Rugby league ball carrier injuries: The relative importance of tackle characteristics during the European Super League

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ABSTRACT

Rugby league (RL) carries a high injury incidence with 61% of injuries occurring at tackles. The ball carrier has a higher injury incidence than the defender, therefore understanding mechanisms occurring during injurious tackles are important. Given the dynamic, open nature of tackling, characteristics influencing tackle outcome likely encompass complex networks of dependencies. This study aims to identify important classifying characteristics of the tackle related to ball carrier injurious and non-injurious events in RL and identify the characteristics capability to correctly classify those events. Forty-one ball carrier injuries were identified and 205 matched non-injurious tackles were identified as controls. Each case and control were analysed retrospectively through video analysis. Random forest models were built to 1.) filter tackle characteristics possessing relative importance for classifying tackles resulting in injurious/non-injurious outcomes and 2.) determine sensitivity and specificity of tackle characteristics to classify injurious and non-injurious events. Six characteristics were identified to possess relative importance to classify injurious tackles. This included ‘tackler twisted ball carrier’s legs when legs were planted on ground’, ‘the tackler and ball carrier collide heads’, ‘the tackler used body weight to tackle ball carrier, ‘the tackler has obvious control of the ball carrier’ ‘the tackler was approaching tackle sub-maximally’ and ‘tackler's arms were below shoulder level, elbows were flexed’. The study identified tackle characteristics that can be modified in attempt to reduce injury. Additional injury data are needed to establish relationship networks of characteristics and analyse specific injuries. Sensitivity and specificity results of the random forest were 0.995 and 0.525.

KEY WORDS

Rugby league, injury, tackle, ball carrier, random forests

INTRODUCTION

Rugby league (RL) is a contact sport that carries an inherent risk of injury (Fitzpatrick et al., 2018). Time loss injuries have been reported as 57/1000 hours during European Super League match-play with sixty-one percent of these injuries occur during the tackle event (Fitzpatrick *et al.*, 2018). The aim of the tackle is to reduce or stop momentum of the ball carrier and/or prevent the ball from being passed before the tackle is complete (Gabbett, King and Jenkins, 2008). The risk of injury during the tackle is likely due to the physically demanding nature of the event and its frequent occurrence, influenced by a number of intrinsic and extrinsic factors which are associated with this risk (King, Hume and Clark, 2012; Burger *et al.*, 2017).

Various sports have investigated mechanisms of injuries including rugby union (RU) (general injuries, concussion and head injury assessment cases) (Hendricks *et al.*, 2016; Burger *et al.*, 2017; Tierney and Simms, 2018), basketball (anterior cruciate ligament injuries) (Krosshaug *et al.*, 2007), soccer (ankle injuries) (Andersen *et al.*, 2004) and handball (anterior cruciate ligament injuries) (Olsen *et al.*, 2004). These studies used retrospective video analysis to identify characteristics of injury events to establish a pattern of events that could influence an injurious scenario. Using this method, previous research in RU has established that tacklers were more likely to be injured during the final quarter of games, and were less likely to be injured when they performed a shoulder/arm tackle compared to making initial contact with the head/neck (Burger *et al.*, 2017). Furthermore, tacklers were less likely to be injured when the ball carrier's legs were brought to ground before another body region (Burger *et al.*, 2017). In RL, it was found that the most frequently reported tackle-related injury occurred when contact with the ball carrier was made at the shoulder or mid-torso height and secondly, having two or more tacklers involved in the tackle event was found to be most prominent for injury (King, Hume and Clark, 2012). However, to date, no research has investigated the characteristics of the RL tackle event and this level of detailed analysis has been confined to RU (Burger *et al.*, 2016, 2017; Hendricks *et al.*, 2016; Tierney *et al.*, 2018).

