Quantifying and Characterising Head Kinematics from Non-Contact Events using Instrumented Mouthguards

Quantifying and Characterising Head Kinematics from Non-Contact Events using Instrumented Mouthguards

James Tooby, James Woodward, Gregory Tierney

I. INTRODUCTION

A 10 *g* resultant threshold is commonly applied within studies measuring head acceleration events (HAEs) using instrumented mouthguards and other wearable sensors [1]. This threshold is implemented with the rationale of removing HAEs from non-contact events such as running, jumping, and cutting manoeuvres. No HAEs exceeded 10 *g* during non-contact events in a biteplate study, with the highest peak linear acceleration (PLA) being 9.54 *g* during a vertical leap activity [2]. Video analysis of HAEs measured by instrumented mouthguards (iMG) revealed that 75.7% of HAEs from contact events occur below 10 *g* in rugby league [3]. Therefore, the application of a 10 *g* threshold may withhold information on the HAE exposure placed on sports players. Consequently, better thresholding techniques are necessary when considering the long-term exposure to HAEs.

II. METHODS

The cohort consisted of 85 professional rugby union players (66 male, 19 female), who were equipped with custom-fit iMG (Prevent Biometrics, Minneapolis MN) for a total of 185 player matches. iMG devices were set with a 5 *g* trigger threshold, meaning that an iMG-triggered event (i.e. a HAE) was collected when a single linear acceleration sample along any axis of the accelerometer exceeded 5 *g*. Linear kinematics were transformed to the head centre of gravity (CG) and all kinematics were filtered by a 4-pole, zero phase, low-pass Butterworth filter with a corner frequency of 200 Hz. Only HAEs deemed to be true positives as per Prevent's detection algorithm were used in the study. For each match, individual devices were time-synchronised to multi-angle video footage to account for differences between the internal clocks of the devices. iMG events were video analysed to determine whether each iMG-triggered event was caused by a contact event or a non-contact event. Contact events included direct contact with the instrumented player's head or indirect HAEs caused by contacts to the body, whilst non-contact events included HAEs from voluntary movements such as running, jumping and cutting manoeuvres. iMG devices outputted 6 degree-of-freedom time-series data, from which PLA and peak resultant angular acceleration (PAA) were extracted. For each HAE, at the index of PLA, the proportion of linear acceleration along each axis was calculated.

III. INITIAL FINDINGS

Non-contact events accounted for 5.8% (n = 279) of all HAEs. The median (IQR) non-contact events per player, per match was 0.5 (0 – 2). Half (n = 92) of all player matches resulted in zero non-contact HAEs. The median (IQR) values for voluntary events were 8.7 (7.9 – 9.8) *g* and 209.5 (167.1 – 287.6) rad/s^2. Applying thresholds at the 95th percentile of voluntary events for PLA (12.7 *g*) and PAA (448.1 rad/s^2) would remove 60.8% (n = 2864) and 7.8% (n = 366) of contact events from this dataset, respectively.

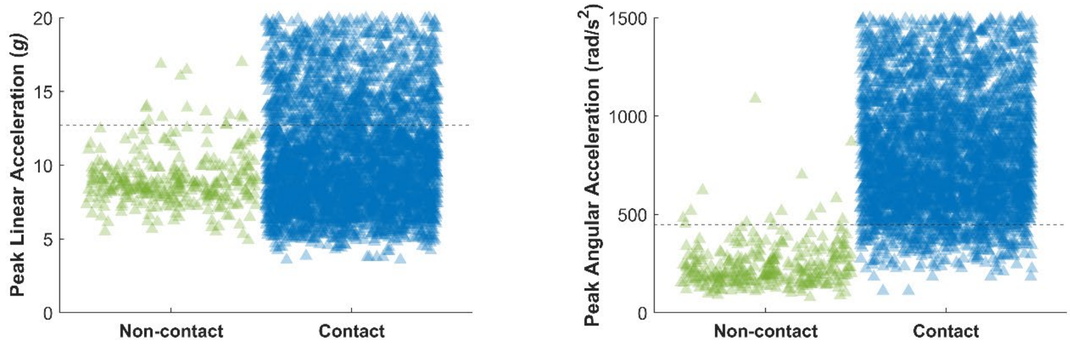

Fig. 1. Peak resultant linear and angular accelerations from non-contact and contact HAEs.

