How to harness and improve on video analysis for youth rugby player safety

A narrative review

Citation for published version:
Shill, IJ, West, SW, Brown, J, Wilson, F, Palmer, D, Pike, I, Hendricks, S, Stokes, KA, Hagel, BE & Emery, CA 2023, 'How to harness and improve on video analysis for youth rugby player safety: A narrative review', *BMJ open sport & exercise medicine*, vol. 9, no. 3, e001645. https://doi.org/10.1136/bmjsem-2023-001645

Digital Object Identifier (DOI):
10.1136/bmjsem-2023-001645

Published In:
BMJ open sport & exercise medicine

Title: How to harness and improve on video analysis for youth rugby player safety: A narrative review.

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Word count: 3,596/4000

Tables/Illustrations: 1 table, 1 figure.

References: 51

Abstract (69/250): Video analysis is a useful tool for injury surveillance in rugby union. Previously, it has been used, sparingly, in professional female with most of the present evidence in the male elite/professional settings. Moreover, there is presently a sparsity of literature in youth rugby settings. The following narrative review outlines the strengths and limitations of the current video analysis literature for injury surveillance in youth rugby union, highlights the

importance of video analysis for youth rugby player safety and welfare, and discusses recommendations for using video analysis to inform player safety in youth rugby.

Key words: Video analysis, rugby union, youth, sport injury epidemiology

Key messages:

- *What is already known on this topic*: Video analysis is a systematic approach to recording observed events and actions. It is a useful tool for injury surveillance and allows researchers to gain a deeper understanding of injury events and risk factors of injury.
- *What this study adds*: The present narrative review outlines the strengths and limitations of the present youth rugby union video analysis field used for injury surveillance and provides opportunities to unify the video analysis methodology to improve video injury and characteristic outcomes.
- *How this study might affect research, practice, or policy*: The present review suggests methods to build on and improve video analysis methodology in the youth rugby injury surveillance setting and beyond.

Introduction

Video analysis has been used to assess performance outcomes and describe physical demands in professional, elite, and non-elite team sports (1-3). Additionally, coaches have used video analysis as a training and feedback tool to inform player technique and knowledge, such as tactical skill development in soccer and volleyball, learning a golf swing, or improving a basketball set shot (4-9). Besides performance outcomes, such as proficient tackle technique, video analysis has extended to sports injury prevention research across multiple team sports (e.g., rugby union, football, handball, ice hockey) (10-12). Over the last two decades, it has been used to describe injury mechanisms and examine potential risk factors in many sports (10, 11, 13-16). For example, a consensus has been released on video signs of concussion in professional sports to identify the most useful video signs of sport-related concussion and operationally define these video signs across professional sports (17).

Rugby union (hereafter rugby) has utilised video analysis extensively to evaluate performance and injury epidemiology within elite cohorts (18, 19). Moreover, it has provided the opportunity to add a unique and rich component in evaluating injury and concussion prevention strategies alongside injury surveillance, such as tackle height law variations (10, 11, 20, 21).

Video analysis in rugby injury epidemiology research has been primarily used in male professional and elite youth cohorts with some early representations of varsity (university student) populations (3, 10, 11, 21-25). Outside these male elite contexts, youth, non-elite, and community populations can benefit greatly from video analysis to inform injury epidemiology, including revealing mechanisms of injury if there is no opportunity to implement a valid injury surveillance methodology (26). Other sports injury video analysis research begins with an independent injury, identifies it on video, and breaks down the biomechanics of the injury, such as that of video review of Achilles tendon ruptures or medial collateral ligament knee injuries in professional football (soccer) (27, 28).

Injury and concussion-specific rates among youth rugby players are among the highest in youth sport (29-31). For the present narrative review, youth rugby players include those 18 or younger. A Canadian female high school cohort (age 15-18) reported the highest concussion rate in youth rugby at 37.5 concussions/1000 match-hours (29). Considering the high concussion rate, a detailed understanding of injury and concussion mechanisms will help provide better evidence to inform decision-making in the youth game. It may also enable a more targeted approach to mechanisms and risk factors that may be youth or gender-specific. To gain this understanding, video analysis methodology has been applied to advance the youth rugby injury and concussion prevention field (21, 23). While the present narrative review is focused on video analysis methodology in youth rugby, similar strengths, limitations, and recommendations can be made across non-elite and community rugby video analysis. The objectives of the present narrative review are to (i) summarise our understanding of the strengths and limitations of video analysis in youth rugby as used for injury surveillance, (ii) highlight the importance of video analysis in relation to youth player safety, and (iii) discuss recommendations for the use of video analysis to inform player safety in youth rugby.

What does video analysis for injury surveillance research entail?

