Quantification of inertial sensor impacts using video analysis in elite rugby union

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Aim

The aim of this study was to identify which activities, based upon video analysis, are responsible for impacts at different intensities, with the intensity measured via the inertial sensor in the GPS unit. Based upon prior research [5-7], inertial sensor impacts involving ≥ 9 G were identified as the most likely to impair subsequent performance and these therefore warranted further investigation. It was hypothesised, that as the inertial sensor impact increases, the percentage of impacts from collisions would also increase and the percentage of impacts from accelerations, decelerations and changes of direction would decrease.

Research by McLellan et al., [3] noted that neuromuscular fatigue was highly dependent upon the number of heavy inertial sensor impacts (> 7.1 G) experienced during game play, with many authors noting positional differences in the number of inertial sensor impacts experienced during match play [8-11]. Collision events recorded using GPS have been compared to video analysis and were noted to strongly correlate (r = 0.89, 0.97 and 0.99) with mild, moderate and heavy collisions respectively, therefore supporting GPS use [12]. In contrast, research in elite level rugby union [13] illustrated inaccuracies in collision assessment, where the smallest mean difference between micro technology and video coding was noted at 2.5 G collision threshold, with statistical differences noted between some positional groups. As reported within rugby union time-motion analysis research [14, 15], the majority of collision events happen during tackle situations, potentially emphasising that a greater number of tackles has greater impact upon post-match fatigue. However, when considering that time-motion analysis only provides a frequency of events with no magnitude of load, some of the data produced by time-motion analysis research may be erroneous and therefore misleading. Reardon et al., [13] stated that GPS technology was not a valid technology for detecting rugby union collisions. A process of combined data collection including both GPS data and video recordings was recommended by Cunniffe et al., [9] for use in elite rugby union in order to produce a more thorough analysis of match demands. Despite research [13] assessing collision counts in elite level rugby union existing, this experimental study differs as it aims to match single collision events coded by inertial sensors to the relevant passage of play within the video file. The results of this study therefore have implications, not only for the players involved, but also for practitioners aiming to implement training sessions in the days post-match.

Method

Athletes

The assessment period covered seven games during a competitive rugby union playing season, with data collected upon one individual from each of the nine positional groups including prop (n=1), hooker (n=1), lock (n=1), back row (n=1), scrum half (n=1), out half (n=1), centre (n=1), wing (n=1) and full back (n=1); meaning nine sets of game data were assessed (age 27.7 ± 5.5 years, height 186.1 ± 10.3 cm, mass 97.4 ± 13.2 kg, training age 9.4 ± 5.7 years).

Match Analysis

GPS Analysis. Player positions were defined as props, hookers, locks, back rows, scrum half, out half, centres, wings and full backs. The match characteristics exported from the GPS units included: accelerations, decelerations, collisions, 9.01-11 G inertial sensor impacts, 11.01-13 G inertial sensor impacts and > 13 G inertial sensor impacts. Measurements were taken with 10 Hz GPS units (StatSports Viper, Northern Ireland) throughout all games in order to assess movement patterns.

GPS impacts are a combination of collisions and impacts created from movement (stepping, jumping, and decelerations). Accelerations and decelerations were also collated by the StatSports Viper GPS unit, with this data collected purely by the accelerometer. Acceleration is a change in velocity/time (using GPS data), with individual acceleration thresholds similar across positional groups, based upon longitudinal analysis of players performing maximal accelerations. Prescribed zones were then categorised from these maximal values and manually inputted into the StatSports Viper software. Collisions (including or excluding set piece elements of rugby union match play) across all positional groups was not considered a concern as the data comparison between all nine positional groups was normalised via percentage calculations of each collision occurring, meaning this potential disparity between positions was accounted for.

Video Analysis. Nine individual player videos were collected with the sole use of typical game footage (side on and covering multiple players) considered too broad for use within

Headline

A n understanding of the cause and magnitude of impacts experienced during elite rugby union match play is an important consideration for practitioners. The development of Global Positioning Systems (GPS) and video analysis technology provides detailed objective data relating to specific movement demands of players [1, 2]. Many studies have attempted to assess the influence of match variables upon restoration of performance [3, 4], yet few studies have incorporated inertial sensor impact variables when evaluating match demands and associated post-match fatigue.

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Design

An observational research design was implemented, with the GPS data providing the magnitude of the inertial sensor impact experienced by the players, and the video footage acted as a reference file against which to compare the inertial sensor impacts. This ‘sense check’ assessment enabled assessment of whether these impacts involved collisions, change of direction, accelerations or decelerations.

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this study. Therefore close up ‘side on’ individual player cameras were also administered alongside. This combination of videos supplied greater detail to activities in contact situations, where typical television footage of the player may be obscured by other players on the field, or by replays of previously completed match events (scrum, ruck and tackle situations). As a result, from the video footage, practitioners would be able to determine if the inertial sensor impact data elicited at the moment in question is actually what is expected for these actions.

