Internal Impact Validation

Technical Report

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1. Introduction

Several wearable athlete tracking systems provide a collision variable calculated from unvalidated algorithms. In lieu of using an automatic collision detection algorithm, we sought to quantify impact frequencies directly from raw accelerometer data measured by one of these systems (EVO, Catapult Sports, Australia). The aim of this technical report is to provide a framework for practitioners to follow in the detection of contact-based events in sport. We recognise that in using this method we are detecting the presence of impacts as measured by *g*-forces which may not directly correlate with contact events coded by video footage.

From here on in, reference to an impact will refer to the specific method of identifying any contact-based activity using the following methods, whereas a collision refers to contact-based activity identified through either an unvalidated algorithm or hand notation during video performance analysis.

2. Methods

Participants

The dataset for this project was provided by Rugby Australia (RA), the governing body for rugby union in Australia. Data was collated from a total of 161 male rugby union players across the following positions: front row (n = 45), lock (n = 18), back row (n = 27), inside back (n = 45), outside back (n = 26). Data was obtained during two seasons (2018 – 2019) of the Super Rugby competition, involving 95 matches. (2232 player-games). All procedures were approved by the La Trobe University Human Research Ethics Committee (HEC19375).

A smaller subsample of data was used in the internal validation process. A random sample of 15 player-game files were used in this analysis and represent examples from each position, multiple games and across both seasons.

Procedures

All athletes wore micro technology devices (Evo, Catapult Sports, Australia) during every scheduled competition game. The EVO athlete tracking system contains a 10 Hz Global Navigation Satellite System (GNSS) receiver chip to measure position and speed, and a 100 Hz triaxial accelerometer to measure linear acceleration.

The internal validation process occurred over five steps (Figure 1). Following the combination of positioning (GPS) and accelerometer datafiles, a process was applied to find the optimal impact detection threshold and then smoothing filter. This process allows for detected impacts to correspond to contact-based events, validated by matching data with OPTA video-coded files, and removes instances of impacts due to other movements such as a heavy foot strike or change of direction. There was no upper threshold applied to the impact detection process in this analysis.

Phase 1

Data combination

- 2232 raw accelerometer files (100 Hz) was matched with raw velocity data (10 Hz), both housed internally in the GPS unit. Combined files were reported at 10 Hz.
- Outlier files (n=5, accelerations >15 *g*) were identified. Time stamped instances were matched to OPTA video footage to identify if erroneous.
- These outlier files were found to correspond to impact occurrences and were not errors. As such, they remained in the dataset.

Phase 2

Threshold detection

- Threshold detection began at an acceleration magnitude value of 2 *g* and increased by 0.5 *g* to view impacts detected at different *g*-force thresholds.
- Video footage and annotations of events which aligned with the identified impacts for each threshold were observed.
- Each impact threshold level was observed until 20 false positives (FP) occurred. Once 20 FP were reached, the impact level increased by 0.5 *g* and the process was performed again until 0 FP were recorded.
- The detection process finished once a threshold was found to removed unwanted movements such as kicking and hard change in direction and only represented movements which included only physical impacts with another player or the ground

Phase 3

Threshold – Secondary Confirmation

- Once a threshold value was set (5.0 *g*), a secondary confirmatory process was undertaken by cross referencing the OPTA video coded XML files with annotated technical events against the aligned accelerometer data.
- A random selection of 15 player game files were used to create acceleration traces for all coded tackle events for an athlete within a game (152 coded tackle events).
- For each coded tackle event, visual identification and annotation of the coded tackle also occurred. This allowed for further identification of the ability for the accelerometer trace to identify contact events.

Phase 4

Filtering

- To reduce error, it was decided that a smoothing filter needed to be applied on the data.
- Smoothing filters of 0.05 s, 0.1 s and 0.5 s were applied to the 15 player game files.
- Potential impacts were identified using the 5.0 *g* threshold established in the threshold detection phase for each smoothing filter. This was then matched with the time stamped video footage for each identified impact.
- Annotations and video examples of each impact occurrence was captured and used to calculate the False Positive rate for each smoothing filter applied.