In RL, the ball carrier (39/1000 hours) is nearly twice as likely to be injured than the tackler (20/1000 hours) during a tackle event (Tee, Till and Jones, 2019). However, no research to date has investigated the tackler-related characteristics during a ball carrier injurious event. Identifying the actions of the tackler and ball carrier and their importance during these events will enhance current understanding of injury prevention strategies during tackles in RL (King, Hume and Clark, 2010). Furthermore, previous tackle injury research within both RL (King, Hume and Clark, 2010) and RU (Burger *et al.*, 2016, 2017; Davidow *et al.*, 2018) typically use statistical approaches that assume each variable included within the model behaves independently of each other, such as multinomial logistic regression or various types of one-way analysis of variance (Kirasich, Smith and Sadler, 2018). The nature of a tackle scenario within RL suggests a tackle event is likely to encompass a network of relationships within a complex dynamic system (Colomer *et al.*, 2020). Consequently, the characteristics of a tackle likely possess some level of shared and unique variance. This multicollinearity violates assumptions of multinomial logistic regression and one-way analysis of variance and likely limit attempts to understand the true mechanism of injury (Dutt-Mazumder *et al.*, 2011). Subsequently, analyses such as random forest, which appropriately consider any underlying interactions between variables (Weaving *et al.*, 2017) are a more appropriate analysis to identify which variables are associated with tackle injury events.

The aims of this study were to firstly identify which tackle-related characteristic variables possess the greatest relative importance to classify injurious tackle events to the ball carrier in comparison to non-injurious tackles. Secondly, the study aims to identify the capability of those characteristic variables to correctly classify ball carrier injurious and non-injurious tackle events in the European Super League. Identifying these variables provides a greater understanding of the mechanisms of the injury to the ball carrier during the tackle event in RL. In doing so, players, coaches and governing bodies can identify aspects of the tackle to develop strategies for better protect players during these events and therefore reduce injury incidence.

METHODS

Injury Surveillance data

Injury surveillance data from the 2017 and 2018 European Super League seasons were collated via an online reporting survey tool (Fitzpatrick *et al.*, 2018). Information regarding the injuries sustained by players in matches were uploaded to an online platform by the lead physiotherapists at each club. Details of all injuries were classified according to the consensus reached in previous RL injury research (Fitzpatrick *et al.*, 2018). Any injury in which the mechanism was tackling or being tackled, and the severity of the injury was minor (4-7 calendar days) or major (28+ calendar days) were included in the study.

Inclusion criteria

The extracted tackle events were then checked against match video footage obtained from the OptaRugby video database. Match footage was reviewed for each injurious tackle, and the respective tackle was identified. The reported time of injury from the injury surveillance data was then cross-checked from OptaRugby match reports to validate. For the injury to be included in the study, the following criteria had to be satisfied; 1) The ball carrier was removed immediately from the field after the apparent tackle injury event, 2) there were no errors within the injury surveillance data entry, 3) the coder could clearly identify the tackle which caused the injury to the ball carrier, 4) the whole contact event was visible on video, i.e. all tackle phases were visible from available video angles and 5) the ball carrier was the injured player in the event. From this inclusion criteria, 41 injuries were identified for inclusion within the study (Figure 1).

FIGURE 1 HERE

Non-injurious tackles

To identify variables which are important for categorising injurious and non-injurious tackle events, a role-matched non-injurious sample is needed. To ensure the non-injurious sample is as appropriately matched to the injurious event, where possible, the non-injurious event was matched within the same game to align with the playing (team vs team) and game (weather/pitch/time in the season) conditions. Five matched non-injurious tackles with the same injured ball carrier were identified per injurious event. When the ball carrier did not complete five carries during the same match prior to injurious event, the non-injurious event was sourced from the previous game at the match time of which the injurious event occurred. This resulted in a total of 205 non-injurious role-matched controls from the video database.