**Statistical analyses**

Statistical analysis was performed using SPSS Version 20 (IBM), with an a priori alpha level set at $p < 0.05$. As playing positions are different in the match demands required, analysis of the percentages distribution of match characteristics was considered important alongside analysis of absolute values. Repeated measures ANOVAs with Bonferroni post-hoc analysis, or non-parametric equivalent (Freidman’s test, with multiple Wilcoxon’s tests for pairwise comparison and subsequent Bonferonni correction applied) were conducted to compare the difference between percentage distribution of inertial sensor impacts incurred by collisions and those that resulted from changes of direction, acceleration or deceleration, across inertial sensor impact zones. Subsequent repeated measures ANOVAs with Bonferroni post-hoc analysis, or non-parametric equivalent (Freidman test, with multiple Wilcoxon tests for pairwise comparison and subsequent Bonferonni correction applied) were performed to determine if there was a significance difference in the percentage of activities resulting in inertial sensor impacts within each zone. Furthermore, Cohen’s d effect sizes (ES) were calculated to determine if any meaningful differences occurred, interpreted based upon the criteria suggested by Cohen [16] and were interpreted as follows; trivial $\leq 0.19$, small $= 0.20 - 0.49$, moderate $= 0.50 - 0.79$ and large $> 0.8$.

**Results**

When assessing absolute values, RMANOVA revealed no significant difference ($p = 0.061; d \geq 5.25; 9.01-11 G$ impacts $= 15 \pm 0.7$; $11.01-13 G$ impacts $= 11 \pm 0.6$; $> 13 G$ impacts $= 13 \pm 0.6$) in collisions between inertial sensor impact zones (Figure 1). Friedman tests revealed that a significant difference ($p < 0.001$) occurred in the frequency of inertial sensor impacts as a result of changes of direction, with Wilcoxon revealing that the greatest number of inertial sensor impacts at $9.01-11 G$ occurred as a result of collisions ($3.8 \pm 3.2$), which was significantly greater than the number of inertial sensor impacts from changes of direction at $11.01-13 G$ ($p = 0.007, 0.0 \pm 0.0; d = 1.67$) and $> 13 G$ ($p = 0.011, 0.2 \pm 0.4; d = 1.57$). The largest frequency match demand in all zones was collisions ($9.01-11 G = 32.7 \pm 40.0%$; $11.01-13 G = 61.9 \pm 8.4%$; $> 13 G = 76.3 \pm 32.1%$) and the frequency of collisions increased in comparison to other zones as the magnitude of the inertial sensor impact also increased (Figure 3; Table 1). Decelerations ($9.01-11 G = 27.9 \pm 33.2%$; $11.01-13 G = 25.3 \pm 16.9%$; $> 13 G = 6.6 \pm 40.9%$) were noted to decrease as the magnitude of the inertial sensor impact increased, while accelerations ($9.01-11 G = 30.8 \pm 34.3%$; $11.01-13 G = 12.8 \pm 12.3%$; $> 13 G = 15.8 \pm 31.7%$) and changes of direction ($9.01-11 G = 8.6 \pm 18.8%$; $11.01-13 G = 0.0 \pm 0.0%$; $> 13 G = 1.3 \pm 0.0%$) were lowest in Zone 5. RMANOVA revealed that there were significant differences ($p < 0.05$) in the percentage distribution of inertial sensor impacts at $9.01-11 G$, $11.01-13 G$, $> 13 G$. Friedman tests revealed that a significant difference ($p < 0.005$) occurred in the percentage distribution of inertial sensor impacts within $9.01-11 G$, with Wilcoxon’s tests highlighting that the greatest number of inertial sensor impacts at $9.01-11 G$ occurred as a result of collisions ($32.7 \pm 18.8%$), this being significantly greater than the number of inertial sensor impacts at $9.01-11 G$ from decelerations ($p = 0.012, 27.9 \pm 33.2%$; $d = 0.17$) and changes of direction ($p = 0.008, 8.6 \pm 18.8%$; $d = 1.28$). Friedman tests also revealed a significant difference ($p < 0.005$) occurred in the percentage distribution
of inertial sensor impacts at 11.01-13 G, with Wilcoxon’s tests highlighting that the greatest number of inertial sensor impacts in at 11.01-13 G occurred as a result of collisions (61.9 ± 8.4%), this being significantly greater than the number of inertial sensor impacts in at 11.01-13 G from changes of direction (p = 0.012; 0.0 ± 0.0%; d = 10.42) and accelerations (p = 0.025, 12.8 ± 12.3%; d = 4.66). Lastly, Friedman tests also revealed a significant difference (p < 0.005) occurred in the percentage distribution of inertial sensor impacts at > 13 G, with Wilcoxon’s tests highlighting that the greatest number of inertial sensor impacts at > 13 G occurred as a result of collisions (76.3 ± 32.1), this being significantly greater than the number of inertial sensor impacts at > 13 G from changes of direction (p = 0.008, 1.3 ± 0.0%; d = 3.30).

