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Consensus on a video analysis framework of descriptors and definitions by the Rugby Union Video Analysis Consensus Group

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Abstract

Objective: Using an expert consensus-based approach, a Rugby Union Video Analysis Consensus (RUVAC) Group was formed to develop a framework for video analysis research in Rugby Union. The aim of the framework is to improve the consistency of video analysis work in Rugby Union and help enhance the overall quality of future research in the sport.

Design: Systematic Review and Delphi Method

Methods: After a systematic search of the literature, seventeen articles were used to develop the final framework that described and defined key actions and events in Rugby Union (rugby). Thereafter, a group of researchers and practitioners with experience and expertise in rugby video analysis formed the RUVAC group. Each member of the group examined the framework of descriptors and definitions and rated their level of agreement on a 5-point agreement Likert scale (1- Strongly disagree; 2-Disagree; 3-Neither agree or disagree; 4-Agree; 5-Strongly agree).

Results: The mean rating of agreement on the 5-point scale (1- Strongly disagree; 5-Strongly agree) was 4.6 [4.3-4.9], 4.6 [4.4-4.9], 4.7 [4.5-4.9], 4.8 [4.6-5.0] and 4.8 [4.6-5.0] for the tackle, ruck, scrum, line-out and maul, respectively.

Conclusion: The RUVAC group recommends using this consensus as the starting framework when conducting rugby video analysis research. Which variables to use (if not all) depends on the objectives of the study. Furthermore, the intention of this consensus is to help integrate video data with other data (for example, injury surveillance).

INTRODUCTION

Video analysis in sport is the systematic observation and interpretation of video to improve objectivity and reduce the bias and subjectivity that are inherent in human observation.¹ It is a branch of the sports science sub-discipline known as performance analysis which merges qualitative biomechanical methods and notational analysis.^{2,3} Arguably, an unintended consequence of the link between performance analysis and video analysis is that most analyses have a performance-orientated focus.

While the utility of video analysis beyond the scope of performance has been recognised before,^{4,6} its role in understanding injury mechanisms and risk factors, and assisting medical protocols (for example, head injury assessment)^{7,8} and referee decision-making (for example, television match official reviewing dangerous play) in rugby has grown over the last 10 years. This growth has precipitated the need for us to rethink video analysis as a predominantly performance-focused subject. In most team settings and within national and international rugby organisations, routine video analysis work falls within the coaching/performance department, without necessarily satisfying the needs of the medical department in terms of understanding injury mechanisms, risk factors, and assisting with medical decision-making.

An important methodological aspect of video analysis is to clearly describe and define actions and events to reduce bias and improve reliability.^{9,10} Despite this, den Hollander (2018) found that half of all video analysis studies in rugby did not provide clear, detailed descriptions and definitions, while those that did, differed in how they defined certain actions and events, limiting opportunities to make inter-study comparisons.¹¹ For example, some studies use the World Rugby (formerly the International Rugby Board) law definition of the

tackle, which requires the player with the ball (ball-carrier) to go the ground before a tackle can be observed, while other studies defined the tackle as “any attempt to stop or impede the ball-carrier, irrespective of whether or not the ball-carrier was brought to ground ”.¹²⁻¹⁶ For the field to evolve and become more integrated, a framework with clear descriptions and definitions of key actions and events needs to be developed. To address the above-mentioned concerns, the Rugby Union Video Analysis Consensus (RUVAC) group was formed to synthesize a framework of descriptors and definitions to improve the consistency and quality of video analysis work in Rugby Union.

METHODS

A two-step process was used to develop the framework of descriptors and definitions and reach consensus. For Step 1, we performed a systematic search of the literature using the methods described by den Hollander et al. (2018).¹¹ Specific search terms were used to identify peer-reviewed articles in three electronic databases: SCOPUS, PubMed, and Web of Science. The search terms were ‘rugby union’ in the title, keywords or abstracts linked with either of the following terms - ‘performance analysis’, ‘video analysis,’ ‘tackle performance’, ‘video’, ‘notational analysis’, ‘match performance’, ‘match analysis’, ‘time motion analysis’, ‘attacking strategies’, ‘defensive strategies’, ‘performance indicators’, ‘injury risk’, ‘injury mechanisms’ or ‘injury rates’ anywhere in the text. Each of these terms were searched separately with ‘Rugby Union’ either in the title, keywords or abstracts (a total of 14 searches for each database). For example, in Scopus, the full electronic search strategy for the term ‘video analysis’ was - (TITLE-ABS-KEY("Rugby Union") AND ALL ("video analysis")) AND PUBYEAR < 2019 AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (SRCTYPE,"j")). The results of all 14 searches were subsequently merged and duplicates removed. The time frame for the literature search was any study

