A Three-Dimensional Video-Based Methodology for Analysing In-Game Helmet-to-Ground Impacts in North American Youth Football: A Preliminary Investigation.

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I. INTRODUCTION

Understanding the underlying mechanisms of football head impacts *in vivo* is critical to help inform helmet test standards and design. Prior research has utilised video-based techniques to quantify in-game head impact velocities, locations and directions, however, this work focused exclusively on concussive impacts in professional National Football League (NFL) players [1-3]. A recent study estimated head impact velocities from single camera video recordings of youth football games [4], although only impacts involving helmet-to-helmet contact between two players were analysed and the impact severity, i.e., change in velocity (ΔV), of these collisions was not quantified. While the biomechanics of helmet-to-ground (H2G) impacts have been examined from video of NFL concussion cases [5] as well as un-helmeted impacts in youth non-tackle American 7v7 football [6], no specific information exists for youth tackle football to date. Therefore, the aim of this research study was to utilise in-game 3D video analysis to conduct a preliminary investigation of the kinematics associated with H2G impacts in youth (≤ 14 years old) football.

II. METHODS

In-Game Video Data Collection Methods

Game video was recorded for two youth football age divisions (9-12 years, 13-14 years) using a multi-camera approach [6][7]. Modified GoPro HERO6 cameras (41° field of view, 2.7 K resolution, 120 frames per second) were positioned at stationary locations around half the field of play at 15-yard intervals along each side line and across the end zone. Video review targetted impact cases involving a clearly visible, direct helmet contact with the ground. No injuries or loss of consciousness resulting in on-field medical attention were observed.

Video Analysis of Helmet-to-Ground Impacts

A total of 16 H2G impact cases (9-12 years: 8; 13-14 years: 8) were selected for 3D video analysis based on the quality of camera views available for the impact event. Quantitative analyses were conducted using 3D motion analysis software (ProAnalyst 3D; Xcitex Inc., Woburn, MA, USA). Markings of known dimensions on the field and calibration stands were used to calibrate the camera views for motion tracking and compute the 3D field coordinate system for the video images (Figure 1). 3D helmet positions were manually tracked pre- and post-contact with the ground in two camera views (Figure 1). Helmet velocities were then differentiated from the position data along each axis in the field coordinate system; ΔV was calculated along each axis and then summated using a time window of ± 50 ms before and after impact. Uncertainty error in the position of the 3D coordinates was calculated to quantify the accuracy of the video tracking.

Fig. 1. (*Left*) Example of 3D field coordinate system with x, y and z axes super-imposed on the video image: x-axis: parallel to side lines (red); y-axis: parallel to yard lines (green); z-axis: vertical (blue). (*Right*) Example of the helmet motion tracking applied to a H2G impact to calculate pre-impact helmet speed and impact-induced ΔV.

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III. INITIAL FINDINGS

TABLE I
PRELIMINARY KINEMATIC RESULTS OF H2G IMPACT CASES FROM VIDEO ANALYSIS

	Max Pre-Impact Linear Velocity (m/s)			Change in Velocity at Impact (Δt_{window} ± 50 ms)			Uncertainty ± Error (m)
	V_{XY}	V_Z	V_R	ΔV_{XY}	ΔV_Z	ΔV_R	
Mean	4.11	3.33	5.23	-1.78	3.64	4.27	0.009
Median	4.32	3.27	5.19	-1.74	3.54	4.18	0.010
Min.	2.02	1.33	2.99	0.48	1.63	2.79	0.003
Max.	6.57	5.12	8.25	-3.58	5.71	6.53	0.015
S.D.	1.30	1.10	1.49	0.98	1.19	1.13	0.003

Note: V_{XY} , ΔV_{XY} = horizontal (ground) plane; V_Z , ΔV_Z = vertical; V_R , ΔV_R = resultant.
Note: No statistically significant differences for max pre-impact linear velocity or change in velocity at impact between 9-12 and 13-14 year old impact cases in any direction ($p > 0.05$).
Note: The velocity data is presented in the field coordinate system.

IV. DISCUSSION

The present work supports previous studies and illustrates that 3D motion tracking software (ProAnalyst 3D) can effectively be used to quantify linear helmet impact velocities in youth football players and quantify impact severity (ΔV). Maximum resultant pre-impact helmet velocities ranged from 3.0 to 8.3 m/s with a downward velocity vector (V_z) of 1.3 to 5.1 m/s. It is important to highlight that pre-impact velocity is not representative of the severity of the impact as it does not consider the change in velocity (ΔV) as a result of impacting the ground. The ΔV in these 16 non-injurious, youth H2G impacts was 4.3 ± 1.1 m/s, which was comparable to eight un-helmeted, non-injurious H2G contacts in American 7v7 football (3.0 ± 1.1 m/s) [6]. Both were significantly less severe than the 16 injurious, helmeted H2G impacts in the NFL (8.1 ± 1.7 m/s) [5]. Furthermore, the ΔV's presented in the present study likely over-predict the actual ΔV since a time window of 100 ms has been used. In this time window some of the change in speed is contributed to the body-to-ground contact prior to and after the H2G contact in the X-Y, i.e., ground plane. ΔV_z is likely most representative of the severity of the impact in these H2G impacts.

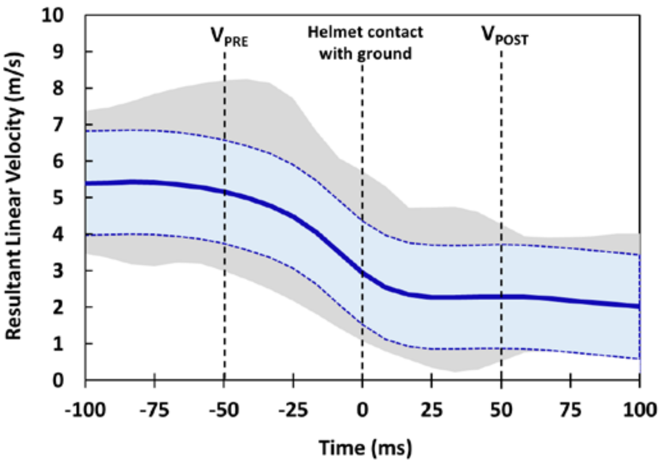

Fig. 2. (Blue) Illustration of the average resultant pre-impact linear velocity profile across all 16 H2G impact cases ± 1 standard deviation. (Grey) Envelope of maximum and minimum values.

These results also indicate that H2G impacts most commonly occurred at the third contact in the progression of an impact event. The typical progression was body-to-body (B2B), body-to-ground (B2G), followed by helmet-to-ground (H2G), which is similar to the general sequence reported elsewhere [5-6]. It should be noted that validation of this video-based methodology using ProAnalyst3D is currently ongoing to evaluate the effects of specific factors shown to influence the accuracy of tracking helmet motion via video, e.g., image resolution, player speed, distance and direction of travel from camera view [1][4][8], however, the general methodology and camera setup has been validated and used in other studies [6].

V. REFERENCES

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