Phase 5

Filtering – Secondary Confirmation

- As a secondary confirmation, the OPTA XML file was aligned with the GPS combined file. Coded tackles were matched to identified impacts using the three different smoothing filters (>5 *g*).
- Accelerometer traces incorporating each smoothing filter using 5 *g* as the threshold were matched to OPTA coded tackles
- This allowed for the quantification of a False Negative Rate for each smoothing filter.
- Once an optimal smoothing filter was identified, Sensitivity of final impact detection method could be calculated.

Figure 1: Details of the five phases taken in the overall internal validation process for impact detection.

3. Results

The first threshold to record 0 false positive (FP, incorrect detection of an impact) contact-based event was found at 5 *g*. All threshold values prior to this recorded 20 or more FP events. Therefore, it was found that an impact threshold of 5 *g* was most appropriate for accurately capturing impact events such as in-play contact with other players (rucks and breakdowns) and tackles (made and by opposition). Impacts less than 5 *g* were omitted from the analysis as these consist of foot contacts from walking, running, or changes in direction which were not appropriate.

Figure 2 shows an example of the secondary confirmation process for the threshold detection. Within one game, the OPTA video coded file identified 10 tackle events for this player. The accelerometer trace for each of those 10 coded tackles appear in Figure 2, with the 5 *g* threshold represented as the dotted line. In this instance, all 10 coded tackles are correctly identified using the 5 *g* threshold. Visual representations and annotations of each of the same 10 tackles are provided in Figure 3. As can be observed, there is considerable variation in tackle type and intensity of each of these coded impacts.

