EVALUATION OF TACKLING BIOMECHANICS IN RUGBY: VIDEO INCIDENT ANALYSIS AND EXPERIMENTAL SET UP

Elena Seminati[1], Dario Cazzola[1], Ezio Preatoni[1] and Grant Trewartha[1]

Sport, Health and Exercise Science, Department for Health, University of Bath, Bath, UK[1]

This study consisted of a video incident analysis of rugby tackles leading to spinal injuries, where players' behaviours and observed loading mechanisms were coded for each incident. The key features of these events were summarised, revealing the role of high-speed impacts, illegal tackles, and poor tackle technique in injury-causing tackles. In addition, lateral bending moments and lateral flexion movements were more prevalent than suggested by previous research. This investigation informed an experimental protocol for the analysis of simulated rugby tackles, with the final goal to obtain measures of cervical spine biomechanics during tackles. Data captured from this protocol could also be input into a full-body musculoskeletal model to provide descriptions of internal cervical spine loading in different tackle event scenarios.

KEY WORDS: sport impacts, collisions, cervical spine.

INTRODUCTION: Rugby Union (rugby) is a full contact team sport that is associated with a number of potential injury risk factors, including on rare occasions serious spinal injury. Although the incidence due to rugby falls within the 'tolerable risk' category (Fuller, 2008), mortality and morbidity associated with spinal cord injury exert a major impact on the individual who sustains the injury and on broader society. Cervical spine injuries occurring during rugby occur mainly during contact match events, with a higher prevalence for tackles. Because of the features of these high-speed contact events it is difficult to collect information on the mechanisms of such injuries and there is currently very little quantitative data to identify and describe the specific risk factors and injury mechanisms. Specifically, there is a lack of information about the forces, motions and internal loading of anatomical structures involved in specific rugby contact events, and, consequently, little objective knowledge about how injuries could be prevented through targeting of the precise mechanisms of injury in these situations. Qualitative video analysis has the potential to undercover any common themes in injury-causing situations within specific sports and to begin to unpick the mechanisms of injury in various situations by providing more detail on what occurs in the short timeframe around the injury event. There are some examples from rugby, which have considered the prevailing characteristics of rugby tackles associated with injuries (Fuller et al., 2010; McIntosh et al., 2010). However, none of them have focussed in detail solely on tackles producing serious neck injuries and no diagnosis was provided. In this study we aim to achieve two main objectives: i) to extract the key characteristics of real injurious rugby tackle events through video analysis, as an initial step for identifying the injury mechanisms; ii) to devise an experimental set-up for the analysis of rugby tackles in order to describe the biomechanical load experienced by the tackling player.

METHODS: *Video analysis*: A descriptive video analysis was designed with an initial pool of 28 videos (obtained via rugby contacts in England, New Zealand, South Africa, and via keyword searching of YouTube© to obtain additional broadcast footage). The initial pool of injury cases was reduced to n=19 to include only those injuries recorded from rugby tackle events. A total of five operators (unaware of the specific objectives of the study) coded each of the individual cases independently, by assigning fields to each variable provided on a pre-constructed template (General Description, Tackler and Ball Carrier characteristics, and Injury Event Description). Within each category a number of variables relevant to the cervical spine injury focus were coded. Each field of the analysis template was synthesised from the

five independent operators by selecting the ensemble option when at least 3 of the operators agreed on the same category. Ensemble results were then used in frequency counts for ball carrier injuries and tackler injuries separately to allow extraction of common themes.