Video analysis

Video footage for injurious and non-injurious tackles to the ball carrier were analysed using Nacsport Scout Plus (Analysis Pro Ltd., Wales). The software allowed for control over the video playback and saving of each coded event descriptor. The tackle events identified were assessed retrospectively by the first author using 229 different tackle-related characteristics (Hopkinson *et al*., 2019) which were guided by previous literature (Deutsch, Kearney and Rehrer, 2007; Quarrie and Hopkins, 2008; Wheeler, Askew and Sayers, 2010; Fuller *et al.*, 2010; King, Hume and Clark, 2010; Austin, Gabbett and Jenkins, 2011; Hendricks *et al.*, 2014; Sewry *et al.*, 2015; Burger *et al.*, 2016, 2017; Speranza *et al.*, 2017). The characteristics identified originated from the following tackle phase categories (1) tackle event, (2) defensive set up, (3) pre-contact, (4) initial contact (5) post-contact for both tackler and ball carrier and (6) play the ball. All of the tackle characteristics and associated descriptors used are included within the supplementary materials. The tackle event was tagged with the appropriate categorical descriptor and was extracted from Nacsport for further analysis.

Reliability

To test the overall reliability of the variables and methodology used, an intra and inter-coder reliability analysis was completed. For intra-coder reliability, 30 randomly selected tackles from the non-injurious group were coded twice. Coding of the same 30 tackles was separated by seven days (Wheeler, Askew and Sayers, 2010). For inter-coder reliability, an additional coder then coded the same 30 randomly selected tackles. Kappa statistics (κ) were used to evaluate intra- and inter-coder reliability for each randomly selected tackle (James, Taylor and Stanley, 2007). Kappa values between 0.90 and 0.99 show almost perfect agreement between repeated measures, values between 0.8 and 0.89 represent strong agreement, and 0.6 to 0.79 represent moderate agreement (ODonoghue, 2014).

Intra-coder reliability for the coded 30 tackles was: Tackle event variables κ = 0.95, defensive start point variables κ = 1, pre-contact variables κ = 0.94, initial contact variables κ = 0.89, post contact variables κ = 0.9. The inter-coder reliability was assessed using the same methods and the results were as follows: Tackle event variables κ = 0.92, defensive start point variables κ = 0.85, pre-contact variables κ = 0.81, initial contact variables κ = 0.82, post-contact variables κ = 0.81.

Statistical analysis

All statistical analyses were carried out using *R* (R Core Team (2013). R: A language and environment for statistical computing. R Foundation for statistical computing, Vienna, Austria – version 3.5.1). The categorical data extracted from Nacsport were converted to binary code (i.e. descriptor present = 1, descriptor absent = 0). Random forest models were built using the *randomForest* package (Liaw and Wiener, 2002) to 1.) reduce the dimensionality of the dataset by evaluating which tackle characteristic variables possessed relative importance (compared to other variables) for classifying tackle events resulting in either injurious or non-injurious outcomes (binary) for the ball carrier and 2.) determine the sensitivity and specificity of the identified characteristics to classify injury and non-injury events for the ball carrier. Relative importance was determined by a Gini index; with a greater decrease in Gini index determining greater relative importance (Goldstein, Polley and Briggs, 2011). The top characteristics of relative importance were determined independently by two researchers agreeing on a visual break (i.e. the 'elbow') within the Gini-index plot (Goldstein *et al.*, 2010). Simply, 'the elbow' is a steep drop in the Gini-index values and through agreement, this point is selected as the cut off for important variables within the model. To allow the most parsimonious model to be used, a refined random forest was then conducted including only the characteristics deemed to possess relative importance from the agreed visual break (Genuer, Poggi and Tuleau-Malot, 2010). Confusion matrices using the *caret* package (Kuhn, 2007) were generated to assess the sensitivity and specificity of the refined model to classifying the outcome variables (injurious/non-injurious. Qualitative interpretation of the sensitivity and specificity results were as follows: 0.5 (*no value*), 0.51 to 0.69 (*poor*), 0.7 to 0.79 (*fair*), 0.8 to 0.89 (*good*), 0.9 to 0.99 (*excellent*) and 1 (*perfect*) (Akobeng, 2007). In addition, descriptive characteristic data were reported by frequency and percentage for both the injurious or non-injurious ball carrier groups.

RESULTS

Tackle characteristics summary

Table 1 provides an overall summary of modelled characteristics of injurious and non-injurious ball carrier tackles. Table 2 displays the descriptive characteristics of each variable in which a descriptor was found to be important.

