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Risk factors for head injury events in professional Rugby Union: A video analysis of 464 head injury events to inform proposed injury prevention strategies

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Abstract

Objectives: The tackle is responsible for the majority of head injuries during Rugby Union. In order to address head injury risk, risk factors during the tackle must first be identified. This study analysed tackle characteristics in the professional game in order to inform potential interventions.
Methods: 464 tackles resulting in a head injury assessment (HIA) were analysed in detail, with tackle type, direction, speed, acceleration, nature of head contact and player body position the characteristics of interest.
Results: Propensity to cause an HIA was significantly greater for active shoulder tackles, front-on tackles, high speeder tackles and an accelerating tackler. Head contact between a tackler's head and ball carrier's head or shoulder was significantly more likely to cause an HIA than contact below the level of the shoulder (IRR 4.25, 95% CI 3.38 – 5.35). The tackler experiences the majority (78%) of HIAs when head-to-head contact occurs. An upright tackler was 1.5 times more likely to experience an HIA than a bent at the waist tackler (IRR 1.44, CI 1.18 – 1.76).
Conclusions: This study confirms that energy transfer in the tackle is a risk factor for head injury, since direction, type and speed all influence HIA propensity. The study provides evidence that body position and the height of tackles should be a focus for interventions, since lowering height and adopting a bent at the waist body position is associated with reduced risk for both tacklers and ball carriers. To this end, World Rugby have implemented law change based on the present data.

WHAT DOES THIS STUDY ADD?

- This study is the largest to date to decribe risk factors for head injuries requiring a head injury assessment in professional rugby union, using a cohort of 464 head injury events over three years
- The tackler more likely to sustain head injuries than the ball carrier
- Energy transfer is a risk factor for head injury, since active shoulder, front on, high speed and acceleration into tackles were more likely to cause head injuries
- We find that higher impacts are more than four times more likely to result in head injury. Tacklers sustain 78% of injuries, even when head to head contact occurs
- Player body position is a significant risk factor, with an injury risk that is 1.5 times greater when tacklers and ball carriers are upright, rather than bent at the waist
- Based on this study, World Rugby have proposed law changes and a global awareness programme to change player behaviour to lower the height of the tackle
- These changes may reduce the risk of head injury both the tackler and ball carrier

Introduction

The tackle is the most injurious match event in Rugby Union, accounting for between 40% and 60% of all match injuries [1-4]. Among the more common tackle injuries are those to the head, with concussion now the most frequently occurring injury in the professional game[1]. Studies examining the risk factors of head injuries in the sport find that head injuries occurred most frequently during front-on [5,6] and high tackles[6].

We have recently investigated the head injury risk during tackles in the male professional game, with 464 out of 611 (76%) analysed HIA events from a cohort of 1516 matches occurring during tackles. Of these, 72% occur to the tackler (Paper 1). Given the growing concern over head injuries in sport, a particular focus on the characteristics of tackles that expose players to the highest risk of head injury is warranted. To our knowledge, no large-scale video analysis study has investigated specific risk factors for head injuries during tackles in professional Rugby Union, though similar studies exist for Rugby League[7], Australian football [8] and American football[9], with smaller studies in Rugby Union [10].

The aim of the present study is to analyse the tackle in detail, using World Rugby's HIA protocol to identify head impacts sufficient to cause a player to either be permanently removed from play, or to require an off-field assessment. This approach is the critical next step towards injury prevention, and necessitates that risk factors for injury be identified so that interventions can be targeted to reduce injury risk [11,12].

Methods

This prospective cohort study was conducted between 2013 and 2015 in six major professional elite Rugby Union competitions. These were both international (Six Nations, Rugby Championship and Rugby World Cup) and national (England Premiership, Super Rugby, Top 14, Pro 12 and European Champions Cup) competitions. Ethics approval was obtained from the World Rugby Internal Ethics Committee, and all players participating in the professional leagues provided written informed consent as part of the World Rugby Head Injury Assessment (HIA) Protocol.

Analysis framework

A tackle was defined as any event where one or more players attempted to stop or impede the ball carrier, irrespective of whether the player was brought to the ground. This distinguishes our definition from that of a tackle in the law, which requires the ball carrier to be held and taken to ground. However, we chose this definition for consistency with previously published research [13]

All cases of tackles resulting in HIA events, as well as a cohort of 3,160 tackles not causing injury from 20 representative control matches were analysed by a single professional rugby video analyst. Where the classification of the tackle was unclear, a second professional rugby analyst was consulted and consensus reached.