published up to the 31st of December 2018. The inclusion criteria were as follows: the article needed to use video analysis to study Rugby Union match footage and needed to be published in English and in a peer-reviewed journal. Inclusion criteria were applied at the title, abstract and full-text level, and any article not meeting the criteria was omitted from the review. The results from all three databases were merged and duplicates were removed. Thereafter, a second reviewer applied the inclusion criteria to the title, abstract and full-text level. Any discrepancies between reviewer 1 and reviewer 2 were discussed and included/excluded from the final database. From this systematic search, papers that provided descriptors and definitions were identified. Only published papers that used video and provided descriptors and definitions of key contact events and outcomes were selected. If the same or similar descriptors and definitions were found in multiple papers, the original paper that provided the definition was cited. In addition to this, a meeting was held to discuss what descriptors are important for each contact event.

For Step 2, a prominent group of researchers and practitioners with experience and expertise in all rugby video analysis objectives (performance, injury, medical/referee decision-making, and physical demands) collaborated to form the RUVAC group. No formal process was used to convene the group; however, consideration was given to having different national Unions represented. Once the group was formed, consensus on the descriptors and definitions developed in Step 1 was attained using a Delphi consensus method.^{17 18} This method required each member to examine the framework of descriptors and definitions and rate their level of agreement on a 5-point agreement Likert scale (1- Strongly disagree; 2-Disagree; 3-Neither agree or disagree; 4-Agree; 5-Strongly agree). Agreement ratings were obtained separately for each contact event, the match characteristics, the tackle technique scoring criteria and the video analysis tackle model. For each of these, the mean agreement [$\pm 95\%$ confidence interval] was calculated by summing all the ratings and dividing it by the total number of

respondents. After the first round of ratings, some comments and suggestions were proposed. Accordingly, these comments and suggestions were added, and a second round of ratings were obtained based on the revised descriptors and definitions. The level of agreement after round 2 (n=17) for each contact event, the match characteristics, the tackle technique scoring criteria and the video analysis tackle model are reported in the results section.

RESULTS

A total of 118 articles on video analysis in rugby matches have been published up to 31 December 2018 (Figure 1). Fifty-five percent (n=60) of these studies provided definitions. Seventeen articles were used to develop the final framework of descriptors and definitions, and the technique criteria for the front-on tackle (Tables 1-5 and Appendix 1-2)^{13-16 19-31}

The mean rating of agreement was 4.6 [4.3-4.9], 4.6 [4.4-4.9], 4.7 [4.5-4.9], 4.8 [4.6-5.0] and 4.8 [4.6-5.0] for the tackle, ruck, scrum, line-out and maul, respectively. For match characteristics, the tackle technique criteria and tackle video analysis model (Figure 2), the mean rating of agreement was 4.6 [4.4-4.9], 4.5 [4.2-4.9] and 4.2 [3.9-4.7], respectively.

DISCUSSION

The aim of this consensus is to improve the consistency and quality of video analysis work in Rugby Union. This list of descriptors and definitions was designed based on the deterministic and phase analysis models^{15 33-35} with the intention of being comprehensive, focusing on key actions, and versatile across video analysis objectives. Therefore, the RUVAC group recommends using these descriptors and definitions as the starting framework when conducting rugby video analysis research. Which variables to use (if not all) depends on the objectives of the study. For example, if it is a tackle-related study, only the tackle variables

may apply. Also, which variables are ultimately captured and analysed depends on the frequency of occurrence of that action in the sample. Further, although comprehensive, the list is finite, and variables can also be added to meet the objectives of the study. For instance, to describe concussion injury mechanism using video analysis, Hendricks et al. (2016) studied descriptors specific to concussion, such as “acceleration of the head”.³⁰ It is also recommended that video analysis projects using one analyst should be tested for intra-rater reliability, and, if possible, inter-rater reliability as well. In the cases where more than one analyst is used, inter-rater testing reliability is essential. Using video to observe body positions and actions is challenging, and reliability across the descriptors will differ. It may be difficult to achieve an acceptable level of reliability on the first round. However, reliability testing for a video analysis project should be considered a process. If an acceptable intra- or inter-rater reliability was not attained during the first round of testing, improvements can be made by engaging the rater(s) to discuss and clarify any analysis issues.^{14 15}