J. Tooby is a PhD student at Leeds Beckett University, UK (+447728569737, j.tooby@leedsbeckett.ac.uk). J. Woodward is a PhD student and G. Tierney is an Assistant Professor in Biomechanics at the University of Ulster, UK.

Figure 2 shows that non-contact HAEs most commonly occur due to negative z-axis and positive x-axis accelerations, whereas accelerations through the y axis are less common based on the SAE-J211 head coordinate system. Contact HAEs appear to occur across all three axes in both directions, and as a result, are not as well characterised by their directions of acceleration as non-contact HAEs.

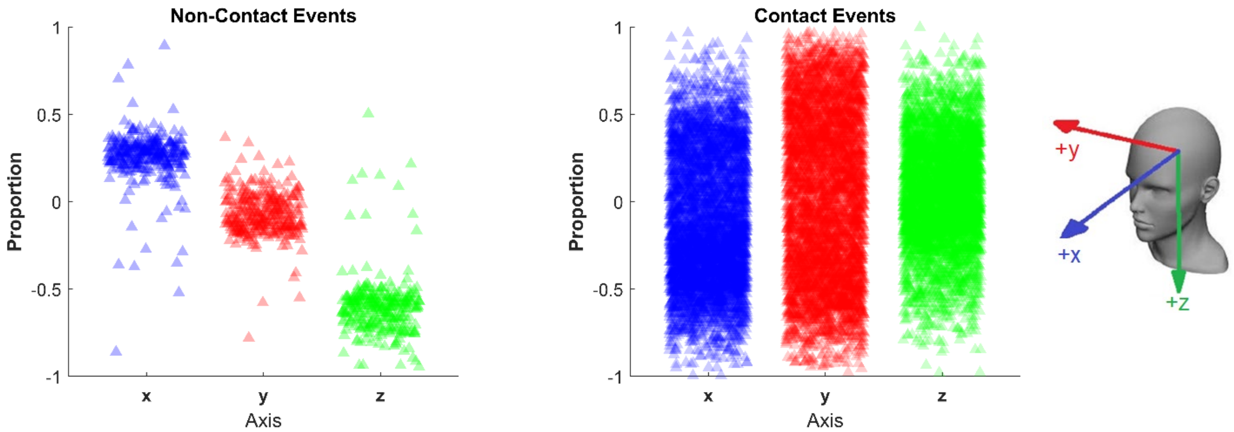

Fig. 2. The proportions of linear acceleration along each axis at the index of the peak of resultant acceleration for contact and non-contact events. For a given HAE, the sum of the absolute proportions is equal to 1. A positive head acceleration solely along the x-axis would have proportions of x = 1, y = 0 and z = 0. The SAE-J211 coordinate system is pictured (right).

IV. DISCUSSION

These preliminary results demonstrate that applying an angular acceleration threshold may be a better solution to removing non-contact HAE from instrumented mouthguard datasets than a linear acceleration threshold. However, as the trigger threshold uses linear acceleration there may be a sampling bias which may preclude HAEs that are low in linear acceleration (below 5 *g*) but high in angular acceleration. Future work may seek to optimise a threshold value that retains contact events and removes non-contact events using PAA, or a combination of both. In this cohort, half of all player matches resulted in zero non-contact events which may suggest that thresholds should be specific to the individual or population. Alternatively, given that non-contact HAE seem to be well characterised by their directions of linear acceleration, a machine learning approach may be the most effective solution in distinguishing between contact and non-contact HAE.

V. REFERENCES

[1] King D et al, Sports Med, 2016
[2] Ng TP et al, Biomed. Sci. Instrum., 2006
[3] Tooby J et al, Sensors, 2022