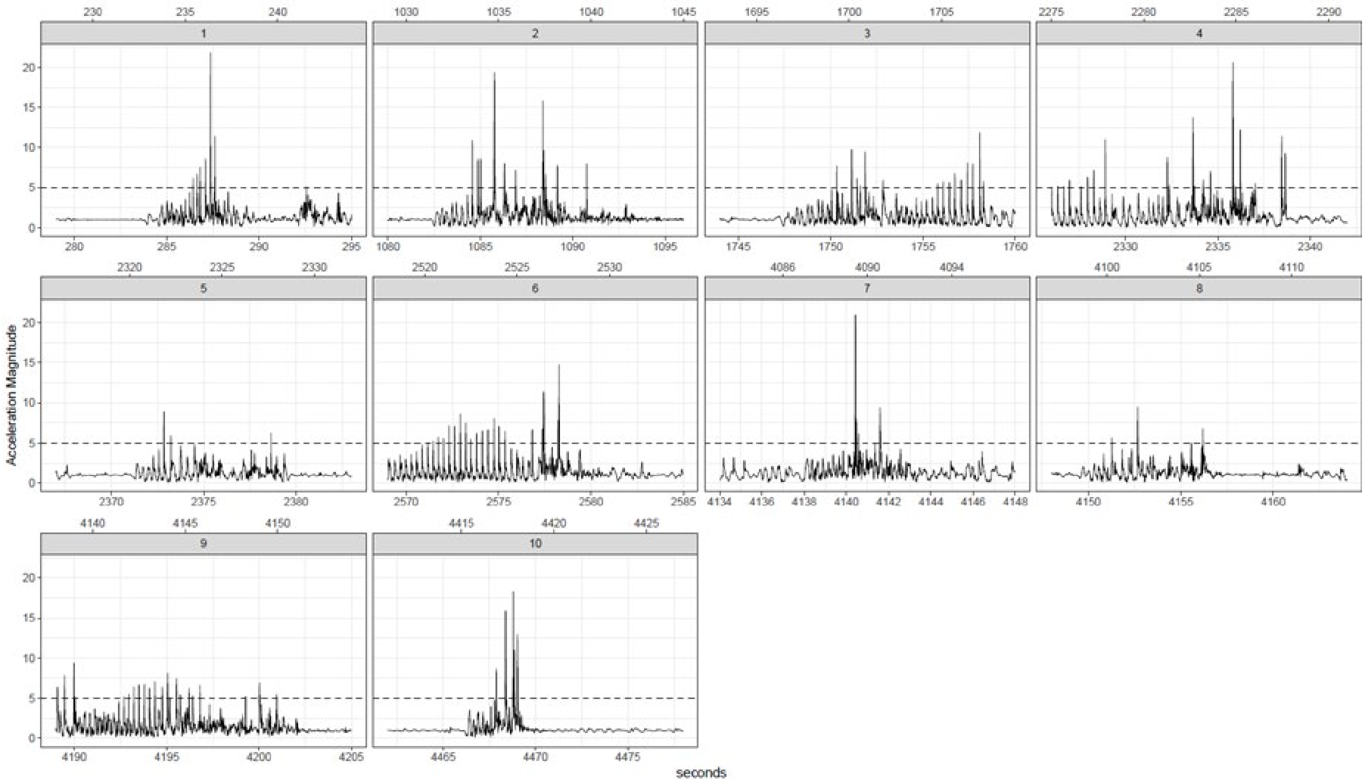

Figure 2: Accelerometer magnitude plot examples of coded OPTA file tackle events for one player-game file. Dotted line representes the 5 *g* threshold used.

1. Lineout prior to contact  Front on RUNNING tackle; DOESN'T go to ground	2. Lineout Prior to contact  Front on RUNNING tackle; Multiple players in contact; DOES go to ground	3. Linebreak prior to contact  MISSED RUNNING tackle; slight contact with player; DOES go to ground	4. Linebreak prior to contact  Front on STATIONARY tackle; Multiple players in contact; DOESN'T go to ground
5. Knock on penalty result of tackle  Front on STATIONARY tackle; DOESN'T go to ground; knock on ball lost in tackle	6. Linebreak prior to contact  Front on STATIONARY tackle; DOES go to ground; drags opponent to ground with him	7. Running into contact  Front on RUNNING tackle; DOES go to ground; brings opponent down with him;	8. 3rd man into contact  Soft Front on STATIONARY tackle; 3rd man in; Does get lifted and flipped in ruck
9. Makes contact, then wrestle  Soft Front on RUNNING tackle; DOES go to ground; then involved in wrestle with opposition	10. Scrum Prior to contact  Front on MISSED RUNNING tackle; DOES go to ground; opposition continues to run overtop		

Figure 3: Image examples and annotations for each OPTA coded tackle event.

Using the 5 *g* threshold, various smoothing filter were then applied to identify the most appropriate for use (Figure 4). A smoothing filter at 0.5 s had the lowest FPR (0%), however, also had a high FNR (41%) and poor sensitivity (68.6%). As such, a smoothing filter of 0.1 s was determined to be the most accurate for detecting impacts with a low FNR (13%), an acceptable level of FP (9%) and 91.1% sensitivity (sensitivity = TP / (TP+ FN).