Integration with additional data sources

Information from external data sources, e.g. injury surveillance data, wearable technology etc. should be integrated with video analysis. For example, observing an injury event using video is not straightforward. An injury in rugby is defined as “Any physical complaint, which was caused by a transfer of energy that exceeded the body’s ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a ‘medical-attention’ injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a ‘time-loss’ injury”.³⁶ This definition is consistently used in rugby injury surveillance studies and requires access to the team or tournament. Injury surveillance data alone, however, do not provide enough detail to design and develop injury prevention

programmes, especially if player behaviour or player technique is the target of an intervention. Therefore, video analysis should be integrated with injury surveillance data of the team or the tournament. Beyond understanding injury mechanisms and risk factors,^{5 6} video analysis can also be used to assess the effectiveness of an injury prevention intervention (be it a training programme or law change). Also, video analysis can be used to determine a change in on-field player behaviour and assist medical/referee decision-making. For example, at the elite level, the Head Injury Assessment (HIA) is a process to manage the potentially serious sequelae of concussion. During the HIA process, video footage is available to the official match doctors to review and identify if any concussive signs and symptoms are apparent at the time of injury to decide whether or not to permanently remove the player from the match.⁸

Wearable microtechnology (for example, GPS) is a common feature in professional rugby union and has been successfully used to describe the physical demands of the sport.³⁷ Like injury surveillance data, linking video analysis data to microtechnology data provides superior information compared to assessing the datasets in isolation. Microtechnology provides objective data of the physical demands. This data, along with standardised injury data and high-quality video analysis data will advance the integration of injury, video and microtechnology data within the rugby.³⁷

Quality of video footage

The quality of the video footage may have a direct impact on the quality of the analysis.³⁴ At the professional level, televised matches provide good quality video, from different angles, with the main camera stable and at a suitable vantage point. At lower levels of rugby (for example, community level), video footage of matches is typically recorded using one-camera with a less professional set-up. With limited resources available for video recording, one-camera angle may be sufficient for detailed analyses. Using one camera, recording should

ideally take place on the half-way line at a height sufficient to capture the full field, with the camera mounted on a tri-pod for video stability. The ball should be kept at the centre of the camera view with a radius of approximately 10m. If more than one camera is available, the aim of the camera set up should be to increase the ability to distinguish body parts and players' on- and off-the-ball actions. Off-the-ball actions are particularly important for post-concussive analysis and HIA review. Related to the quality of the video footage, the software program used to analyse the video should also allow for control over the time lapse during each movement, as well as the recording and saving of each coded instance into a database. During the analysis, the analyst should be able to pause, rewind and watch the footage in slow motion or frame by frame.

Considerations

Another method to analyse rugby contact events is to score the technique of the player.^{20 22 24} The score is based on a list of observable actions that represents the ideal form of the technique, which coaches use during training (Appendix 2).^{35 38} To score a player's technique, one point is awarded when an appropriate action is performed and zero when the action is not. The sum of these points represents the technical ability of the player. To date, this method has demonstrated encouraging construct validity by differentiating between injury and non-injury tackles, head impact tackles and successful tackles, and shown to be stable across match quarters at the elite level.^{20 22 24 39} In this paper we only provided technique criteria for the ball-carrier and tackler during the front-on tackle as an example, however, technique criteria for other types of tackles and contact events do exist.^{20 22 24 39}

From a dynamical systems perspective, video analysis can also be used to study the complex and dynamic movement interactions between players (within the same team and with the opposition) and the environment.^{2 40} For example, how spatial and temporal interactions

emerge between players based on field location.⁴⁰ Limited work has been done on video analysis in rugby matches from a dynamical systems perspective, particularly in understanding injury, which highlights an avenue for future research. Another avenue for future research is the video analysis of training sessions. An appreciable amount of work has been documented on the physical demands of training sessions,^{41 42} however, less is known about specific skill activities and coach behaviours during training. Systematic observation of rugby training sessions using video has a role to play in this regard.^{43 44}

Conclusion

The aim of this consensus is to improve the consistency and quality of video analysis work in Rugby Union. The RUVAC group recommends using this consensus as the starting framework when conducting rugby video analysis research. Which variables to use (if not all) depends on the objectives of the study. Furthermore, the intention of this consensus is to help integrate video data with other data (for example, injury surveillance). This framework of descriptors and definitions can be used or developed further for other rugby football codes such as rugby sevens and rugby league.

What is known:

- Video analysis research beyond the scope of performance has grown in the last 10 years.
- In video analysis studies, descriptors and definitions have either been lacking or inconsistent between studies.
- Video analysis can be linked to injury surveillance data and directly used as part of an injury prevention strategy.

What this study adds:

- A consensus on a framework of descriptors and definitions for video analysis in rugby.
- The framework focuses on key actions and is versatile across video analysis objectives.

