Comprehensive Coach Education Reduces Head Impact Exposure in American Youth Football

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Background: Despite little evidence that defines a threshold of head impact exposure or that participation in youth sports leads to long-term cognitive impairments, it is prudent to identify methods of reducing the frequency of head impacts.

Purpose: To compare the mean number of head impacts between youth football players in practice and games between leagues that implemented the Heads Up Football (HUF) educational program and those that did not (NHUF).

Study Design: Cohort study; Level of evidence, 2.

Methods: During the 2014 season, head impact exposure was measured using xPatch accelerometers from 70 youth football players aged 8 to 15 years from 5 leagues. Data were collected during both games and practices. The NHUF group comprised 32 players from 8 teams within 3 leagues. The HUF group comprised 38 players from 7 teams within 2 leagues. Independent-sample *t* tests evaluated differences in head impact exposure across groups (ie, HUF and NHUF).

Results: Players (mean ± SD: age, 11.7 ± 1.4 years; height, 152.2 ± 10.5 cm; weight, 51.6 ± 9.6 kg) experienced a total of 7478 impacts over 10*g*, of which 4250 (56.8%) and 3228 (43.2%) occurred in practices and games, respectively. The majority of impacts occurred within the NHUF group (62.0%), followed by the HUF group (38.0%). With a 10*g* impact threshold, the mean number of impacts during practice per individual event was lower in the HUF group (mean ± SD, 5.6 ± 2.9) than in the NHUF group (mean ± SD, 8.9 ± 3.1; difference, 3.4; 95% CI, 2.9-3.9). This difference was attenuated when the threshold was changed to 20*g* but remained significant (difference, 1.0; 95% CI, 0.7-1.3). At both the 10*g* and 20*g* impact thresholds, no differences were found in games.

Conclusion: Players who participated in HUF leagues accumulated fewer head impacts per practice at both the 10*g* and 20*g* thresholds. Youth football leagues should consider the HUF educational program, while exploring additional interventions, to help reduce the number of head impacts in players.

Keywords: epidemiology; injury; concussion; pediatric; youth sports

Approximately 3 million youth aged 9 to 14 years are reported to play tackle football annually in the United States.[20] However, participation has declined in recent years, with media reports suggesting that this is due to parental concern over injuries that may be sustained, particularly concussion, during participation.[10,25] Numerous studies have collected head impact data in college-aged athletes[1,6,11] but have yet to correlate the magnitude of a single impact or a series of cumulative subconcussive impacts to the risk of sustaining a concussion. Research at the youth level is limited, but recent research estimates that the incidence of head impacts sustained by players aged 7 to 13 years across 1 season of youth football ranges between 107 and 252 head impacts per player.[5,7,19,26] Although research has yet to explicitly link head impacts sustained during one's youth to any long-term cognitive impairments

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or other health deficits, a recent study suggested that beginning tackle football at an earlier age may be associated with later-life cognitive impairment.[23] Such findings warrant continued examination of cumulative head impact exposure during youth football participation and the need to create policies and programming to lessen the accumulation of head impacts and the incidence of concussion.

In 2012, USA Football instituted the Heads Up Football (HUF) educational program, which included training on proper equipment fitting, proper tackling technique, strategies for reducing player-to-player contact, concussion awareness, heat illness awareness, and sudden death information.[24] To our knowledge, no study to date has evaluated the effect of the HUF educational program, or any other coaching education program, on the frequency of head impact exposure in youth athletes. The purpose of the current study was to evaluate the efficacy of the HUF educational program in reducing the frequency of head impact exposures in youth football players. We hypothesized that teams utilizing the HUF educational program would have a lower frequency of head impact exposure during practices compared with those teams not implementing the HUF educational program (NHUF teams). However, because the HUF educational program is primarily targeted at modifying practice activities, we hypothesized there would be no difference in head impacts during games.

METHODS

League Selection

A subsample of leagues were selected from a larger study comparing injuries between 10 HUF and NHUF leagues in a sample of more than 2000 youth football players between the ages of 5 and 15 years.[13] The subsample of leagues was selected on several criteria, including the leagues: having players aged 8 to 15 years, being located in suburban settings to control for relative socioeconomic status, and being located in similar climates. This included 1 HUF and 2 NHUF leagues in South Carolina and 1 HUF and 1 NHUF league in Arizona. The original subsample included 1 HUF and 1 NHUF league each from both states. However, because there was a low number of participants in the first NHUF league in South Carolina, a second league was recruited to ensure more equal sample sizes in each group.

