacts A, per practice, and C, per game plotted on the x-axis and the percentage of players on each team with the number of impacts or greater plotted on the y-axis. B and D, Ordinary histograms of the same data.

the average number of impacts per player per session was approximately 4, which would be in the lower 20% of the 188 players from our study. However, this prediction of impacts per player per session likely is an underestimate considering that 18 players were not instrumented each day for the entire study. Using similar technology, Schnebel et al[22] reported 54 154 impacts for 40 players over 105 sessions at 1 NCAA Division I school during 1 season. Their overall average number of player head impacts per session was approximately 13, which was greater than our median value of 9.4 impacts per player per session. Mihalik et al[24] reported that the total number of impacts sustained

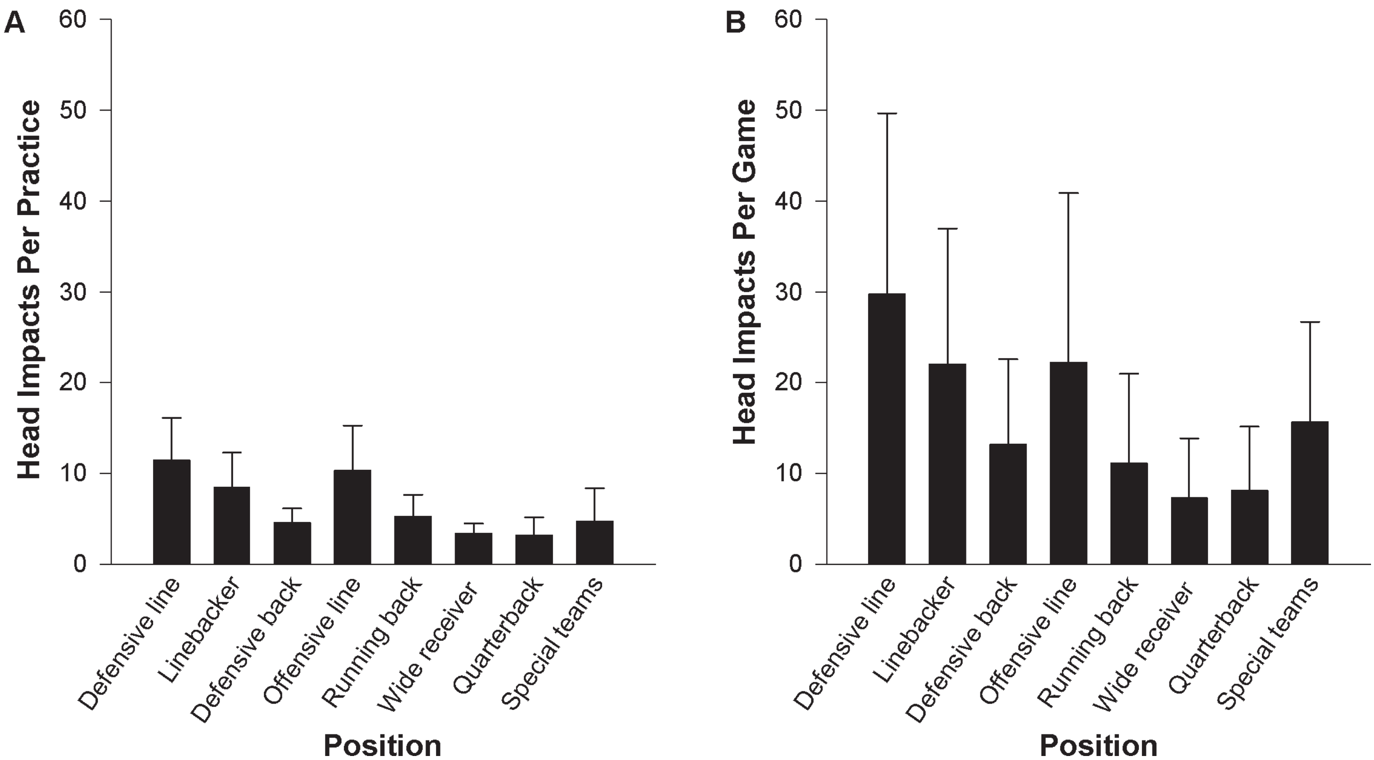

Figure 6. The mean (±1 SD) numbers of impacts A, per practice, and B, per game across player positions did not differ with team and were grouped together. Impacts per game were typically 2.4 times greater than the impacts per practice across these various positions.

in full-contact practice (28 610) was about twice the number of those sustained in games (12 873). This ratio is roughly consistent with our findings.