Competing interests

There are no competing interests for any author.

Contributorship

SH drafted the manuscript, and all other authors provided input to prepare the manuscript for publication. SdH conducted the literature search for the review.

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Data sharing granted.

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Table 1: Tackle Descriptors and Definitions

DESCRIPTOR		DEFINITIONS
Tackle ^{13,14,15,16}		An event where 1 or more tacklers (player or players making the tackle) attempted to stop or impede the ball-carrier (player carrying the ball) whether or not the ball-carrier was brought to ground.
Frequency of tackle		Count of tackle events during match play
Tackle Context	Set piece event before tackle event	Ruck Lineout Maul Scrum Kick-off
	Number of phases before tackle event	Number of phases from the restart to the tackle.
	Total number of passes from the last event (ruck, lineout, maul, scrum, kick-off)	Count of passes (number of times the ball is transferred between attacking players) from the last event (ruck, lineout, maul, scrum, kickoff) leading up to the tackle
Defender		Player/s involved in the tackle on the defending team
Precontact (1 second before contact)	Positional grouping of tackler ^{21,25}	Tight forwards - Loosehead and tighthead prop, hooker and second row Loose forwards - Open-side and blind-side flankers and number 8 Inside backs - Scrum-half, fly-half, and inside centre Outside backs - Outside centre, both wings and fullback
	Body position at 1 second before contact ^{21,29,31}	Upright - Tackler displayed high body height with knees extended and hips neutral/extended Medium - Tackler displayed moderate flexion at knees and hips Low - Tackler displayed low body height
	Body position at 0.5 seconds before contact ^{21,29,31}	Upright - Tackler displayed high body height with knees extended and hips extended Medium - Tackler displayed moderate flexion at knees and hips Low - Tackler displayed low body height
	Head position before contact ^{21,23,29,30,31}	Up and forward – Gaze focused on ball-carrier Away – Gaze away from ball-carrier Down – Gaze pointing towards the ground (and not the ball-carrier) Motion/Tracking - Tackler’s gaze was not fixed (head was moving) in an attempt to follow the ball-carrier through the field of play
	Speed of tackler ^{13,14,15,21}	Fast - Running or sprinting – purposeful running with maximal effort, with high knee lift Moderate - Jogging – non-purposeful slow running with low knee lift Slow - Stationary or walking, or no visible rapid foot movement
	Anticipation—whether the player was aware of impending contact situation	Yes – Player was aware of/attuned to impending contact No – Player was unaware of/oblivious to impending contact
Contact	First point of contact on the ball-carrier (that is, where on the ball carrier is contacted?) ^{13,14,15}	Lower Leg - Area below the knee Hip – <i>On the short’s line</i> Upper Leg - Area between the hips (shorts line) and the knees Torso - Above the ball-carrier’s hip level (shorts line) to the level of the ball-carrier’s arm pit Shoulder - From the ball-carrier’s arm pit level to the shoulder Arm – Below the ball-carrier’s arm pit level but not making contact on the body (contact only to the arm of the ball carrier without any contact to their torso) Head and Neck - Above the shoulder (shirt/neck) with any connection with the head/neck during the course of the tackle For all of the above, left or right side
	Tackler body position at contact	Upright - The tackler is standing in an upright position, with the knees only slightly bent and with minimal hip flexion (when the tackler’s chest is presented to the BC at contact)