Additional criteria for league selection were required for inclusion in the overall study. The leagues had to be located near a university or health system capable of providing outreach athletic trainers (ATs). The investigators partnered with universities and local health systems to provide ATs for each league. The ATs were required to be licensed or certified to practice in the state they were located. Leagues agreed to allow the ATs to attend practices and games, evaluate injuries and illnesses, and collect player demographic and injury information. These leagues also had to conduct practices and games on fields that were centrally located so that ATs were available to all players. Coaches, parents, and players had to agree to the logistics of wearing the xPatch (X2 Biosystems) measurement system.

The HUF leagues were selected if they had completed the HUF educational program, had an identified player safety coach, and were confirmed by USA Football as a participant league. The NHUF leagues were selected if the administrators self-identified the league as having no policy or procedure for systematically educating the league's coaches.

Participant Sample

On-field head-impact data were collected from 70 youth football players aged 8 to 15 years from 5 leagues. Data were collected during both games and practices. As with league selection, we recruited youth football players from convenience samples. The NHUF group comprised 32 players from 8 teams within 3 leagues. The HUF group comprised 38 players from 7 teams within 2 leagues. The xPatch accelerometers were equally distributed among age groups and positions with the NHUF and HUF groups, although "position" can be difficult to define in youth football because players often play various positions within offense or defense during practices and games. We also attempted to recruit players who would be considered starters, but this can also be difficult to define because all leagues required players to participate in a minimal number of plays per game or may rotate who starts games each week. The study protocol was reviewed and approved by the Western Institutional Review Board (Puyallup, Washington, USA) and the institutional review boards at A.T. Still University and the University of South Carolina. Parents or guardians and players attended an informational meeting prior to contact practices beginning. Parents or guardians signed informed consent forms, and players signed separate assent forms.

League Programming

League program (ie, HUF or NHUF) served as the independent variable. The HUF educational program used a top-down training approach in which "master trainers" provided the HUF educational program to "player safety coaches," who represented their league or organization.[24] The player safety coach was generally a long-standing member of the league, although he or she did not coach a specific team; instead, he or she was responsible for teaching the other coaches the components of the HUF educational program. Education occurred prior to the season and included hands-on training of proper equipment fitting, both didactic and participant demonstration of proper tackling technique, and strategies for reducing player-to-player contact (drill development). Education also included didactic information regarding concussion, heat illness, and recognition and immediate management of cardiac events.

Data Collection

The xPatch accelerometers were used to collect the frequency of head impacts. The xPatch is about the size of a quarter and is applied to the mastoid process inside of the helmet. The ATs working with subsample sites also

received standardized training for accelerometer use. The attendance of each participant was tracked, with participants wearing the same accelerometer at each session.

Statistical Analysis

The accelerometers were removed and charged after each session. The X2 Head Injury Monitoring System (IMS) software was used to download and collate head impacts greater than 10*g* from both linear and rotational accelerations (rotational are converted by the software into linear *g*-forces). The default declacking algorithm was applied. These impacts were then extracted and entered into an aggregate database.

From these data, we calculated the mean number of impacts per individual event in practices and competitions discretely. Analyses were then repeated to include all head impacts grreater than 20*g*. Last, analyses were stratified by age. To ensure even-sized groups, we chose the age categories of 8 to 11 years (n = 39) and 12 to 15 years (n = 31).

Independent-sample *t* tests evaluated differences in head impact exposure across groups (ie, HUF and NHUF). An a priori *P* value of .05 was utilized. Because our statistics of interest may be nonnormally distributed, we also conducted nonparametric analyses using the Mann-Whitney *U* test. However, findings did not differ from parametric analyses and are not reported in this article.

We examined findings by affiliation with Pop Warner, which mandated practice contact restriction guidelines in 2012.[22] However, no youth football teams in the NHUF group originated from Pop Warner leagues; in addition, only 1 of 7 teams (with 19 players wearing accelerometers) in the HUF group originated from Pop Warner leagues. Furthermore, no differences were found by Pop Warner affiliation in the HUF group. As a result, only findings between the HUF and NHUF groups are presented.