The characteristics of the tackle that were coded were defined through consultation with professional rugby coaches and a referee and experienced rugby epidemiology researchers, and drawing from previous studies examining the rugby tackle and injury [6,14].

Table 1 summarizes the tackle characteristics analysed.

HIA events

The Head Injury Assessment (HIA) has been described in more detail elsewhere [15]. For this study, an HIA event was defined as any player entering the HIA protocol at the HIA1 stage, having either a) displayed Criteria 1 signs and therefore been immediately and permanently removed from play, or b) received an off-field screening assessment irrespective of whether that player subsequently returned to play or was permanently removed from play.

Data were collected using specifically designed forms, or electronically using a bespoke tablet application (CSx Headguard, New Zealand). Events were then collated in a central database as part of World Rugby's HIA process. This database was used to identify every reported HIA entry at stage 1 in the HIA protocol in seven international and national competitions. During this period, 112 cases were entered into the database with delayed signs or symptoms suggesting a delayed concussion. These cases could not be directly associated to a specific match event and were excluded from analysis. A further 25 HIA events for which video was unclear or unavailable were also not included in the present study.

Data analysis

The propensity, in HIA events per 1000 tackles for each tackle characteristic, was calculated by dividing the number of HIA events occurring from that tackle by the total number of that tackle derived from the control cohort. Incidence is expressed as HIA events per 1,000 match hours.

Data are presented as means and 95% confidence intervals (CIs). The probability of each tackle characteristic being associated with a player undergoing an HIA was assessed using a Poisson regression with a log link function, using exposure to the characteristic as the offset variable to compare predictor/independent variables. Incident Rate Ratios (IRRs) were calculated to compare the propensity of two events by expressing the calculated HIA propensity relative to one another. Data was analysed using a standard statistical package (SPSS), and a conventional type 1 error rate of 0.05 was used, with statistical significance accepted when the 95% CIs did not overlap.

Results

Overall summary

464 HIA events occurred during tackles, with 335 (72%; CI 68%–76%) to the tackler and 129 to the ball carrier (28%; CI 24–32%). The overall propensity for HIA events was 1.94 HIAs/1000 tackles, with tacklers experiencing a more than two-fold higher incident rate than ball carriers (IRR = 2.59, CI 2.12 – 3.18).

Table 2 shows the number of HIA events, the propensity and the incidence of various tackle characteristics to cause an HIA event, along with the proportion of HIAs to the tackler for each of the characteristics.

Tackle Type

The three most common legal tackle types – active shoulder, passive shoulder and smother tackles – accounted for 99% (157 out of 158 tackles per match) of match tackles and 93% of tackle-related HIA events.

Active shoulder tackles had a significantly higher HIA event propensity than passive shoulder and smother tackles (IRR = 2.07, CI 1.65 – 2.59 for Active vs Passive shoulder tackle; IRR 2.13, CI 1.69 – 2.68 for Active shoulder vs Smother tackle, both $P < 0.05$).

Illegal tackles, ruled by the referee, accounted for 25 HIAs. These had a significantly greater propensity than legal tackles (1.84 HIAs/1000 legal tackles vs 65.9 HIAs/1000 illegal tackles, IRR = 35.95, CI 24.02 – 53.79), with high tackles having a particularly high risk (237.5 HIAs/1000 high tackles). Propensity could not be calculated for "No arm" tackles and "Use of Elbow" tackles because no such events occurred in the control cohort.

Tackle direction

Front-on tackles had a significantly higher propensity and incidence than Angled, Side-on or tackles from behind (IRR = 1.65 (CI 1.31 – 2.13), 2.02 (CI 1.58 – 2.60) and 1.73 (CI 1.20 – 2.50) for propensity for Front-on vs Angle, Side-on and Back tackles, respectively).

Acceleration

Propensity was greatest when the tackler accelerated into the tackle (IRR = 2.86, CI 2.28 – 3.58 vs ball carrier; IRR = 2.34, CI 1.78 – 3.09 vs both; IRR = 3.06, CI 2.11- 4.42 vs neither). Incidence was greatest when the ball carrier accelerated into the tackle, by virtue of the high frequency of this situation (93 events per match compared to 17 for tackler accelerating).

Number of tacklers

Tackles in which three or more tacklers were involved, although rare, were associated with a higher likelihood of HIAs than those with one (IRR = 1.67; CI 1.02–2.72) or two tacklers (1.86; CI 1.1.4 – 3.05).