		<p>Bent at the waist – The tackler is bent at the waist or crouched (where the tackler presents the top of the shoulder to the ball carrier, or upper body is perpendicular to the ground)</p> <p>Falling/diving – the tackler is in the process of falling or diving to ground at the point of contact</p>
	<p>Was there contact between the tackler's head and ball carrier's body (Y/N)? (that is, where does the tackler's head go?)</p>	<p>Yes or No If yes, location : - Head to Head Head to Shoulder Head to Arm Head to Torso Head to Hip Head to Upper Leg Head to Knee Head to Lower Leg Head to Ground Head to Equipment Whiplash Injury Head to Head Team-mate For all of the above, left or right side</p> <p><i>If no, BC's body the tackler's head was in closest proximity</i> Head to Shoulder Head to Arm Head to Torso Head to Hip Head to Upper Leg Head to Knee Head to Lower Leg Head to Ground Head to Equipment Whiplash Injury Head to Head Team-mate For all of the above, left or right side</p>
	<p>Primary type of tackle at first point of contact 13,14,15,16</p>	<p>Arm tackle - Tackler impedes ball-carrier with upper limbs Left or right arm</p> <p>Jersey tackle - Tackler holds ball-carrier's jersey</p> <p>Shoulder tackle - Tackler contacts the ball-carrier with the shoulder as the first point of contact followed by the arms Left or right shoulder</p> <p>Smother tackle - Tackler uses chest and wraps both arms around ball-carrier</p> <p>Tap tackle - Tackler trips ball-carrier with hand on lower limb below the knee</p>
	<p>Type of illegal tackle</p>	<p>High tackle – A dangerous, high tackle indicated by the referee. Stiff-arm tackle – A dangerous stiff-arm tackle as indicated by the referee Shoulder charge – A dangerous use of the shoulder to impede the ball-carrier without attempting to grasp that player. Lift tackle - Tackler raises ball-carrier's hips above ball-carrier's head Collision (no-arm) tackle - Tackler impedes ball-carrier without the use of the arms Aerial collision - Player is tackled while both feet are off the ground Late tackle after the whistle – A tackle after the referee whistle has stopped play Late tackle after the ball is played – a tackle after the attacking player has passed or kicked the ball Tackle without the ball – an attacking player, not in possession of the ball, is impeded/tackled</p>
	<p>Active or passive ¹⁶</p>	<p>If a shoulder tackle, was it active or passive Active shoulder tackle – First contact is with the tackler's shoulder, and the tackler drives or attempts to drive the ball-carrier backwards</p>

		Passive shoulder tackle – First contact is with the tackler’s shoulder, and the tackler does not drive or attempts to drive the ball-carrier backwards
	Direction of contact 13,14,15	Front-on - Tackler makes contact with the front of the ball-carrier Side-on - Tackler makes contact with the ball-carrier’s side Behind - Tackler makes contact with the ball-carrier’s from behind
	Number of tacklers	Number of defenders actively attempting to stop or impede the ball-carrier (player carrying the ball) whether or not the ball-carrier was brought to ground. Tacklers are counted until the ball carrier is brought to ground.
	Tackle sequence (additional defender(s) must join while tackle is still in progress, before the ruck begins) 14,15,21	One-on-one - One defender contacts one attacker. Sequential - One defender contacts one attacker, followed by a second defender joining the contact situation. (can be coded as a separate tackle) Simultaneous - Two defenders contact one attacker at the same time (coded as separate tackles) Dual sequential - Two defenders contact one attacker followed by a third/fourth defender joining the contact situation. (coded as separate tackles)
Post-contact	Tackler leg drive after contact 21,23,25	Absent - No leg drive Moderate - Moderate knee movement, with no high lift Strong - High, rapid knee lift
	Upper body usage after contact 23, 31	Yes - Tackler uses upper body (arms, shoulders) to actively pull/wrap/wrestle ball-carrier after contact No - No active upper body (arms, shoulders) usage after contact
	Jackal	A defender competes for the ball using their hands after a tackle was made but before a ruck is formed
Attacker		Player/s involved in the tackle on the attacking team
Precontact (0.5 seconds before contact)	Positional grouping of ball-carrier 21,25	Tight forwards - Loosehead and tighthead prop, hooker and second row Loose forwards - Open-side and blind-side flankers number 8 Inside backs - Scrum-half, fly-half, and inside centre Outside backs - Outside centre, both wings and fullback
	Body position at 1 second before contact 21,29,31	Upright – Ball-carrier displayed high body height with knees extended and hips neutral/extended Medium - Ball-carrier displayed moderate flexion at knees and hips Low - Ball-carrier displayed low body height
	Body position at 0.5 seconds before contact 21,29,31	Upright - Ball-carrier displayed high body height with knees extended and hips extended Medium - Ball-carrier displayed moderate flexion at knees and hips Low - Ball-carrier displayed low body height
	Head position before contact 21,23,29,30,31	Up and forward – Gaze focused on tackler Away – Gaze away from tackler Down – Gaze pointing towards the ground (and not the tackler) Motion/Tracking – Ball-carrier’s gaze was not fixed (head was moving)
	Distance from tackler at ball reception 14,21,26	Near – Less than 2 metre of the tackler Moderate - Between 2-4 metres of the tackler Distant - Greater than 4 metres from the tackler
	Pattern of running prior to contact 21,26	Straight - Ball-carrier ran straight at the defence Side Step - Ball-carrier performed an evasive step initiated by either leg before contact Arcing run - Ball-carrier performed arcing run Lateral run - Ball-carrier performed a run from touchline to touchline Diagonal run - Ball-carrier runs at an angle, instead of straight at the tackler
	Speed of ball-carrier 13,14,15,21	Fast - Running or sprinting – purposeful running with maximal effort, with high knee lift Moderate - Jogging – non-purposeful slow running with low knee lift Slow - Stationary or walking – no visible rapid foot movement
	Anticipation—whether the player was aware of impending contact situation	Yes – Player was aware of/attuned to impending contact No – Player was unaware of/oblivious to impending contact