Video analysis studies apply a deterministic or diagnostic prescriptive approach (21, 32, 33) and involve four distinct steps: (i) video footage and capture, (ii) identifying events, actions, and characteristics of interest, (iii) variable labelling according to the defined events and actions, and (iv) statistical analyses. Video footage is obtained through self-capturing or publicly broadcasted matches. Video footage and capture require appropriate camera angles to ensure an optimal line of sight, frame focus for footage clarity, and steady frame movement to ensure footage follows the play to be coded and labelled accordingly. Additionally, video footage may require multiple camera angles and the ability to watch the capture footage at different speeds to simplify the coding and labelling processes. Identifying events involves generating a count of match events (*e.g.*, tackle, ruck, scrum, lineout) and identifying suspected injuries or concussions. Video labelling applies further event-specific characteristics and descriptors to match events. For example, once all tackles in a game are coded, tackle-specific descriptors (*e.g.*, body position, head position, tackle type) can be added (34). Further, statistical analyses involve descriptive and inferential statistics. Descriptive statistical analyses incorporate a description of all events and actions, which is typically reported as percentage frequency. Then, if outcomes are known, inferential statistical analyses consist of estimating measures of association, such as odds, rate, and risk of injury or concussion, based on labelled characteristics. Labelled characteristics could include playing position, such as tackler vs. ball-carrier and back vs. forward. To date, an important evaluation has been identifying the risk of injury between the ball-carrier (the player who is carrying the ball into contact; attacker) and tackler (the player that is actively tackling the individual with the ball; defender) within the tackle event. The strengths and limitations of using video analysis in rugby are present at all steps and are outlined in Table 1.

Table 1. Current strengths and limitations in rugby video analyses methodology based on current literature

	Strengths	Limitations
Video capture	- Simple data collection process - Can be linked to and add value to injury surveillance data (21, 23, 33, 35)	- Video quality due to inexperienced recorder, wide angle and/or obstructed view - Access to video footage at the youth and community level
Video coding and labelling	- Systematic method to record observed events and actions (e.g., injury risk factors, mechanisms of injury) - Consensus statement present (34) - Intra-rater reliability is completed frequently (21, 23, 36) - Can review video footage for accuracy	- Inter-rater reliability is rarely completed (21, 23, 36) - Potential for biased coding given knowledge of outcome (e.g., concussion, non-concussion) - Time-consuming - Variables (*e.g.,* speed, acceleration, head impact) can be subjective without the use of external data sources
Statistical Analysis	- Quantifies risks, likelihoods, and probabilities based on the relationship between action/events and outcomes - Using a case-control study design can evaluate exposure to multiple event characteristics at one time (11, 35) - Individual and team-based matching for injury and non-injury events (35)	- No evaluations have considered baseline player covariates (e.g., previous playing experience, age, sex) - Descriptive analyses (21, 23) - Small sample sizes or no sample size calculations (37)
Other	- Proficiency scoring criteria previously developed that demonstrate construct validity (21, 33)	- Generalizability - More studies on training settings are required (37)

Why would researchers use video analysis for sports injury epidemiology research?

Within the sports injury epidemiology literature, video analysis allows a researcher to systematically measure and quantify injury and non-injury events with respect to injury mechanisms and potential risk factors. Descriptive studies are useful for quantifying match situations and identifying the extent of the injury problem. Additionally, comparing injurious and uninjured (control) events allows researchers to provide policymakers and stakeholders the opportunity to make evidence-informed decisions surrounding player safety and welfare. For example, video analysis has been conducted in professional adult male settings to inform tackle-based risk factors for head injury assessments (HIA) and diagnosed concussions (11, 22). Tucker et al. estimated that the tackle characteristics with the greatest propensity to cause an HIA were active shoulder tackles, front-on tackles, high-speed tackles, and an accelerating tackler (22). Additionally, contact between a tackler's head and a ball carrier's head or shoulder significantly increased the risk of an HIA compared with contact below the level of the shoulder (22). Similarly, using a case-control study design on a comparable professional male rugby population, the tackle-related variables that were estimated to increase the odds of concussion were tackler speed, acceleration, head contact type, and tackle type (11). The video analysis findings tackle characteristics studies that informed the Head Contact Process (38). Moreover, due to the higher concussive risk associated with an upright body position and head-to-head contact, it was hypothesised that lowering the tackle's height could reduce the concussion rate (20). Based on this hypothesis, an evidence-informed policy change was implemented and evaluated (10, 11, 20).

How can the limitations of video analysis be addressed?

Video Capture

The scope of limitations spans all video analysis steps, as outlined in Table 1. However, within youth and community settings, video footage and capture encompass the primary observed limitations due to unpredictable video quality, which would result in an ability to label and code footage accurately. Video capture and footage are the most prominent limitations, given the lack of availability of professionally filmed or broadcasted video footage. Within youth settings, video capture would be the responsibility of the researchers collaborating with the team, the coaching staff, or the tournament or league that the team partakes in. However, this could vary vastly across different youth teams and contexts. Importantly, due to individual variability in a youth context, standardised directions and recommendations on capturing video (e.g., number of cameras, width of frame) should be made to ensure consistently high video quality. Hendricks et al. (2020) outline some recommendations, but further recommendations to adequately quantify the injury event should be considered specific to a youth setting. Consent and storage are additional considerations when capturing video; however, these will be context-specific (*i.e.,* leagues, teams, ethics boards).