TABLE 1 HERE

TABLE 2 HERE

Relative Variable Importance

Figure 2 shows the relative importance of tackle characteristic variables in the random forest model. Using the agreed visual break, six variables were shown as important for the classification between injurious and non-injurious tackles to the ball carrier. '*The tackler twisted the ball carrier legs when the legs were planted on the ground*' (Gini index = 4.5) dominated the importance scale. '*The tackler and ball carrier collide heads*' (Gini index = 2.1), '*the tackler used their own body weight to tackle the ball carrier*' (Gini index = 1.9), *the tackler has obvious control of the ball carrier after initial contact until play the ball*' (Gini index = 1.6), '*the tackler was approaching the tackle sub-maximally for the movement performed*' (Gini index = 1.6) and '*the tackler arms were below shoulder level and elbows were flexed*' (Gini index = 1.6) were the other variables deemed more important.

FIGURE 2 HERE

Model Performance

When testing the model's ability to classify injurious and non-injurious tackles, 19 (46.3%) false positive classifications, with 22 (53.7%) true positives were found. The model also found 205 (100%) true negatives and 0 false negatives. The model's accuracy was 0.919 (CI:0.877-0.95). The sensitivity of the model was 0.995, with specificity at 0.525. Therefore, the random forest model had *excellent* to *perfect* ability to correctly classify injurious events (true positive rate – sensitivity) but it had *poor* capability to correctly classify non-injurious events (false positive rate – specificity).

Twisting of the ball carrier's legs

Figure 3 in the supplementary material illustrates the most important descriptor to categories injurious and non-injurious tackles 'the tackler twisted the ball carrier's legs when the legs were planted on the ground' and 'the tackler lifted their own legs off the ground and used own body weight to bring ball carrier to ground'.

DISCUSSION

Characteristics of injurious tackles to the ball carrier in the European Super League

Using random forest, the current study aimed to firstly identify which tackle-related characteristics possessed the greatest relative importance to classify ball carrier injurious and non-injurious tackle events to inform injury prevention strategies. Secondly, the study aimed to identify the capability of those characteristics to correctly classify ball carrier injurious tackle events in the European Super League.

Six tackle-related characteristics were identified to be important for injurious tackle events of the ball carrier (Figure 2). The tackle characteristics were : (1) 'The tackler twisted the ball carrier legs when as the legs were planted on the ground', (2) 'the tackler and ball carrier collide heads', (3) 'the tackler used their own body weight to tackle the ball carrier', (4) the tackler has obvious control of the ball carrier after initial contact until play the ball', (5) 'the tackler was approaching the tackle sub-maximally for the movement performed' and (6) 'the tackler arms were below shoulder level and elbows were flexed'. When testing the ability of those characteristics to classify injurious events for the ball carrier, the sensitivity and specificity scores were reported at 0.995 and 0.525 (Table 2). Therefore, the high sensitivity results suggest that collectively, these characteristics can classify injurious tackle events to the ball carrier with *excellent* to *perfect* accuracy. However, the *poor* specificity score also shows that the presence of these tackle characteristic events do not always result in injury of the ball carrier which highlights the complex and dynamic nature of the tackle (Burger *et al.*, 2016; Colomer *et al.*, 2020).

The characteristic with the greatest relative importance was '*the tackler twisted the ball carrier legs when the legs were planted on the ground'* which occurred in 12 injurious events (29% of injurious sample). This suggest that ball-carrier's lower limbs are at risk of injury. Although full injury diagnoses are not available from the current sample, a study from the European Super League between the 2013-15 seasons reported the medial collateral ligament (MCL) injury as one of the most frequent injuries (3.9 per 1000 hrs), only behind hamstring strains (4.6 per 1000 hrs) and concussion (4.6 per 1000 hrs) (Fitzpatrick *et al.*, 2018). Furthermore, consistent with this finding, Gibbs, (1994) hypothesised the likely mechanism of an MCL injury within RL were a players foot being fixed into the ground whilst their body is twisted in the opposite direction.

