HEAD IMPACT FREQUENCY IN YOUTH AMERICAN FOOTBALL, AGES 9-13

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The objective of this study was to quantify head impact frequency in youth American football players, ages 9-13. Kinematic data from head impacts were collected from 25 players on two teams (11.7 ± 1.2 years) using a helmet-mounted accelerometer system. A total of 4432 head impacts were recorded, including 1800 during 265 practice sessions and 2632 during 175 game sessions. Most peak linear acceleration magnitudes were less than 20 g in practices (60%) and games (55%). For impacts greater than or equal to 60 g, players sustained 122% more in games than practices. Both teams played in leagues that limited full-contact practice time, which likely contributed to lower impact frequencies in practices. Interventions to further reduce head impact frequency in youth football should include measures which affect in-game exposure.

KEY WORDS: Concussion, Brain Injury, Helmet, Youth sports, HIT system, Acceleration

INTRODUCTION: Sports-related brain injuries have garnered much attention in recent years with American football receiving much of the scrutiny (McCrory et al., 2013; National Research Council, 2013; Noble & Hesdorffer, 2013). Previously published studies have found that both impact frequency and acceleration magnitude may be important contributors to both short- and long-term health consequences (Rowson & Duma, 2013). While 3.5 million of the 5 million American football players are under the age of 14, most research on football head impact exposure has been conducted on adult players (Daniel, Rowson, & Duma, 2012). The objective of this study was to quantify the head impact frequency in youth American football players, ages 9-13 years old.

Concussions, acute brain injuries caused by abnormal pressures and strains in the brain due to linear and rotational head accelerations, are typically thought to be associated with a specific head impact (McCrory et al., 2013; Rowson & Duma, 2013). Researchers have suggested that previous head impact exposure may also play a role in concussions (Beckwith et al., 2013; Guskiewicz & Mihalik, 2011). Furthermore, long-term health consequences such as neurodegenerative diseases and behavioural changes may be linked to the accumulation of sub-concussive head impacts (Stern et al., 2011).

Prior to the article by Daniel et al. in 2012, no published studies had documented head impact exposure in youth football populations (Daniel et al., 2012). Daniel et al. utilized the Head Impact Telemetry (HIT) system (Simbex, Lebanon, OH), a helmet-mounted accelerometer-based system, to measure on-field head impact kinematics of 7-8 year old players. Since the original article, other studies have expanded the age range to 6-13 years (Cobb et al., 2013; Young, Daniel, Rowson, & Duma, 2014). Approximately 25,000 head impacts have been collected with the HIT system at the youth level.

METHODS: Head impact kinematic data were collected from 25 instrumented youth football players (11.7 ± 1.2 years; 48.1 ± 16.0 kg) on two teams, ages 9-13. Data were collected during all practice and game sessions throughout a football season using the HIT system. This study was approved by the Virginia Tech Institutional Review Board (IRB). Parental consent and player assent were obtained for all study participants.

The HIT system instrumentation, which consists of an array of six non-orthogonally mounted single-axis accelerometers, was fitted to the existing gap between the pads in medium and large Riddell Revolution and Speed Revolution helmets. Data collection was triggered when a single accelerometer detected a linear acceleration greater than 14.4 g. The trigger threshold was selected to limit data collection from normal movements while including relevant data (Ng, Bussone, and Duma 2006). For each impact, 40 ms of data were collected at 1000 Hz, including 8 ms of pre-trigger data. The data were wirelessly

transmitted to a sideline computer where the resultant linear acceleration of the center of gravity of the head was determined for each impact using a previously described algorithm (Crisco, Chu, & Greenwald, 2004). Previously, a validation study found the HIT system peak resultant acceleration data to be reliable (Beckwith, Greenwald, & Chu, 2012).
Individual player and summed data were sorted by peak linear acceleration magnitude and session type. Each practice or game an individual player participated in was considered a player-practice or player-game respectively. A player-session referred to either a practice or a game. Comparisons were made on the mean player head impact frequencies with peak resultant linear accelerations over 10 g, 20 g, 40 g, and 60 g in practices and games using two-tailed paired t-tests ($\alpha = 0.05$).

RESULTS: Instrumented players sustained 4432 head impacts during the season in 440 player-sessions, consisting of 265 player-practices and 175 player-games. The total number of impacts all player sustained greater than or equal to 10 g, 20 g, 40 g, 60 g, and 80 g are provided by session type in Table 1.

Table 1: Number of head impacts recorded over selected peak resultant linear acceleration magnitudes

Session Type	Number of head impacts per player				
	≥ 10 g	≥ 20 g	≥ 40 g	≥ 60 g	≥ 80 g
Practices	72 ± 57	29 ± 20	5 ± 3	1 ± 1	0 ± 1
Games	105 ± 96	47 ± 39	8 ± 8	2 ± 2	0 ± 1
Season	177 ± 145	76 ± 56	13 ± 11	3 ± 3	1 ± 1

On average, individual players sustained 177 ± 145 (mean ± standard deviation) head impacts over the course of the season. Players participated in an average of 11 ± 3 practices and 7 ± 1 games for a total of 18 ± 4 sessions. The average number of head impacts sustained per player greater than 10 g, 20 g, 40 g, and 60 g are provided by session type in Table 2. Significant differences were identified in the average number of head impacts players sustained between practices and games for linear acceleration values greater than or equal to 10 g ($p = 0.015$), 20 g ($p = 0.002$), 40 g ($p = 0.010$), and 60 g ($p = 0.008$).