Video coding and labelling

One of the main limitations when identifying injury and concussion risk factors and mechanisms through video analysis across youth and professional video is the inability to find the injury-inducing event in the captured footage (Table 1). Previously, within a professional male setting, only 74% (182/247) of reported concussions identified through injury surveillance had been identified on footage (11). The authors stated concussions were dropped due to insufficient video quality or inability to identify the inciting event in the footage (11). Without the ability to identify the injury or injury-inducing event on video, there may be an underestimation of the injury count or misrepresentation of the mechanisms of injury.

Several match events and multiple characteristics for each event can be obtained using rugby video analysis based on the 2020 video analysis consensus statement (34). In addition to match events, injury events can provide further detailed characteristics such as injury location, injury type (e.g., suspected concussion), and whether a player was removed from play. Reliability (*i.e*., inter-rater reliability, intra-rater reliability) and validity (*i.e*., content validity, face validity, criterion validity) across measures obtained in video analysis vary. This is partly due to the subjectivity of coding characteristics. Moreover, identifying injury, specifically concussion, could be subjective, given a coder's perception of the event as influenced by their previous clinical experience. Hence, video analysis-based operational definitions of suspected injury and concussion are crucial for video analysis research, such as those outlined by Davis and colleagues (17).

Identifying injury mechanisms and ensuring the validity and reliability of reporting injury outcomes could be improved using two methods: (i) linking video to injury surveillance data and (ii) using validated injury and concussion definitions for video analysis.

The ability to link injury surveillance data based on self- or clinician-reported injuries is an opportunity to validate suspected video analysis-based injuries that meet a surveillance study injury definition, such as all physical complaints, time-loss, medical attention, and/or physician-diagnosed concussion. Linking the two allows for comparison with other studies that have adopted similar injury definitions and can improve the validity of reported injury rates. In a youth male elite South African rugby tournament, injury reports from physicians were reviewed, and match footage was then analysed to identify the injury mechanism (*i.e.,* inciting match event) (21, 23, 33, 35). When using validated injury surveillance to complement video analysis, it is important to ensure that the data linkage between the injury surveillance and the video of the inciting event is as close to the time of injury occurrence as possible. This will improve the accuracy of participant and clinician reports and minimise recall bias or ambiguity surrounding the injury event during video review. Within a South African youth elite rugby cohort, the ability to link video footage to the injury event has been estimated to be 55-58% (21, 36).

While recommended, it is recognised that it might not be possible to link the two data sources due to a lack of resources for injury surveillance or because it is prohibited given ethical considerations for non-anonymity of participants (*e.g*., video data needs to remain de-identified and anonymous). If linkage with an injury surveillance database is impossible, a consensus for methodology to validate video-based suspected injury and/or concussions is an alternative option. This would allow for a standardised definition based only on observable signs of injury or concussion from collected video footage. Importantly, this definition consists of parameters validated for construct, content, and face validity to operationally define a video-based injury (24). Within adult professional and non-professional rugby union, both suspected injury and concussion have been validated to identify valuable video signs for these outcomes(17, 24). Additionally, video signs of concussion have been studied extensively within professional rugby league competitions to understand the reliability, sensitivity, and specificity of key concussion signs (39-41). Such validations and definitions provide a robust video analysis measure to define injury and concussion outcomes operationally. The consensus guidelines by Hendricks et al. consider injury characteristics to support the injury identification process during video coding, which suggests a medical attention definition (34). Importantly, this identification would also capture those athletes who did not receive on-field attention regardless of whether they were removed from play permanently or temporarily. The validation of video-based suspected injury and concussion definitions allows researchers to conduct injury epidemiology research without surveillance data based on collected video footage. This presents a feasible and practical alternative when injury surveillance is impossible (*e.g*., resource limitations in youth rugby settings).

Technology [*e.g.,* head impact sensors, Global Position System (GPS) units, Ultra-Wideband tracking] is an additional tool that has the potential to assist in providing more context surrounding the injury event and can improve video analysis outcomes, whether for injury or concussion definition or video labelling values. However, like the use of injury surveillance platforms in youth, it is important to recognise that such technologies can be cost-prohibitive and infeasible. The practice of using head impact sensors is rapidly developing, and their use and validation could present researchers with additional opportunities to validate suspected concussion events and assist in concussion management (42). Commonly critiqued subjective variables include player speed and acceleration. The ability for a coder to appropriately quantify the speed of the tackler or ball-carrier in a tackle event by categorical descriptors, such as 'slow', 'moderate', and 'fast', or the acceleration of the tackler or ball-carrier as 'accelerating', 'decelerating', or 'none', is challenging. To increase the validity and reliability of these variables, external data sources, such as GPS units, video-based algorithms, or Ultra-Wideband tracking to calculate speed may be utilised (43, 44). As with developing technologies, technology outputs should be interpreted cautiously due to system validity, such as GPS unit output over short distances with change of direction (45).