Player speeds

The propensity for various combinations of player speeds are shown in Figure 1. The propensity increased significantly as the tackler speed increased (IRR = 3.05, CI 2.39 – 3.89, High speed vs Static tackler; IRR = 2.39, CI 1.93 – 2.96, High Speed vs Low speed tackler, $P < 0.05$).

For static and low speed tacklers, propensity increased as the ball carrier speed increased, whereas for high tackler speeds, propensity decreased as the ball carrier speed increased (IRR = 1.82, CI 1.15 – 2.89, Static BC vs High Speed BC when tackler is at high speed, Figure 1).

Type of head contact

Table 3 shows the HIA propensity for the tackler as a result of various types of head contact, along with the number of tackler HIA events for each contact. Data are shown for the tackler

only, because study resource limitations meant that the control cohort was analysed from the tackler perspective only.

The greatest propensity occurred for head to head contact, followed by head to elbow and head to knee contact. All types of head contact injured the tackler relatively more often, with the exception of head to ground (17% to tackler), whiplash (27% to tackler) and head to arm contact (36% to tackler).

When grouped into either "high contact tackles" being tackler head contact with a ball carrier's head or shoulder (as per by the legal definition of a high tackle), or "low contact tackles" below the shoulder, the number of HIAs was 130 from high contact (3.75 HIAs/1000 tackles, 95% CI 3.16 to 4.16) and 165 from low contact (0.88, 95% CI 0.76 to 1.03). The IRR for high vs low contact was 4.25 (CI 3.38 – 5.35). This excludes head contact with the ball carrier's arm, hand or elbow, since these are not necessarily indicative of the area of the ball carrier's body that the tackler is contacting or attempting to make contact with.

Tackler and ball carrier body position

Table 4 shows the HIA propensity and incidence for various tackler and ball carrier body positions, separated into tackler body position in the top panel and ball carrier body position in the bottom panel. For any tackler body position (Table 4 Top panel), propensity was highest when the ball carrier was falling or diving, and lowest when the ball carrier was bent at the waist. HIA incidence was highest for an upright ball carrier and lowest for a falling/diving ball carrier.

For any ball carrier body position (Table 4 bottom panel), the propensity was highest for an upright tackler, and lowest when the tackler was falling or diving.

Figure 2 shows the HIA event propensity for tackler and ball carrier body positions when combined for all possible body positions.

Given the relatively low overall incidence of HIAs occurring for falling/diving tacklers and ball carriers (Table 4), a specific comparison was made for upright vs bent at the waist body positions for both players. The incident rate was 1.44 (CI 1.18 – 1.76) for an upright vs bent at the waist tackler (2.69 HIAs/1000 tackles vs 1.87 HIAs/1000 tackles). The IRR for an upright (2.44 HIAs/1000 tackles) vs bent at the waist ball carrier (1.15 HIAs/1000 tackles) was 2.13 (CI 1.73 – 2.62).

Discussion

The present study expands on previous research in this area [6,16,17], and is the largest such to date, describing a spectrum of propensities for specific tackle characteristics to result in a head injury event.

We find that the propensity for head injury was greatest for active shoulder tackles, front-on tackles, an accelerating tackler, more than one tackler, higher speeds, higher impacts and more upright tacklers.

Application of the sequence of prevention model

According to the sequence of prevention model [18], risk reduction requires first that the extent of the problem be described, something that has been done in numerous injury surveillance studies in various competitions [1,2,19]. Thereafter, the risk factors for injury must be identified, which was the aim of this study, and then strategies implemented to reduce the risk.

Based on the present data, experts from within rugby including elite coaches, players and officials, recommended that the game adopt a zero tolerance to head contact. This is to be reinforced by a global awareness program, the introduction of new tackle sanction categories (reckless and accidental) and an increase in sanctions for all types of head contact. These interventions are recommended to modify player behaviour and reduce the risk of head injury [20]. The effects of these adopted changes are currently being monitored.

This study thus represents the application of suggested best-practice injury reduction methods using the public health approach [12,18],[21]. Subsequently, we describe the significant findings of the present research that informed the recommended measures.

Player body position and tackle height

A novel aspect of the present study was the analysis of player body position in the tackle as a risk factor for head injury. This was examined since previous research had established that high tackles were significantly more likely to cause injury, particularly to the ball carrier[6].

We found that propensity was greatest for an upright tackler and a falling or diving ball carrier, irrespective of the other player's body position (Table 4). Given that a falling or diving ball carrier in the tackle is extremely rare (2 events per match, compared to 82 upright and 74 bent at the waist ball carriers per match), the least desired body position in the vast majority of tackles is for both players to be upright.