The tackler may twist the leg of the ball carrier in an attempt to bring the ball carrier to ground. To do this, the tackler may also use their own body weight to reduce the momentum of the ball carrier. '*The tackler using their own body weight*' was found to be highly important characteristic and was observed on 31 occasions in the injurious group (76% of injurious sample). In bringing the ball carrier to ground using their body weight, they are less likely to be in control of how the ball carrier is being grounded and this could potentially increase the chance of injury. The twisting motion of the ball carrier's legs and the use of the tacklers body weight could be in some instances, coupled together. In the non-injurious tackle group, the use of body weight was observed 60 times (29% of non-injurious sample), showing large differences in relative occurrence between injurious and non-injurious groups (Table 2). Other possible characteristics such as '*drove the legs/pushed with arms'* (12%) or '*squeezing the tacklers legs and using their momentum'* (0%) were scarce within the injurious group and occurred frequently within the non-injurious group (53% and 43%). Likewise, an RU investigation (Quarrie and Hopkins, 2008) found the loading of a ball carrier's body with the weight of the tackler appeared to be of high risk of severe knee, lower leg and ankle injuries. In the current study, *'the tackler was approaching the tackle sub-maximally for the movement performed*' was found to be highly associated with an injurious tackle (49% of injurious sample). It is possible that due to a sub-maximal approach, a non-dominant tackle could occur and therefore the tackler could lose ground and/or be unable to significantly reduce the momentum of the ball carrier. Consequently, the tackler may in a desperate attempt, use their body weight to reduce the momentum of the ball carrier, coupled with a possible twisting motion. This supports Colomer *et al.*, (2020) which suggested that when performing complex tasks in rugby such as tackling, the characteristics which occur comprise of dependencies and should be analysed as a whole tackle, rather than individual variables. Therefore, further insight into the dynamic relationships of these three tackle characteristics will be very informative for injury prevention practises.

The tackler and ball carrier colliding heads occurred on six occasions in the injurious group (15% of injurious sample) vs once in non-injurious (1% of non-injurious sample) and was found to be important for classification (Table 2). Given the known dangers of head impact tackles and the strong association to concussion (Fuller *et al.*, 2010) this is not surprising. In RU, Fuller *et al.,* (2010) found 50% of the injuries sustained to the ball carrier's head were a resultant of direct head/neck collision. Quarrie and Hopkins, (2008) reported that 28% of all injuries to the head/neck came from direct head to head contact. From this study, of the 7 head collisions observed, 86% resulted in injury. However, although not identified in the current study, RU research hypothesises that the tackler's ability to track the ball carrier onto their shoulder could be an important consideration (Tierney *et al.*, 2018). If the tackler is unable to do this, it could result in the head positioning in line with the ball carrier's trajectory, meaning a possible direct head collision (Tierney *et al.*, 2018). High contact type tackles are reported as 4.25 times more likely to cause a head injury assessment and because of this, law changes in RU have been implemented to reduce the chance of head injury (Tucker *et al.*, 2017). To reduce the chance of this injury in the European Super League, injury prevention strategies such as rule changes may be necessary to alleviate the incidence of concussion within the sport, which currently stands at 4.6 per 1000 hours (Fitzpatrick *et al.*, 2018) which is consistent with RU incidence at 4.7 per 1000 hours (Gardner *et al.*, 2014).

The final characteristics associated with injurious tackles were '*the tacklers arms were below the shoulders with elbows flexed'* which occurred 25 times (61% of injurious sample) and '*the tackler was in obvious control of the ball carrier'* occurring 23 times (56% of injurious sample). As '*the tacklers arms were below the shoulders with elbows flexed'* is within the pre-contact phase, this characteristic could be the first in a 'chain' of events that lead to characteristics such as direct head collision or twisting of the ball carrier's leg. In addition, it is important to note that both of these characteristics were also highly present within the non-injurious sample (90% of the non-injurious sample) and therefore it seems that the two characteristics occur frequently in RL tackling. Further research with more injury data will allow the model to capture further details regarding these characteristics which in turn will contextualise their importance for injurious tackle events so that more informative strategies for injury prevention can be implemented.