The use of technology may be limited in non-elite settings, so an opportunity to improve the validity of subjective variables in the youth rugby context would be the validation of ordinal labelling scales for variables such as player speed (e.g., slow, moderate, fast) (34). Considering law changes related to the tackle height (20, 46), another important variable that could be captured with an ordinal scale is the level of head contact to supplement the use of head impact sensors or other technology where resources are limited. The alignment of these scales with technology and using blind coders to validate the ordinal scales to understand the subjectivity of the perceived intensity, speed, and acceleration of a head impact or a moving player is valuable for the video analysis literature.

While no scaling systems exist for youth rugby video analysis, research in youth ice hockey has quantified the intensity of physical contact through a five-point scale (47). Similar scales could be developed for the variables mentioned above, where the validation of these scales could include alignment with head impact sensors, GPS units, or Ultra-Wideband tracking data and blind coders using the developed scales to gain an understanding of the subjectivity of the perceived intensity, speed, and acceleration of a head impact or a moving player.

As previously listed in Table 1, another limitation when estimating injury and concussion risk factors and mechanisms through video analysis is the misclassification of characteristics between injurious and non-injurious events due to methodological flaws, such as previous knowledge of the outcome (*i.e.*, concussive versus non-concussive tackle) affecting coder subjectivity. Ultimately, there is potential for differential misclassification bias away from the null, where the effect of a characteristic on injury would be overestimated due to coder knowledge of the outcome (*e.g.*, injury vs. non-injury). Ideally, coders would be blinded to the injury outcome; however, this is not always feasible. Several options could be considered to mitigate this bias.

The first option could require coders to stop watching the footage before the outcome (or lack of outcome) occurs or stop the footage at the point of contact. Stopping the footage before the outcome occurrence is challenging because knowledge of when the inciting event occurred might be unknown. Additionally, stopping footage at the point of contact limits the number of observable characteristics. Based on Hendricks et al.'s (2020) consensus guidelines, characteristics of the tackle can be categorised into pre-contact, contact, and post-contact phases. Thereby, some of the contact and all post-contact phases would be missed. This is particularly pertinent with emerging evidence around the head-to-ground mechanisms established in the post-contact phase of the tackle within the female game (25).

The second option involves an independent coder who does not know injurious or non-injurious outcomes specific to the video footage being reviewed. The independent coder should have knowledge or previous experience of rugby match play and identifying concussions on video or in-person. By involving an additional coder, inter-rater reliability can be computed between the coders to understand whether the coding has been biased by knowledge of the outcome.

If more than one coder assesses the video footage, the final proposed strategy is to perform a ‘partial’ blinding methodology. Traditionally, within rugby video analysis, initial coding is done to estimate a count of all match events that occurred. This is followed by video labelling to add characteristics that describe the events. While match events count the number of tackles, rucks, lineouts, scrums, etc., the characteristics could be biased based on knowledge of the injury or concussion outcome. Therefore, if more than one coder is present, the coder who initially coded all match events and is aware of the injury outcome would not code the characteristics for that event. Additional coders could code the characteristics without knowledge of the outcome. Figure 1 displays a flowchart of this ‘partial’ blinding methodology that could be applied to future rugby injury video analysis studies. While the proposed methodology attempts to limit bias during labelling, there will be certain scenarios where video signs are more obvious, which may make the blinding process impossible regardless of initial coder knowledge.

[Insert Figure 1]

Growing video analysis injury surveillance research in youth rugby

The *Consensus on a video analysis framework on descriptors and definitions by the Rugby Union Video Analysis Consensus group* has made an important contribution to the rugby video analysis literature (34). The consensus statement provides structure and uniformity for capturing and coding study variables, enhancing comparability across studies and rugby-playing populations. However, this structure and uniformity are only observed when the consensus is followed and considered during protocol development of a video analysis study.

Despite the number of events and characteristics that the consensus statement outlines, the statement provides minimal guidance in the context of injury event characteristics, with no operational injury definitions. Within the consensus statement, the injury characteristic used is a medical attention injury where a "player received medical attention and either continued playing or was removed permanently or temporarily" or a no medical attention injury where a "coder observed a possible injury to a player but said player did not receive medical attention during the match" (34). In addition, coders can report whether the player was removed from play, if it was a possible head injury, who the injured player was (*e.g.*, defender vs. attacker, tackler vs. ball-carrier), and the injury location on the player (34).