Taken in conjunction with the finding that high contact types (tackler head to ball carrier head or shoulder) are 4.25 times more likely to cause an HIA than low contact types (below the shoulder), this finding strongly supports the hypothesis that lowering the height of the tackle, enforcing current laws on tackle height, and changing the tackler body position from upright to bent at the waist through education or law change may be strategies to consider to prevent injury, as has been described previously [6].

Importantly, our data suggest that this would reduce the risk for both the tackler and ball carrier, since it is the tackler who experiences the majority of head injuries, even during head to head impacts (78% of HIAs, Table 3). Lowering the height of the tackle and increasing the number of bent at the waist tackler situations would prevent this highest propensity head contact from occurring. While impacts between the tackler's head and ball carrier's body would still occur, they carry significantly lower risk that head-to-head impacts. In particular, head-to-upper body (hip to shoulder) impacts carry low risk, and may be advised as a focus for greatest tackler safety. These changes may protect both the tackler as well as the ball carrier.

Influence of speed, acceleration and direction on head injury risk

Confirming previous research [14], we also find that high speed tackles and tackles where the tackler accelerates into contact are significantly more likely to cause HIA events, particularly when the tackler speed is high (Figure 1). Of interest was that propensity decreases as ball carrier speed increases when the tackler is running at high speed, whereas it increases with ball carrier speed for static and low speed tacklers (Fig 1).

The reason for this pattern when the tackler is at high speeds requires future analysis. It is possible that an interaction of characteristics is responsible. For instance, as ball carrier speed increases when tacklers are at high speed, the likelihood of front on and active shoulder tackles decreases, while side-on, angled and passive shoulder tackles are more numerous (data not shown). Since these tackle types and directions have a lower propensity (Table 2), the resultant propensity for high tackler and ball carrier speeds may be lower compared to static or low speed ball carriers.

High impact force is another previously identified risk factor [14], which accounts for why front-on tackles and active shoulder tackles have a higher propensity to cause HIA events than other tackler directions and types, respectively (Table 1). This finding contradicts previous research showing that the injury rate per 1000 tackles was highest for tackles from behind and lowest for front-on tackles [6]. However, that study examined all injury types, whereas Kemp et al (2008) studied concussions and found that tackling head-on was the factor most commonly associated with concussions [5].

Appropriately targeted interventions and practical challenges

Interventions to reduce the overall incidence of head injury should be targeted towards those events described here and previously as having a high propensity to cause injury. Based on the present findings, the risk of HIA events would be reduced if the occurrence of those tackle characteristics shown to have a high propensity was reduced.

Practically, however, reducing the occurrence of certain of these events poses a significant challenge. One possible means to reduce speed would be law change to bring opposing players closer together by changing the offside line. This may, however, result in an increase in the number of situations where the tackler accelerates into the tackle to gain the speed with which to dominate the collision, a situation we have found to have a high propensity for injury, but which occurs relatively infrequently at present (Table 2). Increasing the frequency of this situation might offset any reduction in speed at contact and increase the incidence of concussion.

The challenge for Rugby Union's regulatory authorities is to identify practically effective and viable, rather than theoretical, interventions. Practical approaches to risk reduction must focus on shifting player behaviours away from those events identified in this study as having a high propensity and towards low propensity scenarios, as might be achieved if upright tackles could be replaced with bent at the waist tackles. Law change or reinforcement of current laws to sanction undesired behaviours have been proposed to achieve this. Alternatively, the risk within each characteristic or behaviour might be reduced through education to ensure that the tackle is executed safely, and this requires further exploration.

An avenue that is worth exploring further is that of tackle technique, since it has been shown that poor technique is a risk factor for both concussion [10] and other injuries [22]. In considering technique, an important consideration for the ultimate success is whether a

technique is both safe and effective, because the latter will be a key requirement for coaches and players and must be acknowledged if an advised technique is to be adopted.

In this regard, some practical challenges exist, because evidence suggests that front-on shoulder tackles [23] and tackles involving leg drive are most effective for success [23]. In the present study, we show that front-on tackles and tackles involving acceleration and speed, and thus higher energy transfer are more injurious. The optimal coached technique for performance may thus be at odds with the optimal technique to reduce head injury risk, whereas poor tackle execution [22] may increase the risk. This balance of factors must be taken into consideration by future interventions focused on technique education.

