Video Assessment and Evaluation of Two Wearable Sensors in American Football Players

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I. INTRODUCTION

An estimated 1.1 to 1.9 million sports- and recreation-related concussions occur annually in the United States in children aged <=18 years [1]. Among high school athletes, collision sports such as football and ice-hockey and contact sports such as lacrosse and soccer have high rates of concussion per athlete exposure [2]. Studies conducted on the collegiate population have shown similar trends in terms of concussion rates [3].

Despite high rates of concussion, the role of repetitive head impacts in concussion remains unclear. Due to a limited number of commercially available wearable sensors, previous studies focused on instrumenting football athletes using the Head Impact Telemetry System (HITS; Riddell, Des Plaines, IL) to quantify head impact exposure [4-7]. HITS deploys in American football helmets, preventing use in other sports. In recent years, there has been a rise in commercially available wearable sensors in various form factors. Sensors for these systems are mounted in a variety of places, including the helmet, skin, ear canal, teeth and headgear. These sensors provide the ability for use in helmeted and non-helmeted sports other than football [8-9]. The goal of the study was to test the efficacy of a non-helmeted mouthguard sensor in an on-field setting and compare it to the HIT system.

II. METHODS

Research methods were approved by the local IRB. All participants (and parents in the case of minors) provided informed consent prior to the start of data collection and were outfitted with two commercially available sensors: the Prevent "Intelligent Mouthguard" (IMG; Prevent Biometrics, Edina, MN) and the helmet-based HITS. The IMG consists of 4 triaxial linear accelerometers mounted on a flexible circuit and incorporated in a mouthguard. Data collection starts when one of the accelerometers reaches a 10 g threshold. Data are collected at 3.2 kHz for 50 msec and is transmitted via Bluetooth to a companion iPhone application [10]. The HITS sensors consist of six single-axis accelerometers that are mounted inside the football helmet using a modified liner. The system starts data collection at 1 kHz for 40 milliseconds when one of the accelerometers exceeds a 10 g threshold [5].

An on-site study operator distributed instrumented sensors to participating athletes prior to the start of each game or practice session. Two high-resolution sideline cameras covering the entire field were used to collect video for all sessions. Two additional cameras (Endzone and Sideline) were used to collect play-by-play video for all games. Start of video collection on stationary cameras was marked with a global time for synchronisation.

Video assessment was conducted by tracking individual players and labeling their activity at the time of sensor-collected events. Each event was categorised into one of six categories: Contact-Helmet; Contact-Body; Contact-Unclear; No-Contact; Not-in-Play; and Not-on-Video. Helmet impacts were categorised as Contact-Helmet. Events with no visible helmet contact but body contact were categorised as Contact-Body. Events where reviewers were unable to discern isolated helmet or body contact, such as a pileup, were categorised as Contact-Unclear. Events where the player was in the video but there was no visible contact were marked as No-Contact, and events where the player was not participating in the play were marked as Not-in-Play. No-Contact and Not-in-Play events were considered as "false-positives". Events that occurred outside of reported game and practice times were removed. Discrete events from the HITS and IMG were matched based on the respective timestamp from each system and compared based on peak magnitude of linear and angular acceleration.

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III. INITIAL FINDINGS

In our preliminary analysis, video data from two athletes were tracked and categorised during a game. HITS recorded 83 events, with 78 categorised on video. IMG recorded 39 events (38 categorised on video).

TABLE I

VIDEO CATEGORISATION OF EVENTS COLLECTED BY WEARABLE SENSORS FOR TWO ATHLETES

Event Classification	*Athlete 1*						*Athlete 2*					
	HITS			IMG			HITS			IMG		
	#	PLA	PRA	#	PLA	PRA	#	PLA	PRA	#	PLA	PRA
Contact-Body	14	23 ± 11	1035 ± 774	8	18 ± 7	1919 ± 1000	7	21 ± 8	1111 ± 508	1	10 ± 0	902 ± 0
Contact-Helmet	16	27 ± 15	900 ± 791	9	17 ± 7	1140 ± 249	17	26 ± 20	1093 ± 818	9	21 ± 6	2395 ± 1330
Contact-Unclear	12	20 ± 10	976 ± 506	2	22 ± 3	2430 ± 6	4	25 ± 11	1083 ± 545	4	28 ± 20	3119 ± 2183
No-Contact	6	24 ± 7	673 ± 239	2	17 ± 3	1398 ± 457	-	-	-	2	36 ± 15	3188 ± 641
Not-in-Play	2	19 ± 1	917 ± 29	1	60 ± 0	7635 ± 0	-	-	-	-	-	-
Not-on-Video	5	26 ± 10	1233 ± 398	-	-	-	-	-	-	1	26 ± 0	1593 ± 0

HITS had a video-verified false positive (No-Contact & Not-in-Play) rate of approximately 10% (8 of 78 events) and IMG had false positive rate of approximately 12% (5 of 40 events). There were 22 cases during the duration of the session where both systems collected an event that was coincident in time. Peak linear acceleration (PLA), peak angular acceleration (PAA) and the classification of those events are shown in Fig. 1.

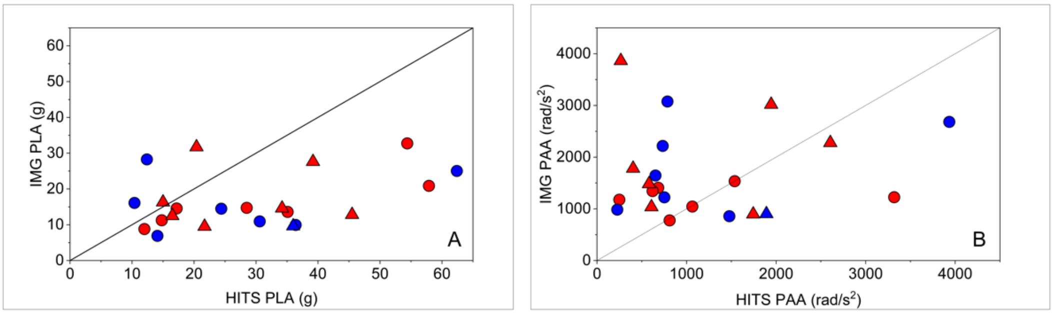

Fig. 1. Contact-Helmet (Circle) and Contact-Body (Triangle) data of PLA (A) and PAA (B) data for Athlete 1 (Red) and Athlete 2 (Blue).

IV. DISCUSSION

This study compared head impact data from American football players collected with two wearable sensors using video assessment. Both sensors reported similar false positive rates for video-verified events. In this study, the HITS recorded twice as many events compared to the IMG. The high number of events may be attributed to the HITS sensor potentially experiencing higher sensitivity to motion detection of head and helmet compared to the fixed IMG sensor. The HITS sensor captured video-verified Helmet-Contact events that the IMG failed to capture. It is feasible that visible contact on video did not meet the required 10 g threshold to trigger data collection on the IMG. Considering recent studies have suggested that repetitive impacts may contribute to onset of concussion, it is critical to capture all head impacts to better understand their role in the concussion mechanism [11]. Additional laboratory validation of commercial sensors should be conducted to better understand the limitations of the system prior to field deployment. For matched contact events HITS generally reported higher PLA values and IMG reported higher PRA values. Further research is required to clarify the accuracy of head impact sensors in accurately detecting true impacts and measuring their biomechanical properties.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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