Limitations and future directions

The current study was the first to accurately associate tackle-related characteristics with injurious tackle events to a ball carrier in the European Super League. However, as with all research, some limitations are apparent. The objective of the random forest is to classify injuries into 2 outcomes (injurious and non-injurious). In doing so, all types (i.e. concussion), locations (i.e. head/neck) and possible causes (i.e. contact with ground) of injuries were grouped into one sample. Consequently, the model is assuming there can only be two outcomes (injury and non-injury). However in reality, as different types of injuries are nested within the injury class and therefore different characteristics of the tackle are likely to be important for classifying different injury mechanisms. This was necessary within the current research design as the number of accurate injury reports available from the surveillance data were limited compared to other tackle epidemiological based research (Quarrie and Hopkins, 2008; Fuller *et al.*, 2010; McIntosh *et al.*, 2010; Cross *et al.*, 2017). Consequently, improvement in RL injury collection protocols is required to increase the quantity of validated injury reports. This will allow a greater sample to be present and facilitate a greater consideration of the interaction of tackle characteristic variables for specific injury types, locations and causes.

CONCLUSION

A random forests analysis of 41 and 205 tackle events, which were injurious and non-injurious of the ball carrier, identified six tackle characteristics important for classifying ball carrier injurious and non-injurious events in the European Super League. Twisting of the ball carrier's legs possessed clear relative importance to classify injurious tackle events of the ball carrier. Additionally, loading of the tacklers body weight, head collision, sub-maximal speed on approach by the tackler, the tackler arms below the shoulder level and elbows flexed and control of the ball carrier emerged as important characteristics that could lead to ball carrier injury. Together, these variables could accurately classify an injury occurrence (true positive) but at the same time misclassified non-injurious events at a high rate (false positive). However, a larger data set through improved reporting accuracy would strengthen the model's ability to classify injurious and non-injurious tackle events. In turn, this will provide further information on the mechanisms which can lead to injurious tackle events. Nonetheless, the identified characteristics may be used to identify aspects of RL tackling that can be modified to reduce the incidence of injuries which are associated with the tackle.

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Figure 1. Criteria and inclusion breakdown of the injurious tackle data from the 2017 and 2018 injury surveillance data.

Figure 2. Random forest plot of Gini index scores for tackle injury variable importance.

(1) The tackler twisted the ball carriers legs as their legs were planted on the ground. (**2)** The tackler and ball carrier collided heads. **(3)** The tackler lifted their own legs off the ground and used their own body weight to bring the ball carrier to the ground. **(4)** The tackler was in obvious control of the ball carrier after initial contact until play the ball. **(5)** The tackler was approaching the tackle sub-maximally for the movement performed. **(6)** The tacklers arms were below shoulder level and elbows were flexed. **(7)** The tacker did not twist the ball carriers legs. **(8)** The tacklers hands were dropped in an extended position. **(9)** The tackle took place between the 90m and try line. **(10)** The tackler was in control of their own body weight. **(11)** The tackler initially struck any area from the ball carriers arm pit to the shoulder, including the arm. **(12)** The tackler did not shorten their steps and decelerate before contact. **(13)** The ball carrier was moving with maximal effort for the movement performed. **(14)** During the tackle, there was neither a reduction or gain of ground towards the defenders try line since initial contact. **(15)** The ball carrier provided a light to moderate fend. **(16)** The attacking team has conceded 2 tackles before the set was reset by the referee**. (17)** The tackler made initial contact at the ball carriers side. **(18)** The tackler had no leg drive during contact. **(19)** The ball carrier provided no fend. **(20)** The tackler produced rotation of the upper body causing explosiveness on impact. **(21)** The tackler initially struck the area above the ball carriers rib cage to arm pit. **(22)** The tackler held any body part above the shoulder. **(23)** The tackler initially struck the area above the shoulder with any connection with the head/neck. **(24)** The tackler displayed no hip flexion and was in an upright position. **(25)** The ball carrier displayed no hip flexion and was in an upright position**. (26)** The tackler uses contact with their should as the first point of contact. **(27)** The tacklers head was higher than the ball carrier's torso during contact. **(28)** The tackler held any body part between ball carriers rib cage to hips. **(29)** The tackler impedes the ball carrier with the arms. **(30)** The chin of the ball carrier was high (neck extension).