An important consideration is that changing behaviour to reduce the risk of head injury may result in an increase in risk of other injuries. Quarrie & Hopkins recognized this when they found that all-injury risk to the tackler was highest for low tackles, and surmised that an increase in the proportion of low tackles might increase the risk of certain injuries to the tackler, even while reducing head injury risk [6]. The potential undesired consequences of any behaviour changes must thus be monitored to allow rapid response to such potential negative outcomes.

Study limitations

The limitations of the method of video analysis used in the present study have been described previously, as have the considerations around the use of HIA events rather than concussions to identify significant head injuries (Paper 1). Future research may compare time-loss concussions to HIA events to ascertain whether more severe head injuries, those diagnosed as concussions, differ from HIA events for any of the analysed characteristics.

Finally, the application of this research to the community game remains unknown. The incidence of concussion is lower in the community game than the currently analysed professional game, but its reduction is no less important. In principle, the introduction of laws should affect every level of rugby (though not equally), and the absence of specific data on the mechanism of head injury in community rugby means that it remains unknown what effect this law intervention may have on community rugby players. Further research is warranted in this regard.

In conclusion, this study examines the risk of HIA events associated with tackling, and finds that direction, speed, tackle type and acceleration all influence risk. Body position is a novel factor influencing risk, with upright tacklers and ball carriers representing a viable possible target for interventions, to reduce the height of the tackle and thus the risk of high propensity head impacts. Based on these data, a group of experts from within the sport have recommended law amendments to change behaviour and reduce injury risk, with future possible interventions including tackle technique and further law changes.

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Tables

Table 1: Characteristics of the tackle analysed in this study

Tackle type	
Active shoulder tackle	First contact is with the tackler's shoulder, and the tackler drives or attempts to drive the ball carrier (BC) backwards
Passive shoulder tackle	First contact is with the tackler's shoulder and the tackler does not drive or attempt to drive the BC back
Smother tackle	Tackler uses the chest and attempts to wrap both arms around the ball carrier
Tap tackle	Tackler trips the BC with a hand on the lower limb below the knee
Lift tackle	Tackler lifts the BC's hips above the BC head
No arm tackle	Tackler impedes the BC without use of their arms
High tackle	Tackler makes contact above the BC shoulders, as adjudicated by the on-field referee
Tackle direction	
Front-on	Tackler makes contact on the front of the BC
On angle	Tackler makes contact with the BC on an angle
Side-on	Tackler makes contact with the side of the BC
Back	Tackler makes contact with the BC from behind
Accelerating player	
Tackler	Only the tackler accelerates into contact
Ball carrier	Only the BC accelerates into contact
Both	Both tackler and BC accelerate into the contact
Neither	Neither player accelerates into contact
Tackler and BC speed	
High	Running or sprinting
Low	Walking or jogging
Stationary	Standing still or moving minimally
Tackler and BC body positions	
Upright	The player is standing in an upright position, with the knees only slightly bent and with minimal hip flexion
Bent at the waist	The player is bent at the waist or crouched
Falling/diving	The player is in the process of diving or falling to ground at the point of contact

Table 2: HIA number, propensity and proportion to tackler for various tackle characteristics

Tackle Characteristic	Events per match	HIA number	Propensity (95% CI), HIAs/1000 Events	Incidence (95% CI), HIAs/1000 hours	Percentage of HIAs to tackler (95% CI)
Tackle type					
Active shoulder	39	177	2.98 (2.57 – 3.46)	2.92 (2.52 – 3.38)	77% (70%–82%)
Passive shoulder	61	134	1.44 (1.22 – 1.71)	2.21 (1.87 – 2.62)	84% (77%–90%)
Smother tackle	57	120	1.40 (1.17 – 1.68)	1.98 (1.65 – 2.37)	64%(55%–72%)
Tap tackle	1	5	3.66 (1.53 – 8.80)	0.08 (0.03 – 0.20)	100.0%
Lift (illegal)	0.05	1	6.60 (0.93 – 46.83)	0.02 (0.00 – 0.12)	0.0%
No arms	0	5			0.0%
High tackle	0.05	18	237.47 (149.61 – 376.91)	0.30 (0.19 – 0.47)	11.1% (3%–33%)
Use of elbow / forearm	0	1		0.02 (0.00 – 0.12)	0.0%
Tackle direction					
Front	61	247	2.67 (2.36 – 3.02)	4.07 (3.60 – 4.61)	67% (61%–73%)
On angle	41	101	1.62 (1.33 – 1.97)	1.67 (1.37 – 2.02)	75% (66%–83%)
Side-on	42	84	1.32 (1.06 – 1.63)	1.39 (1.12 – 1.72)	81% (71%–88%)
Back	14	32	1.54 (1.09 – 2.18)	0.53 (0.37 – 0.75)	78% (61%–89%)
Accelerating player					
Tackler	17	116	4.47 (3.73 – 5.37)	1.91 (1.59 – 2.29)	64% (55%–72%)
Ball carrier	93	221	1.56 (1.37 – 1.79)	3.64 (3.19 – 4.16)	74% (68%–80%)
Both	31	90	1.91 (1.55 – 2.35)	1.48 (1.21 – 1.82)	77% (68%–85%)
Neither	17	37	1.47 (1.06 – 2.02)	0.61 (0.44 – 0.84)	73%(57%–85%)
Number of tacklers					
1	81	246	2.00 (1.77 – 2.27)	4.06 (3.5 – 4.60)	72% (66%–77%)
2	74	201	1.80 (1.57 – 2.06)	3.31 (2.89 – 3.81)	73% (66%–78%)
3 or more	3	17	3.35 (2.08 – 5.38)	0.28 (0.17 – 0.45)	71% (47%–87%)