We found that player position affected both head impact frequency and location. Other researchers have suggested similar trends. Schnebel et al[22] reported that their nonlinemen ("skill positions") received only 25% of the total impacts, in contrast to linemen, who received 75% of the total impacts. In another study of 1 collegiate football team over 2 seasons, the largest percentages of impacts were recorded in OFs (36%) and DLs (22%),[24] which is consistent with our findings. In that study, LBs received only one-third of the impacts that the linemen received, whereas in our study, DLs, OLs, and LBs received approximately the same number of impacts per practice and per game.

We found that most impacts occurred to the front of the helmet for all player positions except QBs. The OLs had the highest percentage of impacts to the front of the helmet, which is consistent with the observation that OLs are more likely to initiate and control the site of impact than other position groups. The highest percentage of impacts to the back of the helmet occurred in QBs, suggesting that the QBs most often were hit from behind or were tackled, falling backward and hitting the backs of their heads on the ground. These explanations are based upon general observation of football and have not been confirmed by video analysis. Mihalik et al[24] did not examine impact location by player position, but their overall results on impact location are in general agreement with our findings for all players.

We focused our analysis on head impact frequency and impact location for individual players. We chose this focus because this analysis for individual players has not been reported and the resulting data are crucial in establishing baseline exposures for the mechanism and the risk of concussion injury, as well as any risk of cumulative subconcussive injury. Accordingly, a substantial number of data from our project were not reported in this study. The severity (magnitude) of the linear and rotational acceleration and the duration of head acceleration during impacts were not reported because these are the subject of an ongoing analysis of specific biomechanical input variables and their relationship to symptoms and cognitive function. In addition, cumulative measures of head impacts have not been formulated and, hence, were not included in this analysis. We did not report concussion injuries or any measure of long-term cognitive deficits. Our study also was limited to 3 teams during a single football season. Our multiyear study is ongoing, and we will analyze any differences among seasons as the study continues. We selected a lower range cutoff of 10*g* of peak linear acceleration of the head for inclusion as an impact to be consistent with data-collection thresholds across the 3 test sites. Given the size of the data set and number of levels of within-subjects (5 [location] × 2 [activity]) and between-subjects (3 [team]) factors, not all sources of heterogeneity of variance could be tested in our statistical analyses. Although we believe that the numbers of samples would minimize this effect, heterogeneity of variance across some factors could affect the mixed-model analyses.

Head impact in sports continues to be an important and growing concern at all levels of football and other sports because of the known adverse outcomes in some cases and the potential for long-term detrimental cognitive effects. The exact mechanisms for and variability of concussion