Contact	Was there contact between the ball-carrier's head and tackler's body (Y/N)? (that is, where does the ball carrier's head go?)	<p>Yes or No If yes, location : -</p> <p>Head to Head Head to Shoulder Head to Arm Head to Torso Head to Hip Head to Upper Leg Head to Knee Head to Lower Leg Head to Ground Head to Equipment Whiplash Injury Head to Head Team-mate</p> <p>For all of the above, left or right side</p> <p><i>If no, tackler's body the BC's head was in closest proximity to</i></p> <p>Head to Shoulder Head to Arm Head to Torso Head to Hip Head to Upper Leg Head to Knee Head to Lower Leg Head to Ground Head to Equipment Whiplash Injury Head to Head Team-mate</p> <p>For all of the above, left or right side</p>
Contact	Fend ^{16,21,26}	<p>Absent - Ball-carrier provided no fend Moderate - Ball-carrier provided a light to moderate fend (e.g. Swat or slap technique) Strong - Ball-carrier provided strong fend (e.g. Push technique)</p>
	Contact Impact intensity ^{14,15,16,30}	<p>Subjective description of physical impact between the ball-carrier and tackler</p> <p>Low Medium High</p>
	Attacker sequence (additional attacker(s) must join while tackle is still in progress, before the ruck begins) ^{14,30}	<p>One-on-one - One defender contacts one attacker. Sequential - One attacker contacts one defender, followed by a second attacker joining the contact situation. Simultaneous - Two attackers contact one defender at the same time Dual sequential - Two attackers contacts one defender followed by a third / fourth attacker joining the contact situation.</p>
	Attacker body position at contact	<p>Upright - The ball-carrier is standing in an upright position, with the knees only slightly bent and with minimal hip flexion (when the ball-carrier's chest is presented to the tackler at contact) Bent at the waist – The ball-carrier is bent at the waist or crouched (where the ball-carrier presents the top of the shoulder to the tackler, or upper body is perpendicular to the ground) Falling/diving – the BC is in the process of falling or diving to ground at the point of contact</p>
Post-contact	Ball-carrier leg drive after contact ^{21,23,25}	<p>Absent - No leg drive Moderate - Moderate knee movement, with no high lift Strong - High, rapid knee lift</p>
	Upper body usage after contact ^{23,31}	<p>Yes – Ball-carrier uses upper body (arms, shoulders) to actively wrestle/push the tackler after contact No - No active upper body (arms, shoulders) usage after contact</p>

Tackle Outcomes	Tackle result ^{21,23,27}	<p>Offload - The ball-carrier is able to pass the ball to a teammate during the tackle</p> <p>Tackle break - The ball-carrier successfully penetrates the attempted tackle and continues to advance</p> <p>Tackle completed - When an offload or tackle break does not occur, and either player goes to ground or the ball-carrier is held up and cannot progress further. This can also be considered a successful tackle.</p> <p>Ruck formed - A phase of play whereby one or more players from each team, who are on their feet, in physical contact, close around the ball on the ground.</p> <p>Possession lost - The attacking team is unable to advance through an offload or tackle break, or form a ruck, and lose the ball either through an infringement or error</p>
	Which player achieves contact territorial dominance? ^{21,23}	<p>The direction of progression the tackler and ball-carrier made (as a single unit) towards the opposition try-line from the point of contact to the point where both players went to ground (completed tackle) or when a maul is formed. This is considered an indication of the physical dominance of the tackler or ball-carrier in the contact.</p> <p>Ball-carrier Tackler No change</p>
	Infringements	Penalty awarded against defender Penalty awarded against attacker Infringement acknowledged by referee – advantage used by defending team Infringement acknowledged by referee – advantage used by attacking team (Reason for infringement can also be captured)
	Injury	<p>Medical attention - Player received medical attention and either continued playing or was removed permanently or temporarily.</p> <p>No medical attention – Coder observed a possible injury to a player, but said player did not receive medical attention during the match</p> <p>Was the player removed from play? – yes/no</p> <p>Possible Head Injury? – yes/no</p> <p>*For professional level only* Was a Head Injury Assessment instigated? -yes/no</p> <p>- Did the player return to play? - yes/no</p>
	Injured Player	Ball-carrier Tackler Not clear
	Injury Location	<p>Lower Leg - Area below the knee</p> <p>Hip – <i>On the short's line</i></p> <p>Upper Leg - Area between the hips (short line) and the knees</p> <p>Torso - Above the ball-carrier's hip level (short line) to the level of the ball-carrier's arm pit</p> <p>Shoulder - From the ball-carrier's arm pit level to the shoulder</p> <p>Arm – Below the ball-carrier's arm pit level</p> <p>Head and Neck - Above the shoulder (shirt/neck)</p> <p>When an injury is observed the injurious event should recorded and linked to injury surveillance data.</p> <p>Injury Location – Head & neck Upper-extremity (Shoulders and arms) Lower-extremity (Legs) Torso Unknown location</p>