RESULTS

Participant Demographics

Players fitted with accelerometers were all males, ranging in age from 8.5 to 15.1 years (mean ± SD, 11.7 ± 1.4 years) (Table 1). The mean (±SD) height and weight were 152.2 ± 10.5 cm and 51.6 ± 9.6 kg, respectively. There were no differences in height, weight, or age between the HUF and NHUF groups.

Head Impact Statistics

A total of 7478 impacts greater than 10*g* were measured, of which 4250 (56.8%) and 3228 (43.2%) occurred in practices and games, respectively. The majority of impacts occurred within the NHUF group (62.0%, n = 4637), followed by the HUF group (38.0%, n = 2841). Each player sustained a mean ± SD of 7.5 ± 3.4 impacts (range, 1-17) per practice, 12.9 ± 3.9 impacts (range, 2-21) per game, and 106.8 ± 70.1 impacts (range, 9-393) per season. Among players wearing accelerometers, 6 concussions were reported, all of which came from the NHUF group; 5 occurred during games and 1 occurred during practice.

TABLE 1
Youth Football Player Demographics by Group, 2014 Season

Group	No. of Players	Variable[a]	Mean ± SD	Range
Heads Up Football	38	Age	11.7 ± 1.5	8.5-14.4
		Weight	51.8 ± 9.5	32.8-73.8
		Height	152.7 ± 11.9	116.1-167.6
Non–Heads Up Football	32	Age	11.7 ± 1.3	8.8-15.1
		Weight	51.4 ± 9.9	29.9-72.1
		Height	151.7 ± 8.7	133.4-165.1
Overall	70	Age	11.7 ± 1.4	8.5-15.1
		Weight	51.6 ± 9.6	29.9-73.8
		Height	152.2 ± 10.5	116.1-167.6

[a]Age is measured in years, weight is measured in kilograms, and height is measured in centimeters.

Comparison by Group

With a 10*g* impact threshold, the number of impacts during practice per individual event was lower in the HUF group (mean ± SD, 5.6 ± 2.9) than in the NHUF group (8.9 ± 3.1; difference, 3.4; 95% CI, 2.9-3.9) (Table 2). This difference was attenuated when the threshold was changed to 20*g* but remained significant (difference, 1.0; 95% CI, 0.7-1.3). At both the 10*g* and 20*g* impact thresholds, no differences were found in games.

Age

When stratified by age, the mean number of impacts per event was similar between both the 8- to 11-year and 12- to 15-year groups (Table 3). As a result, differences from age-combined analyses were maintained. With a 10*g* impact threshold, among 8- to 11-year-olds, the mean number of impacts during practice per individual event were higher in the NHUF group (9.1 ± 3.3) compared with the HUF group (5.5 ± 3.2; difference, 3.6; 95% CI, 2.9-4.3). With a 10*g* impact threshold, among 12- to 15-year-olds, the mean number of impacts during practice per individual event were higher in the NHUF group (8.7 ± 2.9) compared with the HUF group (5.7 ± 2.5; difference, 3.0; 95% CI, 2.3-3.7). Again, these differences were attenuated when the threshold was changed to 20*g* but remained significant.

DISCUSSION

To our knowledge, this is the first study to compare head impact exposure in leagues with different coaching education requirements (HUF vs NHUF). It is also one of the largest samples (70 players) of youth football players to

TABLE 2
Number of Impacts Overall and per Individual Event in Youth Football Players by Group, 2014 Season[a]

Type of Event	Group	No. of Impacts	No. of Impacts per Individual Event		
			Mean ± SD	Difference (95% CI)[b]	Median
10*g* cutoff					
Practice	NHUF	2933	8.9 ± 3.1	0.0	9.0
	HUF	1317	5.6 ± 2.9	3.4 (2.9 to 3.9)[c]	6.0
	Overall	4250	7.5 ± 3.4		7.5
Games	NHUF	1704	12.7 ± 4.0	0.0	13.0
	HUF	1524	13.1 ± 3.7	–0.4 (–1.4 to 0.5)	13.0
	Overall	3228	12.9 ± 3.9		13.0
20*g* cutoff					
Practice	NHUF	1235	3.9 ± 1.9	0.0	4.0
	HUF	580	2.9 ± 1.4	1.0 (0.7 to 1.3)[c]	3.0
	Overall	1815	3.5 ± 1.8		3.0
Games	NHUF	741	5.6 ± 2.5	0.0	5.0
	HUF	671	5.8 ± 2.4	–0.2 (–0.9 to 0.4)	5.0
	Overall	1412	5.7 ± 2.5		5.0

[a]HUF, Heads Up Football; NHUF, non–Heads Up Football.
[b]Difference of the mean number of impacts per individual event between NHUF and HUF; 95% CI obtained from independent-samples *t* test.
[c]Statistically significant difference.