West et al. undertook a rigorous suspected injury and concussion validation process using video analysis (24). An expert group of sports medicine physicians, physiotherapists, athletic therapists, and rugby researchers was assembled to validate all suspected injuries and concussions identified from video analysis (24). For suspected injury, the group modified the criteria Arnason et al. used to identify an injury-risk event in professional soccer (24, 48). Arnason et al.'s criteria included an injury event where "the match was interrupted by the referee, a player lay on the pitch for more than 15 seconds, and the player appeared to be in pain, or the player received medical attention" (24, 48). The original criteria were modified as part of the content validation process and in consultation with the expert group. The modification included altering the time a player laid on the pitch from 15 seconds to 10 seconds as it was more representative of a rugby population and as inclusive as possible. Additionally, West et al. used several different concussion resources (i.e., the Pocket Concussion Recognition Tool, clear indicators and signs from the World Rugby guidelines, the head injury assessment criteria, and the international consensus of video signs of concussion in professional sports) to validate all suspected concussions observed in the match footage (17, 49-51). Given the potential limitations surrounding linking or setting up injury surveillance in youth populations, a rigorous and validated injury definition for video analysis, similar to that outlined previously, is an opportunity to appropriately inform injury rates, mechanisms of injury, and risk factors (17, 24).

Considerations for male and female differences in youth video analysis outcomes

Evidence exists across non-elite to elite adult female playing populations (52-54). However, minimal evidence is available regarding youth female rugby injury. Some initial representations of youth female rugby in the literature suggest that injury and concussion rates are amongst the highest reported in youth rugby (29, 31). Given these initial findings, sex-related differences in youth rugby must be considered to inform safety recommendations, such as policy development or prevention training programs. Video analysis can be used to understand the different injury mechanisms between males and females. When approaching sex-related differences in video analysis, there are two distinct areas to consider: match event frequency and injury mechanism.

Match event frequency has yet to be analysed in youth female rugby. Some initial performance analyses beyond that of women's international rugby have been completed in a female varsity population (3). Presently, no sex-specific differences in match event occurrence could be anticipated; however, we would expect an overall lower event count (*e.g.*, fewer tackles) in a youth rugby context, given shorter game length and different pitch sizes. As such, researchers should consider reporting rates and counts to allow for comparison between the different levels.

Differences could also be anticipated due to differences in game pace and collision intensity at the younger and non-elite levels. When comparing U12, U14, U16, U18, and senior male rugby union across amateur and elite settings, significant differences were found for match event frequency between age groups, where older age groups had a higher event frequency (55). Similar trends could be anticipated for the female game.

Sex-related injury mechanisms should be evaluated at the event characteristic level. Within a female high school rugby setting (age 14-18), the tackle accounted for 70% of match injuries (29). Conversely, 55-57% of match injuries in male high school populations have been estimated to result from the tackle (56, 57). When dividing the tackle event into ball-carrier and tackler mechanisms, the tackler accounted for 40% of injuries (ball-carrier: 30%) among high school females and 25-28% among males (ball-carrier: 27-32%) (29, 56, 57). Given the higher proportion of injuries to the tackler in the female context, we could speculate that different mechanisms might be observed between youth males and females. While no video analysis has been performed on youth female rugby players to date, Williams et al. 2021 estimated that 85% of head impacts at a female varsity level were within the tackle event, where 61% were to the tackler and 39% to the ball-carrier (25). Male varsity players had 74% of head impacts observed in a tackle, with 53% to the tackler and 48% to the ball-carrier (25). Additionally, 50% of all recorded female head impact events resulted from uncontrolled whiplash actions compared with less than 0.5% among males (25). Given these differences within an older and more elite population, we could hypothesise that the frequency of head impacts to the tackler would vary between female and male youth players.

Moreover, if a head contact is present, we might anticipate different tackler head contact locations on the ball-carrier’s body or elsewhere. Youth females could have higher uncontrolled whiplash mechanisms than males because of a higher head-to-body or head-to-ground contact frequency. Besides the head contact, differences in the tackler's body and head position might be observed, given the higher number of injuries to the tackler in a youth female context.

Key points and future directions

This narrative review outlines the strengths and limitations of the current video analysis literature. We recommend improving research to prioritise video assessment of injury and concussion outcomes to inform youth rugby player safety and welfare. Given video analysis for sports injury epidemiology research was discussed in the narrative review, it is important to highlight the value of the analysis of performance outcomes when completing video assessment of injury and concussion. Ultimately, this guides the development of targeted injury and concussion prevention strategies and aids in implementing and disseminating these strategies to players, coaches, and key stakeholders (58-61).

Future studies should consider some of the recommendations outlined in the present narrative review to minimise bias, improve study methodology and increase researchers’ capacity to provide evidence to community stakeholders to inform their player welfare recommendations. Currently, there is no video analysis framework consensus specific to youth rugby, but this should be prioritised given the lack of resources and differences in study populations compared with a professional or elite playing population.