Table 2: Ruck Descriptors and Definitions

DESCRIPTOR		DEFINITIONS
Ruck ²⁸		A ruck is formed when at least one player from each team is in contact, on their feet and over the ball which is on the ground. Once a ruck is formed, additional players joining the ruck to compete for the ball, without being guilty of foul play, are considered rucking.
Frequency of ruck		Count of ruck events during match play
Defender		
How did the ruck start		Tackle Maul Lineout
Number of defenders in ruck		Count of defenders actively engaged in ruck
Speed of entry into ruck		Fast - Running or sprinting – purposeful running with maximal effort, with high knee lift Moderate - Jogging – non-purposeful slow running with low knee lift Slow - Stationary or walking, or no visible foot movement
Time in ruck		Duration (in minutes: seconds) from when the ruck has formed to when the ball is available to be played
Activity at the ruck ^{23,27}		No pressure - Defenders are not actively attempting to regain possession Early counter ruck - Defenders compete for the ball without the use of their hands before attackers had secured possession Late counter ruck - Defenders compete for the ball without the use of their hands after attackers had secured possession
Attacker		
Number of attackers in ruck		Count of attackers actively engaged in ruck
Speed of entry into ruck		Fast - Running or sprinting, purposeful running with maximal effort, with high knee lift Moderate - Jogging, non-purposeful slow running with low knee lift Slow - Stationary or walking – no visible foot movement
Ruck arrival ²³		Early - Ball-carrier's teammates are first to arrive and engage in the ruck Late – Tackler's teammates are first to arrive and engage in the ruck
Activity at the ruck ^{23,27}		Clearing - Attackers are actively pushing and/or driving opponents off the ball, either on their own or binding to team members Protecting the ball - Attackers are positioned over the ball to prevent access to the opponents In sequence, a combination of clearing and protecting - Attackers actively clear the ruck first, before protecting the ball In sequence, a combination of protecting and clearing - Attackers actively protect the ball first, before clearing the ruck
Ball-carrier falling direction ²³		Forward - Ball-carrier falls with the ball positioned between the ball-carrier and the opposition's try-line Sideward - Ball-carrier falls with the ball positioned between the ball-carrier and either side-line Backward - Ball-carrier falls with the ball positioned between the ball-carrier and their own try-line
Active ball placement ²³		Yes - Ball-carrier actively placed the ball after going to the ground to continue play No - Ball-carrier fails to actively place the ball after going to the ground to continue play
Ruck Outcomes	Ruck result ^{23,27}	Attacker retains the ball - attacking team maintains possession of the ball after the ruck contest and the ball is made available to be played Defender gains the ball - attacking team fails to maintain possession of the ball after the ruck contest Ball unplayable – ball is unavailable to be played by either team.
	Infringements	Penalty awarded against defender Penalty awarded against attacker Handling error by attacker Handling error by defender (Reason for infringement can also be captured)
	Injury	See Injury Table 1
	Injured Player	Attacker Defender Not clear
	Injury Location	See Injury Location Table 1

Table 3: Scrum Descriptors and Definitions

DESCRIPTOR		DEFINITIONS
Scrum ²⁸		<p>A scrum is formed in the field of play when eight players from each team, bound together in three rows for each team, engage with their opponents so that the heads of the front rows are interlocked.</p> <p>Scrum engagement occurs when the front-row of each team make contact with each other.</p>
Frequency of scrum		Count of scrum events during match play
Frequency of engagement attempts		Count of engagements and re-engagements (resets) before the scrum was considered contestable.
Duration of (re-)engagement (reset)		The time (in minutes:seconds) from the engagement to when the whistle is blown to reset the scrum
Duration of contestable scrum		The time (in minutes:seconds) from the engagement to when the ball is played
Scrum Outcomes	Scrum result (for complete scrums)	<p>Attacking team retains the ball - attacking team maintains possession of the ball after the scrum contest</p> <p>Defending team gains the ball - attacking team fails to maintain possession of the ball after the scrum contest</p>
	Infringements	<p>Penalty awarded against attacking team</p> <p>Penalty awarded against defending team</p> <p>Free-kick awarded against attacking team</p> <p>Free-kick awarded against defending team</p> <p>Penalty type {World, 2018 #214} –</p> <p>Popping - Intentionally lifting an opponent off their feet or forcing them upwards out of the scrum.</p> <p>Collapsing - Deliberately collapsing a scrum.</p> <p>Falling – Deliberately falling or kneeling.</p> <p>Pulling - Pulling an opponent.</p> <p>Intentional wheeling – Deliberately wheeling the scrum</p>
	Injury	See Injury Table 1
	Injured Player	See Injured Player Table 2
	Injury Location	See Injury Location Table 1

