BIOMECHANICS OF HEAD IMPACTS IN AMERICAN FOOTBALL PLAYERS

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INTRODUCTION

Concussion and subconcussive injuries remain poorly understood in part because the injury mechanism remains elusive. The purpose of this study was to quantify head impact exposures (impact frequency, location on the helmet and magnitude) for individual collegiate football players and to investigate differences in head impact exposure by player position.

METHODS

A total of 314 players from three National Collegiate Athletic Association (NCAA) football programs (Brown University, Dartmouth College, and Virginia Tech) were recruited in this institutional review board approved observational study after informed consent was obtained. During the 2007, 2008 and 2009 fall football seasons, each player was categorized into one of eight positions: defensive line (DL, n = 49), linebacker (LB, n = 47), defensive back (DB, n = 55), offensive line (OL, n = 75), offensive running back (RB, n = 37), wide receiver (WR, n = 30), quarterbacks (QB, n = 14), and Special Teams (ST, n = 7). ST players were not included in this analysis because of the relative low number of players.

All players wore Riddell (Riddell, Chicago IL) football helmets instrumented with the HIT System, consisting of six linear accelerometers (sampling 1000 Hz) and associated electronics that enable the recording of every head impact and computation of head accelerations and associated severity measures [1]. Laboratory impact tests have determined that the linear and rotational accelerations measured by the HIT System were within ± 4% of those accelerometers measured concurrently with a Hybrid III dummy fitted with a HIT System helmet [2].

Head impact exposure was defined for each individual player using measures of impact frequency, location and magnitude. Head impact frequency was quantified by impacts per season, the total number of head impacts for a player during all team sessions in a single season. Impact locations were categorized as front, side (left and right), back, and top. Impact magnitude was quantified by peak linear acceleration (g) and peak rotational acceleration (rad/s²). Additionally, a non-dimensional measure of head impact severity, HITsp [3] was computed. HITsp transforms the computed head impact measures of peak linear and peak angular acceleration into a single latent variable using Principal Component Analysis, and applies a weighting factor based on impact location. It thus serves as a measure of impact severity, with weight given to factors shown in previous head injury research to predict increased likelihood of clinical or anatomic injury. Impacts were further reduced for analysis by computing the 95th percentile value of all seasonal impacts for each individual player.

Results were expressed as median [25-75% interquartile range]. The significance of the differences among player positions in impact frequency (impacts per season) and in severity measures (95th percentile peak linear acceleration, 95th percentile rotational acceleration, and 95th HITsp) were examined separately using a Kruskal-Wallis one-way ANOVA on ranks with a Dunn's post-hoc test for all pairwise comparisons. Statistical significance was set at α = 0.05. All statistical analyses were performed using SigmaPlot (Systat Software, Chicago, IL).
A total of 286,636 head impacts were analyzed in this study. The total number of impacts received by an individual player during a single season was 420 [217-728], with a maximum of 2492.

The number of impacts per season ranged from 149 [96-341] for QB to 718 [468-1012] for DL (Fig. 1). DL, LB and OL received the highest number of impacts per season, and QB and WR the lowest. The number of impacts per season received by DL were significantly (P < 0.05) more frequent than QB, WR (157 [114-245]), RB (326 [256-457]), DB (306 [204-419]), but not different than LB (592 [364-815]) or OL (543 [264-948]). LB received significantly (P < 0.05) more frequent impacts per season than QB, WR, DB and RB. OL received significantly (P < 0.05) more frequent impacts per season than QB, WR and DB.

![Figure 1](image_url)

**Figure 1.** Median [25%- 75%] 95th percentile of peak linear acceleration (g) as a function of the median [25%- 75%] number of head impacts per season categorized by player position.

RB received the impacts with greatest magnitude accelerations and highest HITsp values. The 95th percentile peak linear and rotational acceleration for RB were significantly (P < 0.05) greater than OL, DL and DB. The 95th percentile HITsp for RB and LB were also significantly (P < 0.05) greater than OL and DL. Although OL and DL received the most frequent impacts per season, the magnitudes of the impacts were the least of all player positions. The median 95th percentile peak linear and rotational accelerations values were greatest for QB, but these were not significantly different from the other player positions.

**RESULTS AND DISCUSSION**

The magnitudes of impacts to the front of the helmet were significantly (P < 0.05) greater for RB than for OL, DL, WR and DB. LB, which were not different from RB, received significantly (P < 0.05) greater magnitude front impacts than OL and DL. Although the magnitudes were the least, OL received significantly (P < 0.05) more frequent front impacts than QB, WR, DL, and LB. QB received significantly (P < 0.05) less frequent front impacts than all player positions except WR. For all player positions, top impacts were significantly (P<0.05) the least frequent impact location (approximately 13% of all head impacts), but were associated with the greatest (P<0.05) peak linear acceleration magnitudes of all impact locations. In contrast, peak rotational accelerations associated with top impacts had significantly (P<0.05) less magnitude than all locations for all player positions. Impacts to the back of the helmet tended to be the highest magnitude for the QB and WR, and were significantly (P < 0.05) more frequent for QB and WR than for all other positions.

**CONCLUSIONS**

We have reported head impact exposures for a large cohort of collegiate football players. We found that player position was the largest factor (as opposed to team or session) in determining an individual player’s head impact exposure. Concussion injuries are a result of an impact that results in head accelerations. In order to prevent and to help diagnosis concussion and subconcussive injuries an understanding the biomechanics of these impacts is necessary. These impacts are complex events that we are studying by quantifying the head impact exposures measures of frequency, location and severity.

**REFERENCES**


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