TABLE 3
Number of Impacts Overall and per Individual Event in Youth Football Players by Group and Age, 2014 Season[a]

Type of Event	Group	Age 8-11 y (n = 39)				Age 12-15 y (n = 31)			
		No. of Impacts	No. of Impacts per Individual Event			No. of Impacts	No. of Impacts per Individual Event		
			Mean ± SD	Difference (95% CI)[b]	Median		Mean ± SD	Difference (95% CI)[b]	Median
10*g* cutoff									
Practice	NHUF	1828	9.1 ± 3.3	0.0	9.0	1105	8.7 ± 2.9	0.0	8.0
	HUF	676	5.5 ± 3.2	3.6 (2.9 to 4.3)[c]	6.0	641	5.7 ± 2.5	3.0 (2.3 to 3.7)[c]	6.0
	Overall	2504	7.7 ± 3.7		8.0	1746	7.3 ± 3.1		7.0
Games	NHUF	1243	12.7 ± 3.9	0.0	13.0	461	12.8 ± 4.2	0.0	13.0
	HUF	886	13.0 ± 3.4	–0.3 (–1.5 to 0.8)	13.0	638	13.3 ± 4.2	–0.5 (–2.3 to 1.4)	14.0
	Overall	2129	12.8 ± 3.7		13.0	1099	13.1 ± 4.2		13.0
20*g* cutoff									
Practice	NHUF	900	3.9 ± 1.9	0.0	4.0	335	3.9 ± 1.8	0.0	4.0
	HUF	351	2.9 ± 1.5	1.0 (0.7 to 1.4)[c]	3.0	229	2.9 ± 1.4	1.0 (0.5 to 1.5)[c]	3.0
	Overall	1251	3.5 ± 1.8		3.0	564	3.4 ± 1.7		3.0
Games	NHUF	589	5.5 ± 2.6	0.0	5.0	152	5.8 ± 1.9	0.0	6.0
	HUF	452	5.7 ± 2.5	–0.2 (–1.0 to 0.5)	5.0	219	6.1 ± 2.2	–0.2 (–1.3 to 0.8)	6.0
	Overall	1041	5.6 ± 2.6		5.0	371	6.0 ± 2.1		6.0

[a]HUF, Heads Up Football; NHUF, non–Heads Up Football.
[b]Difference of the mean number of impacts per individual event between NHUF and HUF; 95% CI obtained from independent-samples *t* test.
[c]Statistically significant difference.

wear accelerometers during an entire football season. Overall, we found that players who participated in HUF leagues received fewer impacts to the head per practice at both the 10*g* (mean difference, 3.4) and 20*g* (mean difference, 1.0) thresholds. Over the course of a 12-week season with a mean 3 practices per week, this would equate to 90 fewer ≥10*g* or 36 fewer ≥20*g* practice impacts sustained by players in the HUF leagues. These differences were also maintained when examining the 8- to 11-year and 12- to 15-year age groups. Based on these data, the HUF educational program may be an effective strategy for reducing head impact exposure during practices in 8- to 15-year-old football players.

Despite the findings within practices, there was no evidence of an effect on the number of head impacts sustained during games due to the HUF educational program.

Coaches may have less control as to what happens during a game, unlike practices, which may occur in more controlled environments where skills development can be better supervised. However, the HUF educational program is primarily targeted at modifying practice activities, and as we hypothesized, it would have no effect on head impacts during games. Previous research has suggested that rule changes within games have successfully reduced the number of impacts in games, or at the least modified the types of impacts occurring (eg, spearing).[4,16-18] This is particularly important when considering that compared with practices, games historically had a higher incidence of catastrophic head and cervical spine injuries,[2,3,17] although other research has found a higher incidence of concussions in practices over games.[8,12,15] Foundational research has investigated possible reasons for head impact frequency and magnitude during games. For example, a landmark study that changed the location of kickoff and punt returns determined that decreasing the number of yards traveled in these special team plays decreased the magnitude of head impacts.[21] However, no recent research in American football has examined whether teaching a tackling technique in practice modified tackling form in games. Future research should seek practice-related and rule change methods in which head impact exposure can be minimized during games.

