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Frequency, magnitude, and distribution of head impacts in Pop Warner football: The cumulative burden

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ABSTRACT

Background: A growing body of research suggests that subconcussive head impacts or repetitive mild Traumatic Brain Injury (mTBI) can have cumulative and deleterious effects. Several studies have investigated head impacts in football at the professional, collegiate, and high school levels, in an attempt to elucidate the biomechanics of head impacts among football players. Youth football players, generally from 7 to 14 years of age, constitute 70% of all football players, yet burden of, and susceptibility to, head injury in this population is not well known.
Methods: A novel impact sensor utilizing binary force switches (Shockbox®) was used to follow an entire Pop Warner football team consisting of twenty-two players for six games and five practices. The impact sensor was designed to record impacts with linear accelerations over 30*g*. In addition, video recording of games and practices were used to further characterize the head impacts by type of position (skilled versus unskilled), field location of impact (open field versus line of scrimmage), type of hit (tackling, tackled, or hold/push), and whether the impact was a head-to-head impact or not.
Results: We recorded a total of 480 head impacts. An average of 21.8 head impacts occurred per practice, while 61.8 occurred per game. Players had an average of 3.7 head impacts per game and 1.5 impacts per practice ($p < 0.001$). The number of high magnitude head impacts (>80*g*) was 11. Two concussions were diagnosed over the course of the season. However, due to technical reasons the biomechanics of those hits resulting in concussions were not captured.
Conclusion: Despite smaller players and slower play when compared to high school, collegiate or professional players, those involved in youth football sustain a moderate number of head impacts per season with several high magnitude impacts. Our results suggest that players involved in open-field, tackling plays that have head-to-head contact sustain impacts with the highest linear accelerations. Our data supports previously published data that suggests changes to the rules of play during practice can reduce the burden of hits.

1. Introduction

Recent efforts have been focused on the prevention of the acute, subacute, and chronic effects of brain injury in sports and, accordingly, the reduction of concussive and sub-concussive hits, as well as their cumulative impact [1–10]. As such, increasing interest has been given to the consequences of head impacts not only in professional level athletes, but also at the collegiate and high school levels [11–17]. As yet, few studies have investigated the burden of head impacts among pre-high school, youth football players.

In the United States, there are approximately 3.5 million youth football players, representing nearly 70% of all organized football. Recently, Daniel et al. utilized accelerometers installed in football helmets to quantify and qualify the number of hits sustained in youth football [18]. Although only seven players were studied, there was documentation of an average of 107 hits per player per season. Most of those hits (59%) occurred during practice. In addition, higher magnitude impacts were associated more with practices rather than games. This provided opportunity to alter practice rules to effect a change in both the frequency and magnitude of head impacts in youth football. Several youth football leagues subsequently altered their practice structure in an attempt to reduce the frequency and severity of head impacts. In a follow-up study, Cobb et al. followed three youth football teams and found statistically significant reductions in both the frequency and magnitude of head impacts occurring during practice in the team that adopted practice changes [19]. Analysis of head impacts during games across those three teams did not yield any significant differences in head impacts.

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Fig. 1. Video capture of head impact.

Pop Warner football was one of the first youth football league to implement practice changes. In the present study, we followed an entire team of Pop Warner youth football players in order to elucidate the frequency and magnitude of head impacts in youth football and to further characterize those hits.

2. Methods

During the 2012 football season, an entire Pop Warner football team consisting of 22 youth football players of the "Junior Midgets" class was recruited to participate in this observational study. The necessary informed consent was obtained from the players and parents involved. All players wore Xenith X2 (Xenith LLC, Lowell, MA) youth helmets. A novel, non-accelerometer based impact sensor (Shockbox Impact Alert Sensors, Impakt Protective Inc., Canada) was installed at the inner vertex of the football helmets. Each player received a unique identifier that allowed collection of head impact data specific to the player. Their play was followed over the course of eleven play sessions consisting of six games and five practices.

The impact sensor used in this study utilizes four binary force switches that replace the traditional accelerometers used in previous studies. Differential voltage activation of each force switch on impact is recorded and sent via Bluetooth® to a smartphone where a resultant linear acceleration is determined using a helmet-specific algorithm. These binary force switches have been shown to measure accelerations of head impacts with an average error of 8.9% in a limited study [20]. The sensors are programmed to record impacts that register linear accelerations greater than 30*g*. As the device is a commercially available product, designed for general use and not necessarily for research purposes, the sensor threshold is substantially different in previous studies of head impact exposure.

Head impact data, including magnitude, frequency, and site of impact were recorded. It is common for players to play multiple positions at the youth football level, though they generally remained in either skilled or unskilled roles. Unskilled positions included defensive and offensive linemen, while skilled positions included all other positions. In youth football, not every player participates in every session; therefore final calculations of hit counts were based on per session (either game or practice) analysis.

Video recording was routinely made of practices and games for the purposes of training and this data was used to further characterize the hits (Fig. 1). Film of 3 games and 2 practices were available for review. Of the total 480 hits recorded by impact sensors, 138 were captured on video. During video analysis, hits were classified by location on the field (at the line of scrimmage or in the open field), type of hit (player was tackling, being tackled, or pushed/blocked), and whether there was head-to-head contact.

Table 1
Player and head impact characteristics.

Players	Total participants	22
	Position	
	Skilled	13
	Unskilled	9
Average age	12.7 years (range: 12–13)	
Average weight	129.4 pounds (range: 90.6–161.5)	
Hits	Total hits recorded	480
	Event	
	Games	109
	Practices	371
	Position	
	Skilled	300
	Unskilled	180

2.1. Statistical analysis

Paired *t*-test was used to determine the significance in hits per practice versus hits per game. In order to determine the sample size necessary to power the subgroup analysis performed using video recordings, a difference of 5*g* was used as the threshold for clinical significance, while α and β were set at 0.05 and 0.2, respectively.

3. Results

Through the course of this analysis (six games, five practices), 22 players were followed (Table 1). Total head impacts recorded was 480. The mean linear acceleration value was 46.7*g* (range: 30–150*g*, standard deviation: 14*g*). Average head impact that occurred per practice was 21.8 (range: 14–33, standard deviation: 9). Average head impact that occurred per game was 61.8 (range: 27–90, standard deviation: 23). The summary data of head impacts for games and practices was calculated (Table 2). Players were found to sustain 2.2 hits more per game than per practice ($p = 0.001$). Utilizing the high-magnitude impact classification of Daniel et al. (>80*g*), 11 high-magnitude impacts occurred during games, while only two occurred during practices.

Game and practice video analysis during the study allowed for additional characterization of 138 hits (Table 3). Three categories were assessed: position of the player, field location of impact, and the action that led to the hit. With respect to each category, hits were classified as either head-to-head or non-head-to-head.

Two concussions were diagnosed over the course of the season. However, due to technical reasons the biomechanics of those hits resulting in concussions were not captured. Of those two hits, one occurred on a player whose sensor was not charged properly and one occurred when the research assistant and, subsequently, the receiving device was not present.

Table 2
Distribution of head impacts.

	Practice	Game
Average hits/player	1.5 (range: 0–9, SD: 1.3)	3.7 (range: 0–24, SD: 3.6)
Average acceleration/hit	45.1g (range: 30–150, SD: 15)	47.2g (range: 30–125, SD: 14)
Average hits/skilled player	1.3 (range: 0–9, SD: 1.4)	3.9 (range: 0–24, SD: 4.3)
Average hits/unskilled player	1.7 (range: 0–7, SD: 1.2)	3.3 (range: 0–12, SD: 1.4)

SD, standard deviation.