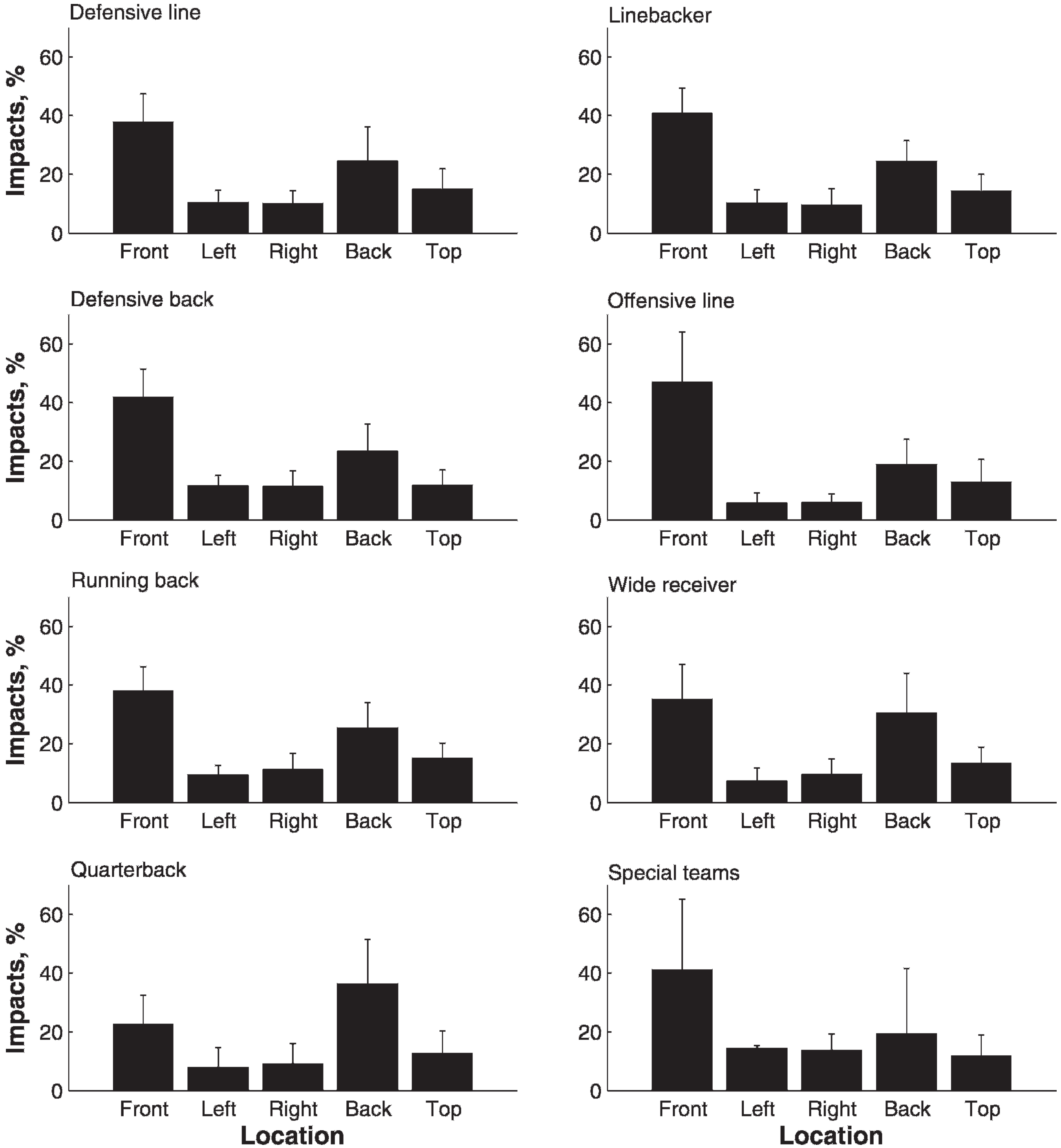

Figure 7. A–H. The mean (±1 SD) percentage of season head impacts at each helmet location (front, left, right, back, top). Most players had the highest percentage of impacts to the front of the helmet. Offensive linemen had the greatest percentage of impacts to the front of the helmet, whereas quarterbacks had the greatest percentage of impacts to the back of the helmet.

signs, symptoms, and long-term sequelae from head impacts, particularly in helmeted sports, are not well understood. Few data address possible differences in mechanisms and susceptibilities among athletes of different ages, including children, and between sexes. Estimates of concussion injury thresholds based on laboratory reconstructions using animal, cadaver, and manikin surrogates[15,28,29] have been inadequately predictive of injury when compared with measurements of actual head acceleration.[26] To appropriately evaluate the risk of concussion injury and the potential for interventions likely to reduce the incidence of concussions in sports, as well as the potential role of accumulated subconcussive events, a detailed understanding of the exposure and the mechanism of injury is needed. Using animal models, researchers have suggested that multiple factors likely influence the risk of neurologic and somatic symptoms after concussive head impacts and that these might include previous head impact events, location or direction of head impact, and other mechanical and physiologic factors.[7–12] The data that we presented begin this process of quantifying head impact exposure in collegiate football players by focusing on head impact frequency and location.

CONCLUSIONS

We found that an individual player can receive as many as 1400 head impacts during a single season. The average number of head impacts per game was nearly 3 times greater than the average number of head impacts per practice. We noted differences in impact frequency and impact location among different player positions. We also demonstrated differences in head impact frequency among teams, but it is unclear if this is related to differences among the players themselves, coaching approaches, or other factors that remain to be identified. We found no difference among teams in the average number of head impacts per game. These data documented head impact exposure in terms of frequency and location sustained by individual players in college football, which varies according to practice versus game, player position, and team. These data could aid football-helmet manufacturers in establishing design specifications and governing bodies in setting testing criteria and, with further studies, could provide clinicians and scientists with a more complete understanding of the relationship among head impact exposure, concussion injury, and long-term cognitive deficits.

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FINANCIAL DISCLOSURES

Joseph J. Crisco, PhD; Jonathan G. Beckwith, MS; Jeffrey J. Chu, MS; Richard M. Greenwald, PhD, and Simbex reported having a financial interest in the instruments (HIT System, Sideline Response System [Riddell Inc]) that were used to collect the data in this study.

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