Tackle simulation: A tackle simulator was set up using a 50 kg punch bag filled with sand and rags. The punch bag was pulled manually through a pulley from rest, three metres away from the tackler, to reach a velocity at impact that mimics a typical tackling scenario (4.8 ± 2.9 m/s from Hendricks et al., 2012). Four pressure sensors (Model #3005E VersaTek-XL, F-Scan, Tekscan Inc, USA) were used to collect pressure data and derive force data. The sensors were calibrated specifically for the aim of the pilot study and considering the different kind of surface on which the forces act. Two sensors were placed on the punch bag (Figure 1A), while the other two were placed on the left and right shoulder of the tackler, who was standing still, waiting for the impact, with his feet on two force platforms (9287BA, Kistler, Switzerland) sampling GRF data at 2000 Hz (Figure 1B-C). In addition, two inertial measurement units (IMUs) (MTw, Xsens Technology B.V., NL) and 8 reflective markers were positioned on the punch bag to record, respectively, the punch bag acceleration and its displacement. A total body biomechanical model was developed to provide kinematic measurements of the tackler and to drive future musculoskeletal simulations. Markers positions (69 markers) were recorded with a 16-camera motion capture system (Oqus, Qualysis, Sweden) at 250 Hz. A bespoke control and acquisition system (cRIO-9024, National Instruments, Austin, Texas, USA) synchronously triggered the acquisition hardware (IMU, Tekscan and Qualysis) and 6 separate trials were recorded.

RESULTS: *Video analysis*: 2 out of 19 injuries were omitted from the analysis because there was not complete agreement between operators on which of the players (ball carrier or tackler) involved in the event was injured as a result of the tackle. This left 10 tackle injury events coded as injuries to ball carriers and 7 tackle injury events coded to tacklers.

For injuries sustained by ball carriers, 5 out of 10 involved instances where the ball carrier was tackled by more than one tackler. Half of all ball carrier injuries were as a result of tackles which were coded as illegal tackles. Initial contact was made on the ball carrier's head/neck (7 out of 10 injuries), upper trunk (2 out of 10), or shoulder (1 out of 10) region. There was considerable variation in the loading conditions coded for ball carrier injuries. For example, loading type between different injury events was variously determined as flexion (3), extension (3), lateral bending (3) and combined loading (1 out of 10).

For injuries to tacklers, most cases involved a tackle event with only one tackler (5 out of 7 injuries), with 2 out of 7 cases occurring when two tacklers were present. In all cases of tackler injuries the operators determined that the attempted tackle would have been deemed law compliant (legal). However, while the tackles were deemed legal, in 5 out of 7 cases the initial contact point on the tackler was the vertex of the head with the remaining cases making contact with the upper trunk or shoulder. The type of loading was categorized variously as compression (2 injuries), flexion (1 injury), lateral bending (1 injury) and unsure (3 injuries). The neck position of the injured player just prior to impact was neutral (2 injuries), flexed (2 injuries) or laterally flexed (3 injuries). Interestingly, in 4 out of 7 cases the primary neck motion during the impact event was considered to be lateral flexion, with the remaining cases being compression motion (1 injury), flexion (1 injury) or unsure (1 injury).