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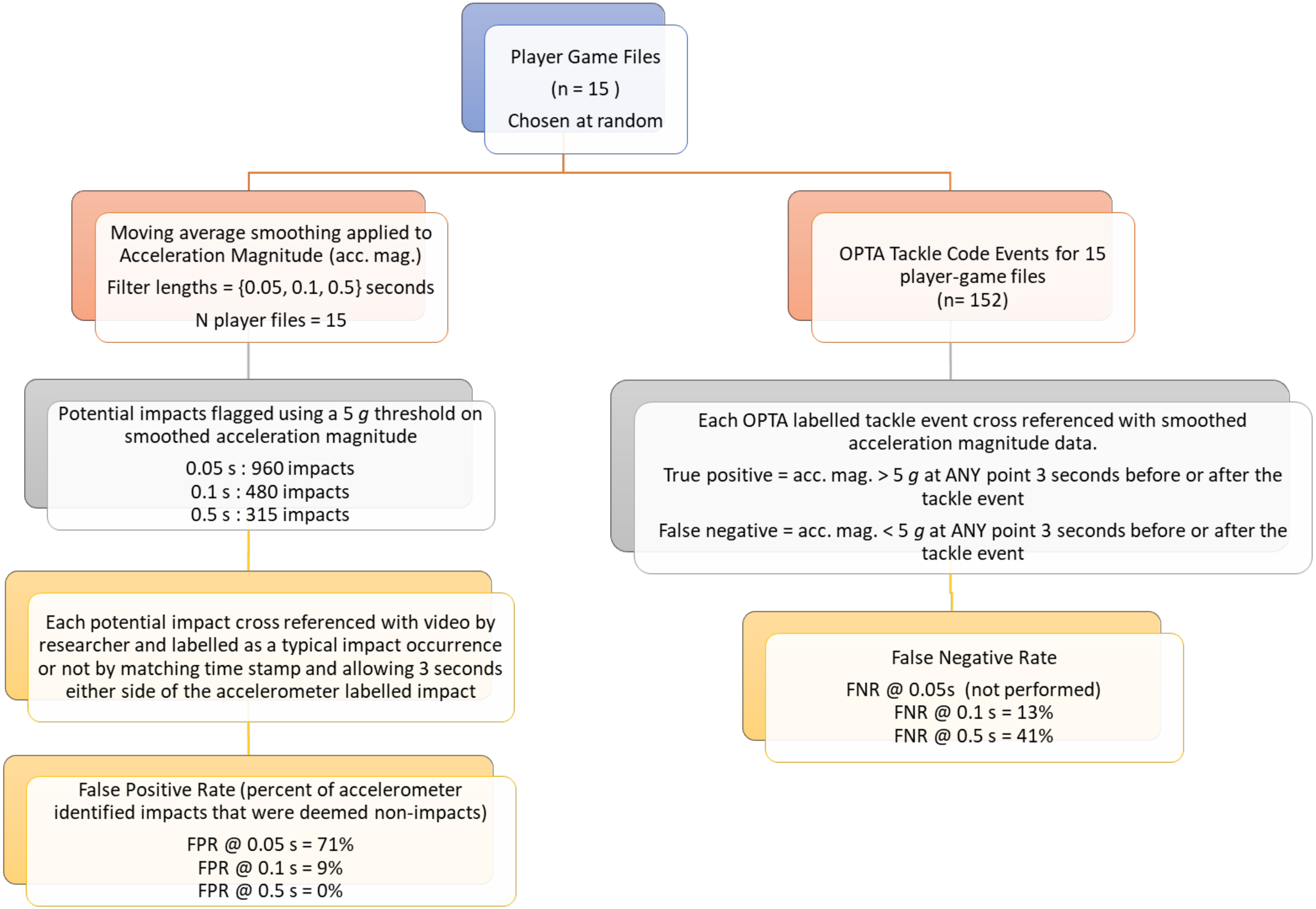

Figure 4: Flow chart diagram of the filtering process which was undertaken as phase four (left hand side) and five (right hand side) in the internal validation process. False positive rates (FPR) and false negative rates (FNR) reported for each filtering level observed included.

4. Conclusion and Future Work

Conclusion

In conclusion the internal validation process found that a *g*-force value of 5 *g* and a 0.1 s smoothing filter was accurate at detecting impacts in professional rugby union players. When matched with video coded footage, this resulted in a FPR of 9% and a FNR of 13%.

In lieu of validated collision detection algorithms, the process outlined here for the use of EVO accelerometer data to identify impacts in rugby union players appears appropriate. It is encouraged that this internal validation process be undertaken for specific cohorts of interest, however, the general use of a 5 *g* threshold and a 0.1 s smoothing filter should provide reasonable impact detection within similar cohorts. Consideration should be taken for cohorts of female players, youth or sub-elite competitions, and different collision-based sports due to differences in the body composition of individuals and the variations in technical aspects of match-play. Future research should also look to validate the various company-specific collision algorithms.

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