Table 2: Average number of head impacts recorded by player over selected peak resultant linear acceleration magnitudes

Session Type	Number of head impacts				
	≥ 10 g	≥ 20 g	≥ 40 g	≥ 60 g	≥ 80 g
Practices	1800 (100%)	727 (40%)	126 (7%)	23 (1%)	7 (0%)
Games	2632 (100%)	1181 (45%)	206 (8%)	51 (2%)	10 (0%)
Season	4432 (100%)	1908 (43%)	332 (7%)	74 (2%)	17 (0%)

DISCUSSION: The instrumented players in this study experienced more head impacts in games than practices, despite participating in more practice sessions. In-game head impacts tended to be slightly less skewed toward lower linear acceleration magnitudes than practice impacts, as evident by a higher percentage of impacts greater than 20 g, 40 g, and 60 g. While the percentages of impacts for each peak linear acceleration magnitude differed only slightly by session type, the number of impacts in games increased relative to those in practices with increasing magnitude. For impacts greater than or equal to 10 g, players sustained 46% more head impacts in games compared to practices. For impacts greater than or equal to 20 g and 40 g, players sustained 62% and 64% more head impacts in games respectively. Players experienced 122% more impacts greater than or equal to 60 g in games. Large between-player variances were evident in the data due to the wide range of player head impact frequencies. For the season, the number of impacts sustained by each player ranged from 9 to 572. Nonetheless significant differences were found between practice and game frequencies at all acceleration magnitudes investigated.

The original head impact exposure study on youth American football by Daniel et al. (2012) found that more of the higher magnitude impacts players experienced occurred in practices. Since that study, some youth American football leagues and organizations have adopted new rules aimed at reducing head impact exposure in practices by restricting some drills and limiting the amount of time for full-contact practice (Pop Warner Little Scholars, 2012). Both teams in the current study participated in leagues which have implemented such rules which largely explains the difference in findings between the current study and that by Daniel el al. (2012) on practice and game exposure. In another study by Cobb et al. (2013), teams with and without contact restrictions in practice were included. Players on the team with contact restrictions sustained fewer head impacts in practices than games during the season while players on the other teams did not. In that same study by Cobb et al. (2013), the authors found significant differences in impact magnitudes between games and practices, where both the median and 95th percentile values were larger for games. Even though players on the unrestricted teams sustained more impacts in practices, they tended to experience a greater proportion of their higher magnitude impacts in games.

Current research offers limited insight on the relationship between acceleration magnitude and brain injury in youth populations. While concussion injury risk curves have been developed for adult players, no such metric exists for youth players due to limited injury data (Rowson & Duma, 2011). Studies on adult American football players have found that concussions may occur at accelerations as low as 60 g though injury risk begins to increase appreciably above 80 g and the average acceleration magnitude for concussions is approximately 100 g (Rowson & Duma, 2011). In the present study, 74 head impacts were observed with acceleration magnitudes greater than 60 g and 17 greater than 80 g but no concussions were diagnosed. Some researchers have suggested that the accumulation of sub-concussive head impacts over time may also be of concern (Stern et al., 2011). Though the damage that may be done by sub-concussive impacts cannot be quantified at this time, current understanding of the issue supports reducing head impact exposure as a means of reducing the occurrence of brain injury in sports. Future studies should continue to collect data from head impacts in youth football with an emphasis on identifying concussive impacts as well as relating brain injury and sub-concussive head impacts.

While the data presented here do support the use of practice restrictions to lower head impact exposure in youth American football, they also show that future interventions should include steps which will reduce head impact exposure in games as well as practices. These interventions could come in the form of rule changes, coaching/teaching better technique, or equipment improvements. Rule changes which limit playing time, reduce the number of games in a season, reduce the length of games, or alter the way the game is played may be considered. Coach education on topics such as “Heads Up Tackling”, promoted by USA Football, may lead to safer tackling (USA Football, 2010). Future helmet advances driven by youth-specific data would reduce cumulative head impact acceleration magnitudes experienced by youth players (Rowson & Duma, 2011, 2012).

There are several limitations that should be considered when interpreting the findings of this study. First, the study only included 25 players on 2 teams from the same region. It is unclear how well these teams represent youth American football players across the country. Second, some players were excluded from the study due to helmet size restrictions. Size small helmets cannot be instrumented with the HIT system utilized in this study. The exclusion of players with smaller heads could have introduced some sample bias. Third, HIT system data have some measurement error. A validation study by Beckwith, Greenwald, & Chu (2012) found that on average, the system over estimates linear acceleration by 0.9%, and that random error associated with individual measurements is ±15.7%. In the current study, the measurement error was overcome by analysing groups of data points rather than individual points. The values presented in this paper do have some associated uncertainty which is dominated by the between-player variance described by the standard deviations presented in Table 2.

CONCLUSION: This study quantified the head impact frequency experienced by youth American football players during a single season. The majority of recorded head impacts had peak resultant linear accelerations of less than 20 g. Though concussions are typically associated with higher magnitude impacts, those over 80 g, it is unclear what affect lower magnitude impacts have on the brain. Future research should study the effects of repeated sub-concussive head impacts on short- and long-term health outcomes. In the meantime, further reductions in head impact exposure in youth American football could be achieved through interventions which reduce in-game exposure. Interventions to reduce head impact exposure may come in the form of advancements in rules, coaching, and equipment.

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Acknowledgement

The authors would like to thank the National Highway Traffic Safety Administration and the Virginia Tech-Wake Forest School of Biomedical Engineering & Sciences for providing support for this study.