Tackle simulation: Punch bag velocities estimated from its centre of mass position at contact were on average 4.06 ± 0.16 m/s. Mean acceleration peak measured with the IMUs was 8.80 ± 0.60 g. Peak impact forces estimated with the Tekscan sensors on the punch bag (simulated ball carrier) were on average 1.96 ± 0.26 kN, versus 1.78 ± 0.35 kN for the sensors on the shoulders of the tackler (Figure 2).
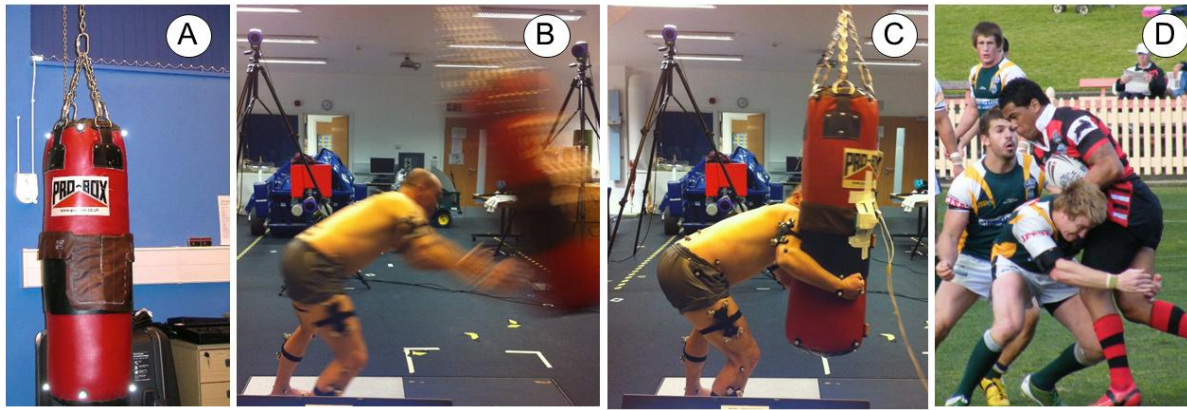
Figure 1: A: instrumented punch bag; B: tackler preparing for the tackle; C: simulated tackle; D: real tackle (CC BY-SA 2.0, by John Tamanika).
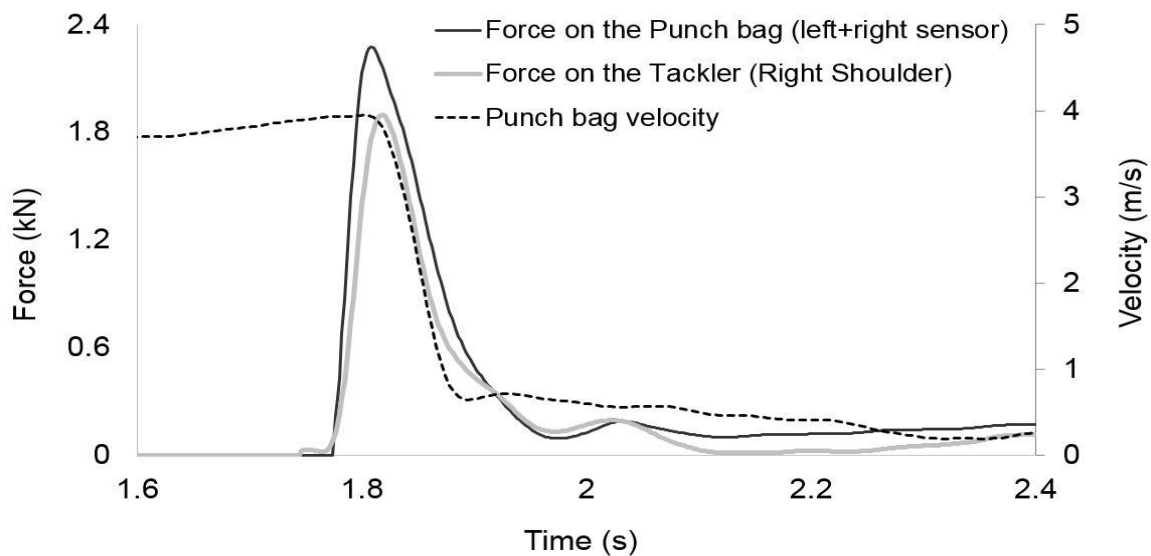

Figure 2: Example of forces measured on punch bag (black line) and tackler (grey line), and punch bag velocity (black dashed line), versus time.

DISCUSSION: The aim of this study was to use a video incident analysis to describe the mechanisms of cervical spine injuries caused by rugby tackles in order to set up an experimental protocol to describe the biomechanical loads experienced by the tackler. Tackle-related injuries were typically associated with highly dynamical occurrences, especially in the frontal direction. Similar to previous research (McIntosh et al., 2010), the injury cases reviewed in this study support that notion that injury risk is increased if either or both the ball carrier and tackler are moving at high speed, often with both the ball carrier and tackler both moving at medium-high speeds. The analysis supports previous suggestions of the need for continuing player/coach education to encourage tackling players to use sound tackling technique in terms of foot placement, trunk and head position, and legal tackling techniques (not high or collision [no arm] tackles) to minimise their own and the ball carrier's injury risk. In terms of loading characteristics, there was a variety of loading types observed, indicating that there is no single mechanism leading to cervical spine injury from rugby tackles. Even if this analysis is likely not refined enough to concretely address the issue of whether 'hyperflexion' or 'buckling' mechanisms predominate, it has highlighted that a range of loading types are observed in tackle situations which lead to serious neck injury, which in addition to flexion and compression loads certainly include elements of extension loading (for ball carriers) and lateral bending for both ball carriers and tacklers.