Table 4: Line-out Descriptors and Definitions

DESCRIPTOR		DEFINITIONS
Line-outs and quick line-outs ²⁸		<p>A lineout is formed on the mark of touch. Each team forms a single line parallel to and half a metre from the mark of touch on their side of the lineout between the five-metre and 15-metre lines. A minimum of two players from each team are required to form a lineout.</p> <p>A quick line-out (quick throw) can take place before a line-out is formed and is observed when a player whose feet are both outside the field of play throws the ball parallel to or towards the thrower's own goal line, between the mark of touch and the thrower's own goal line, so that it reaches the five-metre line before it touches the ground or makes contact with a player.</p>
Frequency of line-out events		Count of line-out events during match play
Number of players in the line-out		Number of attackers and defenders in the formed line-out
Ball Thrown		<p>Short - Ball is thrown to the first 3rd of players in the line-out.</p> <p>Mid - Ball is thrown to the second 3rd of players in the line-out.</p> <p>Long - Ball is thrown to the last 3rd of players in the line-out.</p>
Line-out Outcome		
Line-out outcomes	Line-out result	<p>Attacking team retains the ball - Attacking team maintains possession of the ball after the line-out contest</p> <p>Defending team gains the ball - Attacking team fails to maintain possession of the ball after the line-out contest</p>
	Post line-out event	<p>Maul - When a ball-carrier and at least one player from each team, bound together and are on their feet.</p> <p>Catch & Drive - A player in the line-out catches the ball and moves towards the opposition try-line</p> <p>Distribute - A player in the line-out catches the ball and immediately passes the ball to a team member. This can be accomplished from the top of the line-out or after the player lands on their feet.</p> <p>Line-out missed - Players in the lineout did not receive the ball, either by intentional overthrow or missed jumper</p>
	Infringements	<p>Penalty awarded against attacking team</p> <p>Penalty awarded against defending team</p> <p>Free-kick awarded against attacking team</p> <p>Free-kick awarded against defending team</p> <p>Scrum awarded to attacking team</p> <p>Scrum awarded to defending team</p> <p>(Reason for infringement can also be captured)</p>
	Injury	See Injury Table 1
	Injured Player	See Injured Player Table 2
	Injury Location	See Injury Location Table 1

Table 5: Maul Descriptors and Definitions

DESCRIPTOR		DEFINITIONS
Maul ²⁸		A maul begins when a player carrying the ball is held by one or more opponents, and one or more of the ball carrier's team mates bind on the ball carrier. A maul therefore consists, when it begins, of at least three players, all on their feet; the ball carrier and one player from each team
Frequency of mauls		Count of maul events during match play
Duration of maul		Time (in minutes: seconds) from when the maul has formed to when the ball is played
Number of attackers in maul		Total number of players from the attacking team, including the player carrying the ball in the maul, involved when the maul ended.
Number of defenders in the maul		Number of players from the defending team
Maul outcomes	Maul result	Attacking teams retains the ball - Attacking team maintains possession of the ball after the maul contest Defending team gains the ball - Attacking team fails to maintain possession of the ball after the maul contest
	Infringements	Penalty awarded against defender Penalty awarded against attacker Handling error by attacker Handling error by defender
	Injury	See Injury Table 1
	Injured Player	See Injured Player Table 2
	Injury Location	See Injury Location Table 1

*****Insert Tables here*****

Table 1: Tackle Descriptors and Definitions

Table 2: Ruck Descriptors and Definitions

Table 3: Scrum Descriptors and Definitions

Table 4: Line-out Descriptors and Definitions

Table 5: Maul Descriptors and Definitions

*****Insert Figure 1 here*****

Figure 1: Flow diagram of literature search.

*****Insert Figure 2 here*****

Figure 2: Video analysis model for the tackle