

Development of a Methodology and Preliminary Analysis of Head Impacts in American 7-v-7 Non-Tackle Football

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I. INTRODUCTION

The nature of head contacts and injuries in American 7-v-7 non-tackle football is not well known [1]. The only epidemiological study reporting on youth athletes determined a time-loss injury incidence of 5.77 per 1000 athlete-exposures (AE) for 7- to 13-year-old flag football athletes [2]. Concussions were 23% of the injuries (1.3/1000 AE). Studies of adult recreational flag football report a lower time-loss injury incidence of 0.14–1.6 per 1000 AE with less than 20% of injuries to the head or face and 2–11% of injuries considered concussions [3-4]. This creates a challenge to developing protective headgear. The overall aim of this research study was to develop an understanding of the types and frequency of contacts, contact locations on the body and speeds of players' heads involved in impacts in under-18 7-v-7 non-tackle American football using in-game video analysis and 3D video reconstruction.

II. METHODS

Feasibility and Validation of Video Analysis Methods

A parametric laboratory validation study was conducted to assess the feasibility of using stationary action cameras (Hero6, GoPro, USA) to quantitatively assess head impacts via multibody image matching. Camera parameters were varied across nine impact tests to determine the optimal configuration: distance from impact (12–31 m), field of view (FOV) (41° , 87°), and video resolution/frame rate (2.7 K/120 fps, 1080 p/240 fps).

Multibody image matching was used to calculate resultant ΔV and $\Delta \omega$ from video. Predicted values were compared to Anthropomorphic Test Dummy (ATD) data (head-to-head impacts, H2H) or the known pre-impact velocity (head-to-ground impacts, H2G). Across the range of distances, 41° FOV with 2.7 K/120 fps video produced the smallest errors for resultant ΔV and $\Delta \omega$ ($\Delta V = 0.24$ m/s, $\Delta \omega = 3.4$ rad/s) and was used for the subsequent in-game video analysis.

In-Game Video Analysis of Head Impacts

In-game video analysis was conducted for a 7-v-7 non-tackle football tournament at the Football Hall of Fame Stadium (Canton, OH, USA). Fifteen GoPro Hero6 stationary action cameras (41° FOV, 2.7 K, 120 fps) were positioned such that every location on the field of play was less than 30 m from the closest camera. The stadium was scanned using 3D laser scanning to calibrate the video images. The game video was qualitatively assessed by two raters to identify impacts (H2H, body-to-body (B2B), body-to-ground (B2G), head-to-body (H2B), H2G) and the location on the field, play type and the approximate location of impact on the head. In several cases the player experienced multiple contacts during the impact event, and each impact was coded as 1st, 2nd, or 3rd contact. A



Fig. 1. (Left) 15 modified Hero6 stationary action cameras (41° FOV, 2.7 K, 120 fps) were placed around the field, within 30 m of any on-field play, to conduct qualitative and quantitative analysis of seven non-tackle football games. (Right) Sample of multi-body image tracking applied to a H2G impact to compute pre-impact head speed and impact-induced ΔV and $\Delta \omega$.

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subset of H2H and H2G impacts were extracted for multibody image matching to assess the pre-impact speed and ΔV and $\Delta \omega$ of the head impact events.

III. INITIAL FINDINGS

TABLE I

CHARACTERISTICS OF PLAYS AND CONTACTS RECORDED ACROSS SEVEN 7-V-7 NON-TACKLE FOOTBALL GAMES

Total Plays	Contact Plays	Number of Contacts on Play			Contact Type				
		1	2	3	B2B	B2G	H2B	H2G	H2H
186	56	37	14	6	22	50	2	9	0

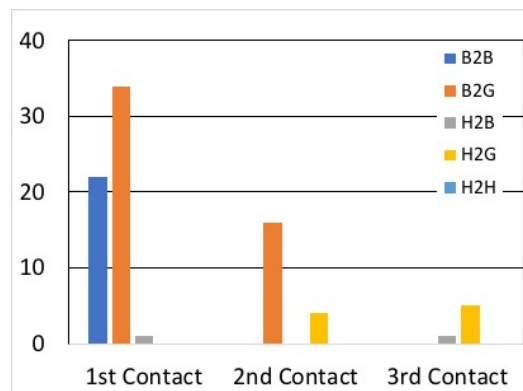


Fig. 2. Distribution of contact type by 1st, 2nd and 3rd contact of play. B2G and B2B were the most common types of impact. No H2H impacts were detected. H2G impacts only occurred on the 2nd or 3rd contact.

TABLE II

PRELIMINARY ANALYSIS OF H2G IMPACTS

	Max Pre-Impact Translational (V, m/s) and Rotational (ω , rad/s)								Change in Velocity at Impact			
	V _{xy}	V _z	V _r	$ \omega_x $	$+\omega_y$	$-\omega_y$	$ \omega_z $	ω_r	ΔV_R	Δt_{window}	$\Delta \omega_R$	Δt_{window}
Avg.	5.03	-3.62	5.91	8.97	8.31	-16.03	11.33	21.46	2.96	0.06	23.4	0.07
Med.	4.83	-3.69	5.82	9.60	7.12	-10.38	6.89	20.31	2.98	0.06	21.8	0.06
Min.	1.45	-4.85	2.16	2.22	1.02	-36.58	3.35	11.37	1.47	0.04	10.1	0.05
Max.	8.15	-1.69	9.31	12.94	20.55	-6.94	34.04	37.03	4.89	0.10	43.3	0.09
SD	2.05	1.11	2.18	3.64	6.81	9.75	9.47	9.24	1.13	0.02	10.8	0.01

V_{xy}, horizontal (ground) plane; V_z, vertical; V_r, resultant; ω_x , head lateral flexion; $+\omega_y$, head extension; $-\omega_y$, head flexion; ω_z , head twist; ω_r , resultant.

IV. DISCUSSION

Preliminary findings suggest that head impact kinematics can be tracked in an American football field environment using a modified action camera with 2.7 K/120 fps setting. It should be noted that 120 fps underpredicts ΔV and $\Delta \omega$ in the first one or two frames (8–16 ms) since the impact very rarely occurs at the instant an image is acquired. Therefore, head accelerations cannot be calculated. This appears to be a reasonable trade-off, however, when considering the degradation in image quality when the frame rate is increased to 240 fps and resolution decreases to 1080 p and still allows for an estimate of head ΔV and $\Delta \omega$. Preliminary findings suggest that head impacts in American 7-v-7 football occur more commonly on the 2nd or 3rd contact of an impact and tend to involve H2B or H2G, and not H2H. Head ΔV and $\Delta \omega$ were 3.0 ± 1.1 m/s and 21.5 ± 9.2 rad/s, respectively, in the nine H2G impacts analysed. None of these impacts resulted in a reported injury.

V. REFERENCES

- [1] Lynall, R., et al., *J Neurotrauma*, 2019.
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