In the present analysis, only tackle events resulting in spinal injuries have been analysed so there is no knowledge of how the characteristics of these tackles compare with the characteristics of tackles which do not lead to cervical spine injury. However the video incident analysis uncovered some recurring themes and informed the development of an experimental protocol able to simulate tackles events, whose outcomes will be exploited to drive computer musculoskeletal model simulations of potentially injurious scenarios. In this way it will be possible to understand how contact loads transmit across the anatomical structures and translate into mechanical stresses acting on the cervical spine and upper trunk of the player.

The tackle is one of the most open and unpredictable events in the game, in terms of the movements performed, and is a challenging situation to take measurements from. Even if we didn't consider all the variables analysed with the video analysis, the experimental set up organised for the pilot study seemed to successfully replicate the real tackle event (Figure 2D). Maximal punch bag (ball carrier) velocity and force peaks measured through pressure sensors, reflected values from the literature (Hendricks et al., 2012; Pain et al., 2008). Usman et al. (2011) estimated values between 1.6 and 1.7 KN for the forces acting on the shoulder during a frontal tackle, while Trewartha & Stokes (2003) reported values between 1.95 and 2.31 body weights. Some limitations characterise this set up: shear forces are not considered and the force acting on the punch bag vs. the force acting on the tackler shoulder revealed a mean difference of 336.6 N (17%). However we decided to remove the pressure sensors from the tackler shoulder for future trials to improve the motion analysis results for the shoulder region.

CONCLUSION: This analysis represents an initial attempt at synthesising data on the circumstances of rugby tackle events which are known to lead to serious spinal injury. The analysis has reinforced certain risk elements which have been suggested from previous rugby tackle studies, including the role of high-speed impacts in injury-causing tackles, particularly of the tackler during tackler injuries. It is apparent that a range of mechanisms of injury (loading characteristics) can lead to cervical spine injuries in rugby but this analysis has begun to suggest that lateral bending loads and lateral flexion neck movements are important aspects to consider moving forward in the quantitative analysis that will be performed with a simulated tackle event as described before.

REFERENCES:

Fuller, C.W., 2008. Catastrophic injury in rugby union is the level of risk acceptable? *Sports Medicine,* 38, 975-986.

Fuller, C.W., Ashton, T., Brooks, J.H.M., Cancea, R.J., Hall, J., Kemp, S.P.T. (2010). Injury risks associated with tackling in rugby union. *British Journal of Sports Medicine* 44, 159-167.

Hendricks S., Karpul D, Nicolls F. & Lambert M. (2012). Velocity and acceleration before contact in the tackle during rugby union matches. *Journal of Sport Science* 30, 1215-1224.

McIntosh, A.S., Savage, T.N., McCrory, P., Frechede, B.O., Wolfe, R. (2010). Tackle Characteristics and Injury in a Cross Section of Rugby Union Football. *Medicine and Science in Sports and Exercise,* 42, 977-984.

Pain MTG, Tsui F. and Cove S. (2008). In vivo determination of the effect of shoulder pads on tackling forces in rugby. *Journal of Sport Science,* 26, 855-862.

Trewartha, G., & Stokes, K. (2003). Impact forces during rugby tackles [abstract] in *Procedings of the International Conference on the Science and Practice of Rugby.* 2003. P25.

Usman, J., McIntosh, A.S., & Frechede B. (2011). An investigation of shoulder forces in active shoulder tackles in rugby union football. *Journal of Science and Medicine in Sport.* 547–552.