Overall, our findings regarding head impacts in youth football were similar to those of prior investigations into this population. First, as seen in previous research,[7] in a sample of 7- to 8-year-old football players, we noted more head impacts during practices compared with games. However, the difference between the mean number of impacts per practice and per game in our study (7.5 vs 12.9) was greater than those reported by Cobb et al[5] (9.5 vs 9.6), Young et al[26] (9 vs 11), and Munce et al[19] (9 vs 12). One additional study found the mean number of impacts per practice was greater than that per game (6.7 vs 5.8).[7] Second, the mean number of impacts across the season (106.8) in the current study was similar to that of Daniel et al[7] (107) but lower than that of other studies (range, 161-252).[5,19,26] These variations may be due to differences in the demographics of our sample, such as age and location. However, this difference may also be due to our purposeful selection of teams implementing the HUF educational program. Had we utilized a sample of all NHUF groups, it is likely that our mean number of impacts per practice and across the season would have been similar. Nevertheless, given that all these studies utilize small sample sizes, further exploration of head impact exposure is warranted.

These small sample sizes also inhibit the ability to provide more in-depth analyses. For example, we were limited in our ability to examine additional policy that may have affected head impact exposure. As noted, initial analyses further stratified players in the HUF group by whether they played in leagues with Pop Warner affiliation, which enforced practice contact restriction guidelines.[22] However, although previous research found that leagues utilizing the HUF educational program had lower injury rates when also having Pop Warner affiliation,[13] no differences in head impact exposure were found in the present study. Nevertheless, it is important to consider that other variations in policy may occur at multiple levels, including the overarching organization (eg, USA Football, Pop Warner), state, league, and team. Restricting samples to 1 team controls for such confounding effects but limits generalization. To better infer findings in such research, future studies must explore manners to sample diverse populations and account for covariates associated with exposure and outcome.

Limitations

Our study had several limitations. First, we chose to limit the subsample of head impact exposure to 8- to 15-year-olds to maximize our chances of capturing concussions. From previous research,[9,14] we expected few if any concussions in the 5- to 7-year age group. Despite this, we captured few concussions on players wearing accelerometers and were underpowered to examine statistical differences between impacts resulting and not resulting in concussion. In addition, although all concussions occurred in NHUF leagues, differences in concussion rates between HUF and NHUF leagues were not found among the entire cohort.[13] Future research should include a broader sample and perhaps include players at the youngest levels.

Second, this study only evaluated the effect of a single coaching education program (ie, HUF). Therefore, these results may not be generalizable to other comprehensive coaching education programs. In addition, we are unsure whether our findings were attributable to a single particular component of the HUF educational program or the pooled effect of multiple components. As an observational study, we also did not obtain information as to how the HUF education program specifically affected coaches' approaches to practices and games. Future research should evaluate each component or several components separately while directly examining how they modified coaching behaviors.

Third, our study was also limited because we could not confirm head impacts with video analysis. To mitigate this challenge, the X2 IMS provides an algorithm (declacking) to clean or account for spurious impacts (accelerations, dropped helmets, etc). In addition, our mean number of expected impacts over the season in the NHUF group was similar to that reported by previous research.[5,7,19,26]

Fourth, the inability to completely control for position and playing status was also a limitation. The mean youth football team in our research comprised 25 players, so it is common for players to play both offense and defense as well as play multiple positions during both practice and games. We were unable to control for these sources of variation on a day-to-day basis. Nonetheless, the lack of differences in age, height, and weight suggest the samples were likely fairly equal in size distribution, which generally dictates positions played at the youth level (eg, players above certain weights cannot the carry ball). If possible, to better control for position played, future research may focus on specific positions that are more prone to head impacts such as linemen or defensive backs.

Last, while our sample is the largest to date and the only one to compare 2 different practice conditions, it only represents a single season of data and may be subject to annual variation similar to what we see in injury frequencies. We believe this variation is mitigated by our inclusion of 5 different leagues and near equal numbers of participants from each condition. Despite this, future research should include multiple seasons of observations.

CONCLUSION

Youth football players in leagues that implemented the HUF educational program had fewer head impacts during practices, but not during games. Differences were consistent across both 8- to 11-year-old and 12- to 15-year-old players. Findings are promising in that they may suggest the success of interventions to modify coaching and consequently player behavior during practices.

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