Table 1. Descriptive summary data of typically reported variables for injurious and non-injurious tackles to ball carrier.

	Injurious tackles to ball carrier (*n* = 41)	**Percentage of injurious sample (%)**	**Non-injurious tackles to ball carrier (*n* = 205)**	**Percentage of non-injurious sample (%)**
Number of tacklers				
1	15	37	42	20
2	15	37	86	42
3	10	24	76	37
4	1	2	1	>1
Tackle outcome				
Dominant	1	2	6	3
Passive	14	34	116	57
Neutral	20	49	57	28
Tackle break	0	0	4	2
Offload	2	5	13	6
Try scored	1	2	3	1
Tackled out of play	0	0	2	1
Ball dropped	1	2	4	2
Illegal tackle	2	5	0	0
Tackle direction				
Front	20	49	125	61
Oblique	10	24	65	32
Side	9	22	14	7
Behind	2	5	1	>1
Tackle type				
Shoulder tackle	10	24	46	22
Smother tackle	8	20	82	40
Arm tackle	23	56	71	35
Shirt grab	0	0	5	2
Tap tackle	0	0	1	>1
Pitch area (0m = own try line)				
0m-10m	1	2	7	3
10m-30m	6	15	38	19
30m-50m	8	20	68	33
50m-70m	7	17	41	20
70m-90m	4	10	24	12
90m-100m	15	37	27	13

Table 2. Descriptive characteristic data of injurious and non-injurious tackles for each variable which included a descriptor of relative importance.

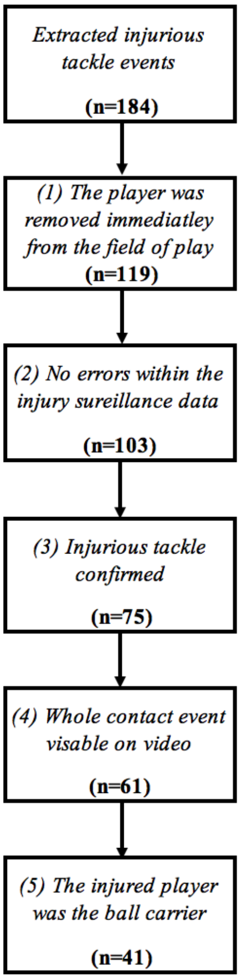
	Injurious tackles to ball carrier (*n* = 41)	**Percentage injurious of sample (%)**	**Non-injurious tackles to ball carrier (*n* = 205)**	**Percentage of non-injurious sample (%)**
Twisting of the ball carrier hips/legs				
The tackler did not twist the ball carrier legs	29	71	201	98
The tackler twisted the ball carrier's legs as the legs were planted on the ground (Supplementary material) *	12	29	0	0
The tackler twisted the ball carrier's legs when the legs were not planted on the ground	0	0	4	2
Ending the tackle				
The tackler pulled the ball carrier to ground with the arms	1	2	0	0
The tackler drove the legs or pushed with the arms to ground the ball carrier	5	12	53	26
The tackler lifted their own legs off the ground and used own body weight to bring ball carrier to ground (Supplementary material) *	31	76	60	29
The tackler impeded (i.e. squeeze the legs) the ball carrier and the momentum grounded the ball carrier	0	0	43	21
The tackler appeared to have no clear strategy in bringing the player to ground.	4	10	49	24
Arm position				
The tacklers arms were dropped in extended position	12	29	15	7
The tacklers arm(s) were level or above the height of their shoulders	4	10	5	3
The tacklers arms were below the shoulder and the elbows were flexed (an active position)*	25	61	185	90
Head collision				
The tackler and ball carrier collide heads *	6	15	1	1
The tackler and ball carrier did not collide heads	35	85	204	99
Speed of tackler				
The tackler was approaching the tackle with maximal speed for the movement performed	14	34	17	8
The tackler was approaching the tackle with sub-maximal speed for the movement performed *	20	49	174	85