Discussion

In line with the hypothesis, the results confirm that as the magnitude of inertial sensor impacts increase the percentage of inertial sensor impacts from collisions increase and the percentage of inertial sensor impacts from accelerations, decelerations and changes of direction decrease. The notion that at > 13 G the most inertial sensor impacts accrued were from collisions (Frequency = 13; Distribution = 76.3%) was expected within this study, yet the results from this study showing a large contribution of inertial sensor impacts from collisions at 9.01-11 G (Frequency = 15; Distribution = 32.7%) was unexpected (Figure 1 and 3). The causes of the collision inertial sensor impacts occurring at > 13 G are likely to be due to both the match demands occurring in open field play and those encountered within set piece elements of match play. Players are required to exert maximal force onto the opposition during collision moments in an attempt to halt or continue momentum; meaning collision inertial sensor impacts occurring at > 13 G are likely.

As would be expected within this study, the largest number of changes of direction, accelerations and decelerations were accrued at 9.01-11 G, yet surprisingly, only changes of direction revealed a significant difference in both the percentage distribution of inertial sensor impacts and absolute values between zones (p < 0.0001) (Figures 1, 2 and 3). Absolute values did, however, show significant difference between zones for changes of direction (11.01-13 G, p = 0.007, 0.0 ± 0.0; d = 1.67; > 13 G (p = 0.011, 0.2 ± 0.4; d = 1.57) and accelerations (11.01-13 G, p = 0.018, 0.7 ± 1.3, d = 1.07; > 13 G, p = 0.049, 1.5 ± 2.2, d = 0.98). Upon further assessment of inertial sensor impacts occurring from changes of direction, accelerations and decelerations, separately from those incurred from collision, it was found that decelerations accounted for the greatest proportion of these explosive movements in 9.01-11 G. A further potential point for consideration when considering decelerations is that results from this experimental study alongside prior research [17] would indicate that elite level rugby players (and specifically the backline players), need to therefore be conditioned to be able to perform a high frequency of changes of direction, accelerations and decelerations within training and match play. If elite backline players are not conditioned to perform these demands, it could be argued that avoidance of injury and achievement of optimal performance will be sub-optimal.

The unexpected finding of a large contribution of inertial sensor impacts from collisions has implications for the assessment of likely fatigue. When considered alongside the findings from Suárez-Arrones et al., [18], which indicate that contacts induce greater internal loads (measured via heart rate response) to that accumulated from running, the influence of collisions on restoration of performance and the role that analysis of inertial sensor impact data can have upon this interpretation is further emphasised. In addition, the recommendations by Reardon et al., [13] are of importance for future considerations, as assessment of collision counts in rugby union should perhaps investigate smaller G-force increments. These assessments of smaller G-force increments would develop a better understanding of micro-technology collision classification and therefore potentially avoid the false positives seen within this experimental study, when assessing impacts. Additionally, when considering that Reardon et al., [13] noted in unpublished findings that accelerations are likely to be mistaken for collisions, due to the G-force experienced and the tilt in body orientation associated with acceleration actions, the questionable accuracy of inertial sensor impact data is further emphasised. This notion of accelerations likely to be mistaken for collisions could be explained by an over-coding of inertial sensor impacts at the 2 G threshold, as represented by the frequency of inertial sensor impacts associated with accelerations within this study.

As prior research has not included inertial sensor impacts incurred from accelerations, decelerations and changes of direction, and solely those that involved collisions, the comparison of inertial sensor impact frequencies between the studies is ill advised. In addition to the research by McLellan et al., [3] not involving accelerations, decelerations and changes of direction, the inertial sensor impact zones classifications (measured in G) were different to this study. The differing inertial sensor impact zone classifications between studies, combined with a difference in accelerometer unit specification, mean that the frequency and magnitude of inertial sensor impacts assigned to each study are likely to be misaligned. Future research should therefore perhaps consider the alignment of inertial sensor impact zones between studies to enable better comparison of data.

Practical Applications

- From this research it could be argued that the values presented from inertial sensor outputs alone cannot be taken at face value, as erroneous interpretation of impacts of high magnitude may be incorrectly identified as collisions.
- Inertial sensor impacts experienced during match play are likely to be fatiguing, but the notion that impacts need to be classified is warranted, as some impacts will impose more fatigue than others depending upon the match demands and movements involved.
- The use of both video and inertial sensor data will provide a greater representation of match involvements and their likely influence upon fatigue post-match, with percentage distribution and absolute values being key to this interpretation.

Limitations

- The results are only a representation of the individual players in question, yet the time consuming nature of this analysis and the ‘real world’ nature of the elite setting from which the inertial sensor impact data was taken were major determining factors in the testing protocol implemented.
- The fit of the GPS unit between the shoulder blades was a determining factor in the sensitivity of the frequency and distribution of inertial sensor impacts generated. This no-
tion was supported in research [19] which illustrated the influence of wearing a GPS unit either at the scapula area or closer to the player’s centre of mass.
• Many inertial sensor impacts recorded during foot strikes are likely to be vertical accelerations and decelerations and not horizontal impacts, therefore presenting problems for practitioners when assessing the frequency of impacts generated ≥ 9 G.

References

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