Conclusion

Video analysis is a useful tool to provide detailed descriptions of the mechanisms of injury and concussion and to identify risk factors for their occurrence. Given its emerging success in professional populations, video analysis may be a methodology to improve youth rugby and sports injury prevention research, particularly to improve player safety and welfare. While the present paper focuses on youth rugby, the presented recommendations could be useful in advancing video analysis across non-elite rugby levels to assist in injury surveillance. The issues identified and potential solutions are not limited to video analysis completed in youth rugby union. Still, they could improve sports video analysis broadly and maximise analyses and understanding of injury outcomes, evaluation, and management in youth sports.

Acknowledgements: The Sport Injury Prevention Research Centre is one of the International Olympic Committee Research Centers for the Prevention of Injury and Protection of Athlete Health.

Funding & Disclosures: JB's salary is partially funded by World Rugby, the international governing body of rugby union. In addition, JB has previously received research grants from World Rugby. KS is employed by the Rugby Football Union, the national governing body for rugby union in England. SH is a BMJ Open Sport and Exercise Medicine Editorial Board Member. IJS would like to acknowledge the support of CIHR-Vanier Canada Graduate Scholarships (NSERC/SSHRC/CIHR Vanier CGS) program.

Contributions: IJS contributed to initial manuscript draft. All authors critically reviewed manuscript for submission.

References

1. den Hollander S, Jones B, Lambert M, Hendricks S. The what and how of video analysis research in rugby union: a critical review. Sports Medicine - Open. 2018;4(1).
2. Kolstad AT, Nadeau L, Eliason PH, Goulet C, Hagel BE, Emery CA. Does disallowing body checking impact offensive performance in non-elite under-15 and under-18 youth ice hockey leagues? A video-analysis study. International Journal of Sports Science and Coaching. 2022.
3. West SW, Shill IJ, Clermont C, Pavlovic N, Cairns J, Seselja B, et al. Same name, same game, but is it different? An investigation of female rugby union match events in Canadian Varsity players. International Journal of Sports Science and Coaching. 2021.
4. O'Donoghue P. The use of feedback videos in sport. International Journal of Performance Analysis in Sport. 2006;6(2):1-14.
5. Guadagnoli M, Holcomb W, Davis M. The efficacy of video feedback for learning the golf swing. Journal of Sports Sciences. 2002;20(8):615-22.
6. Gil-Arias A, Del Villar F, García-González L, Moreno A, Perla Moreno MP. Effectiveness of video feedback and interactive questioning in improving tactical knowledge in volleyball. Perceptual and Motor Skills. 2015;121(3):635-53.
7. Perla M, Moreno A, García-González L, Ureã A, Hernández C, del Villar F. An intervention based on video feedback and questioning to improve tactical knowledge in expert female volleyball players. Perceptual and Motor Skills. 2016;122(3):911-32.
8. Aiken CA, Fairbrother JT, Post PG. The effects of self-controlled video feedback on the learning of the basketball set shot. Frontiers in Psychology. 2012;3(SEP):1-8.
9. van Maarseveen MJJ, Oudejans RRD, Savelsbergh GJP. Self-controlled video feedback on tactical skills for soccer teams results in more active involvement of players. Human Movement Science. 2018;57(September 2017):194-204.
10. Tucker R, Raftery M, Fuller GW, Hester B, Kemp S, Cross MJ. A video analysis of head injuries satisfying the criteria for a head injury assessment in professional Rugby Union: A prospective cohort study. British Journal of Sports Medicine. 2017;51(15):1147-51.
11. Cross MJ, Tucker R, Raftery M, Hester B, Williams S, Stokes KA, et al. Tackling concussion in professional rugby union: A case-control study of tackle-based risk factors and recommendations for primary prevention. British Journal of Sports Medicine. 2019;53(16):1021-5.
12. Hutchison MG, Comper P, Meeuwisse WH, Echemendia RJ. A systematic video analysis of National Hockey League (NHL) concussions, part I: Who, when, where and what? British Journal of Sports Medicine. 2015;49(8):547-51.
13. Andersen TE, Floerenes TW, Arnason A, Bahr R. Video Analysis of the Mechanisms for Ankle Injuries in Football. American Journal of Sports Medicine. 2004;32(SUPPL. 1):69-79.
14. Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury mechanisms for anterior cruciate ligament injuries in team handball: A systematic video analysis. American Journal of Sports Medicine. 2004;32(4):1002-12.
15. Hutchison MG, Comper P, Meeuwisse WH, Echemendia RJ. An observational method to code concussions in the National Hockey League (NHL): The heads-up checklist. British Journal of Sports Medicine. 2014;48(2):125-9.