The tackler was stationary or walking	7	17	14	7
Control of ball carrier				
The tackler has obvious control of the ball carrier after initial contact until play the ball *	23	56	170	83
The tackler does not have obvious control of the BC after initial contact until play the ball	18	44	35	17

**High relative importance*

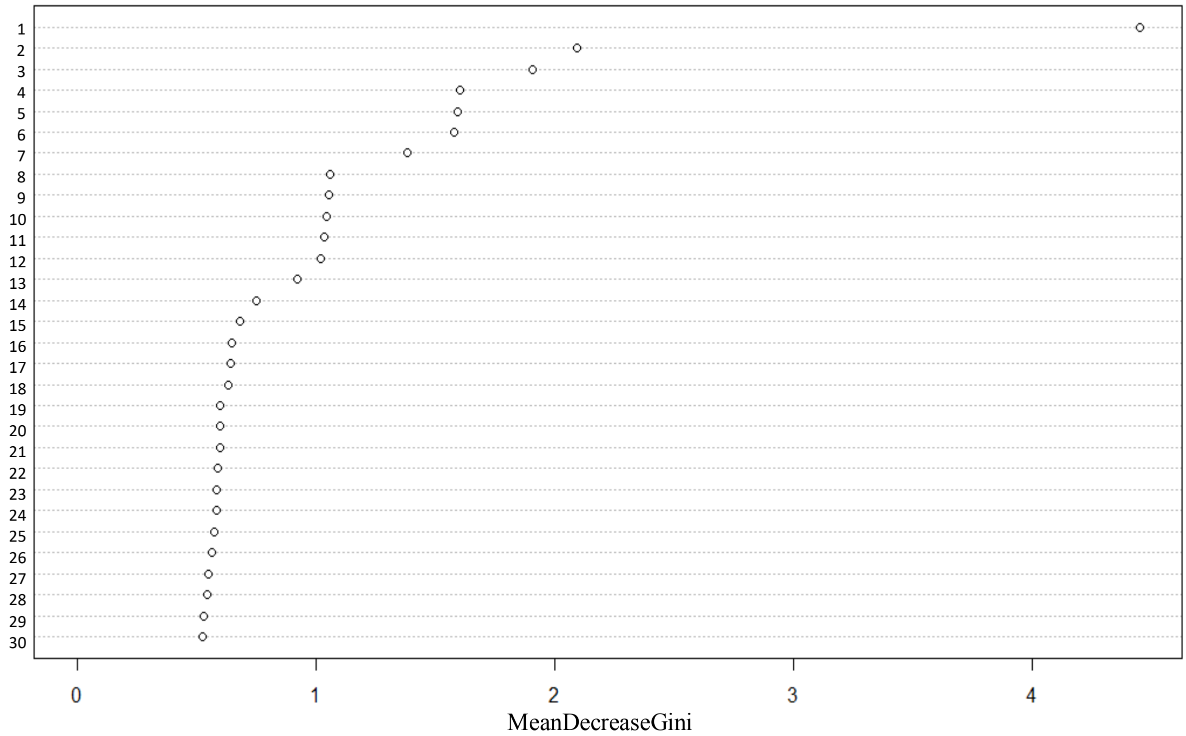
I, Injury; NI, non-injury

Figure 1



Extracted injurious tackle events
(n=184)
(1) The player was removed immediatley from the field of play
(n=119)
(2) No errors within the injury sureillance data
(n=103)
(3) Injurious tackle confirmed
(n=75)
(4) Whole contact event visable on video
(n=61)
(5) The injured player was the ball carrier
(n=41)

Figure 2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