16. Theilen TM, Mueller-Eising W, Bettink PW, Rolle U. Video Analysis of Acute Injuries in Elite Field Hockey. Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine. 2021;31(5):448-52.
17. Davis GA, Makdissi M, Bloomfield P, Clifton P, Echemendia RJ, Falvey ÉC, et al. International consensus definitions of video signs of concussion in professional sports. British Journal of Sports Medicine. 2019:1264-7.
18. Paul L, Naughton M, Jones B, Davidow D, Patel A, Lambert M, Hendricks S. Correction: Quantifying Collision Frequency and Intensity in Rugby Union and Rugby Sevens: A Systematic Review (Sports Medicine - Open, (2022), 8, 1, (12), 10.1186/s40798-021-00398-4). Sports Medicine - Open. 2022;8(1).
19. Paul L, Naughton M, Jones B, Davidow D, Patel A, Lambert M, Hendricks S. Quantifying Collision Frequency and Intensity in Rugby Union and Rugby Sevens: A Systematic Review. Sports Medicine - Open. 2022;8(1).
20. Stokes KA, Locke D, Roberts S, Henderson L, Tucker R, Ryan D, Kemp S. Does reducing the height of the tackle through law change in elite men's rugby union (The Championship, England) reduce the incidence of concussion? A controlled study in 126 games. British Journal of Sports Medicine. 2019:1-6.
21. Hendricks S, O'Connor S, Lambert M, Brown J, Burger N, Fie SM, et al. Contact technique and concussions in the South African under-18 Coca-Cola craven week rugby tournament. European Journal of Sport Science. 2015;15(6):557-64.
22. Tucker R, Raftery M, Kemp S, Brown J, Fuller G, Hester B, et al. Risk factors for head injury events in professional rugby union: A video analysis of 464 head injury events to inform proposed injury prevention strategies. British Journal of Sports Medicine. 2017;51(15):1152-7.
23. Hendricks S, O'Connor S, Lambert M, Brown JC, Burger N, Mc Fie S, et al. Video analysis of concussion injury mechanism in under-18 rugby. BMJ Open Sport and Exercise Medicine. 2016;2(1).
24. West SW, Shill IJ, Sutter B, George J, Ainsworth N, Wiley JP, et al. Caught on camera: a video assessment of suspected concussion and other injury events in women's rugby union. Journal of Science and Medicine in Sport. 2022;25(10):805-9.
25. Williams EMP, Petrie FJ, Pennington TN, Powell DRL, Arora H, Mackintosh KA, Greybe DG. Sex differences in neck strength and head impact kinematics in university rugby union players. European Journal of Sport Science. 2021;0(0):1-10.
26. Emery CA, Meeuwisse WH, Hartmann SE. Evaluation of risk factors for injury in adolescent soccer: Implementation and validation of an injury surveillance system. American Journal of Sports Medicine. 2005;33(12):1882-91.
27. Buckthorpe M, Pisoni D, Tosarelli F, Danelon F, Grassi A, della Villa F. Three Main Mechanisms Characterize Medial Collateral Ligament Injuries in Professional Male Soccer-Blow to the Knee, Contact to the Leg or Foot, and Sliding: Video Analysis of 37 Consecutive Injuries. Journal of Orthopaedic and Sports Physical Therapy. 2021;51(12):611-8.
28. Della Villa F, Buckthorpe M, Tosarelli F, Zago M, Zaffagnini S, Grassi A. Video analysis of Achilles tendon rupture in male professional football (soccer) players: injury mechanisms, patterns and biomechanics. BMJ Open Sport and Exercise Medicine. 2022;8(3):1-9.
29. Shill IJ, West SW, Sick S, Schneider K, Hagel BE, Pasanen K, et al. Injuries and Concussions in Female High School Rugby: Prevention is Worth a Try. Clin J Sport Med. 2021;Pre-print:1-9.

30. Pfister T, Pfister K, Hagel B, Ghali WA, Ronksley PE. The incidence of concussion in youth sports: A systematic review and meta-analysis. British Journal of Sports Medicine. 2016;50(5):292-7.
31. Barden C, Quarrie KL, McKay C, Stokes KA. Employing Standardised Methods to Compare Injury Risk Across Seven Youth Team Sports. International Journal of Sports Medicine. 2021.
32. Chow JW, Knudson DV. Use of deterministic models in sports and exercise biomechanics research. 2011. p. 219-33.
33. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle-related injury rates and nature of injuries in South African youth week tournament rugby union players (under-13 to under-18): An observational cohort study. BMJ Open. 2014;4(8):1-7.
34. Hendricks S, Till K, Den Hollander S, Savage TN, Roberts SP, Tierney G, et al. Consensus on a video analysis framework of descriptors and definitions by the Rugby Union Video Analysis Consensus group. British Journal of Sports Medicine. 2020:566-72.
35. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Den Hollander S, Hendricks S. Mechanisms and Factors Associated with Tackle-Related Injuries in South African Youth Rugby Union Players. American Journal of Sports Medicine. 2017;45(2):278-85.
36. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle technique and tackle-related injuries in high-level South African Rugby Union under-18 players: Real-match video analysis. British Journal of Sports Medicine. 2016;50(15):932-8.
37. Den Hollander S, Ponce C, Lambert M, Jones B, Hendricks S. Tackle and ruck technical proficiency in rugby union and rugby league: A systematic scoping review. International Journal of Sports Science & Coaching. 2020;16(2):421-34.
38. Rugby W. Head Contact Process. 2021.
39. Sciences C, Gardner AJ, Kohler RMN, Levi CR, Grant L, Coast G, et al. Usefulness of Video Review of Possible Concussions in National Youth Rugby League. 2016;131.
40. Gardner AJ, Howell DR, Levi CR, Iverson GL. Evidence of Concussion Signs in National Rugby League Match Play : a Video Review and Validation Study. 2017.
41. Gardner AJ, Howell DR, Iverson GL. A video review of multiple concussion signs in National Rugby League match play. 2018:0-7.
42. Jones B, Tooby J, Weaving D, Till K, Owen C, Begonia M, et al. Ready for impact? A validity and feasibility study of instrumented mouthguards (iMGs). British Journal of Sports Medicine. 2022;56(20):1171-9.
43. Hendricks S, Karpul D, Nicolls F, Lambert M, Hendricks S, Karpul D, et al. Velocity and acceleration before contact in the tackle during rugby union matches union matches. 2012;0414.
44. Bastida-Castillo A, Gómez-Carmona CD, De la Cruz-Sánchez E, Reche-Royo X, Ibáñez SJ, Ortega JP. Accuracy and inter-unit reliability of ultra-wide-band tracking system in indoor exercise. Applied Sciences (Switzerland). 2019;9(5).
45. Jennings D, Cormack S, Coutts AJ, Boyd LJ, Aughey RJ. Variability of GPS units for measuring distance in team sport movements. International Journal of Sports Physiology and Performance. 2010;5(4):565-9.

46. van Tonder R, Starling L, Surmon S, Viviers P, Kraak W, Boer P-H, et al. Tackling sport-related concussion: effectiveness of lowering the maximum legal height of the tackle in amateur male rugby – a cross-sectional analytical study. Injury Prevention. 2023;29(1):56-61.
47. Malenfant S, Goulet C, Nadeau L, Hamel D, Emery CA. The incidence of behaviours associated with body checking among youth ice hockey players. Journal of Science and Medicine in Sport. 2012;15(5):463-7.
48. Arnason A, Tenga A, Engebretsen L, Bahr R. A prospective video-based analysis of injury situations in elite male football: Football incident analysis. American Journal of Sports Medicine. 2004;32(6):1459-65.
49. Concussion in Sport G. Pocket CONCUSSION RECOGNITION TOOL™. British journal of sports medicine. 2013;47(5):267-.
50. Rugby W. Concussion guidance Introduction Concussion guidance Concussion information. 2015(2017):1-12.
51. Rugby W. HIA Protocol. 2021. p. 1-19.
52. King D, Hume P, Cummins C, Pearce A, Clark T, Foskett A, Barnes M. Match and Training Injuries in Women's Rugby Union: A Systematic Review of Published Studies. Sports Medicine. 2019(0123456789).
53. King D, Hume PA, Hardaker N, Cummins C, Clark T, Pearce AJ, Gissane C. Female rugby union injuries in New Zealand: A review of five years (2013–2017) of Accident Compensation Corporation moderate to severe claims and costs. Journal of Science and Medicine in Sport. 2019;22(5):532-7.
54. Taylor AE, Fuller CW, Molloy MG. Injury surveillance during the 2010 IRB Women's Rugby World Cup. British Journal of Sports Medicine. 2011;45(15):1243-5.
55. Till K, Hendricks S, Scantlebury S, Dalton-barron N, Hollander SD, Kemp S, et al. A global perspective on collision and non-collision match characteristics in male rugby union : Comparisons by age and playing standard. European Journal of Sport Science. 2023:1-15.
56. Palmer-Green DS, Stokes KA, Fuller CW, England M, Kemp SPT, Trewartha G. Match injuries in English youth academy and schools rugby union: An epidemiological study. American Journal of Sports Medicine. 2013;41(4):749-55.
57. Leung FT, Franettovich Smith MM, Brown M, Rahmann A, Mendis MD, Hides JA. Epidemiology of injuries in Australian school level rugby union. Journal of Science and Medicine in Sport. 2017;20(8):740-4.
58. Hendricks S, Den Hollander S, Tam N, Brown J, Lambert M. The relationships between rugby players' tackle training attitudes and behaviour and their match tackle attitudes and behaviour. BMJ Open Sport and Exercise Medicine. 2015;1(1):1-8.
59. Hendricks S, Jordaan E, Lambert M. Attitude and behaviour of junior rugby union players towards tackling during training and match play. Safety Science. 2012;50(2):266-84.
60. Finch CF. Getting sports injury prevention on to public health agendas - addressing the shortfalls in current information sources. Br J Sports Med. 2012;46(1):70-4.
61. Fuller CW, Drawer, Scott. The Application of Risk Management in Sport. Sports Med. 2004;34(6):349-56.

Figure legend:

Figure 1. Flowchart of a ‘partial’ blinding methodology for rugby video analysis using two coders