Table 3: HIA number, propensity and proportion to tackler as a result of various types of head contact

	HIAs to tackler	Propensity (95% CI), HIAs/1000 Events	% of HIAs to the tackler (95% CI)
Head to head	84	11.30 (9.13 - 14.00)	78% (69%–85%)
Head - elbow	13	6.35 (3.69 - 10.94)	100%
Head - knee	19	3.09 (1.97 - 4.85)	61% (44%–76%)
Head - hip	71	1.72 (1.36 - 2.17)	97% (91%–99%)
Head - shoulder	46	1.69 (1.27 - 2.26)	65% (54%–75%)
Head - arm	20	1.37 (0.88 - 2.12)	36% (25%–50%)
Head - lower leg	18	1.36 (0.86 - 2.17)	82% (61%–93%)
Head - ground	1	0.73 (0.10 - 5.20)	17% (3%–56%)
Head - upper body	42	0.46 (0.34 - 0.62)	79% (67%–88%)
Head - upper leg	15	0.43 (0.26 - 0.72)	83% (61%–94%)
Whiplash	3	-	27% (10%–57%)
Head - equipment	0	-	
Head - hand (fist)	3	-	75.0% (30%–95%)

Table 4: HIA number, propensity and proportion to tackler for tackler and ball carrier body position combinations

Tackler body position	Ball carrier body position	Events per match	HIA number	Propensity (95% CI), HIAs/1000 Events	Incidence (95% CI), HIAs/1000 hours	Percentage of HIAs to tackler (95% CI)
Upright	Upright	31	131	2.80 (2.36 - 3.32)	2.16 (1.82 - 2.56)	65% (56% - 73%)
	Bent at the waist	9	28	1.99 (1.37 - 2.88)	0.46 (0.32 - 0.67)	46% (30% - 64%)
	Falling/diving	0.05	5	65.96 (27.46 - 158.48)	0.08 (0.03 - 0.20)	40% (12% - 77%)
Bent at the waist	Upright	33	133	2.64 (2.23 - 3.13)	2.19 (1.85 - 2.60)	87% (80% - 92%)
	Bent at the waist	48	83	1.14 (0.92 - 1.41)	1.37 (1.10 - 1.70)	66% (56% - 76%)
	Falling/diving	1	17	14.95 (9.29 - 24.05)	0.28 (0.17 - 0.45)	35% (17% - 59%)
Diving	Upright	18	40	1.46 (1.07 - 1.99)	0.66 (0.48 - 0.90)	98% (87% - 100%)
	Bent at the waist	16	17	0.69 (0.43 - 1.11)	0.28 (0.17 - 0.45)	88% (13% - 53%)
	Falling/diving	1	10	4.89 (2.63 - 9.08)	0.16 (0.09 - 0.31)	50% (24% - 76%)

Ball carrier body position	Tackler body position	Events per match	HIA number	Propensity (95% CI), HIAs/1000 Events	Incidence (95% CI), HIAs/1000 hours	Percentage of HIAs to tackler (95% CI)
Upright	Upright	31	131	2.80 (2.36 - 3.32)	2.16 (1.82 - 2.56)	65% (56% - 73%)
	Bent at the waist	33	133	2.64 (2.23 - 3.13)	2.19 (1.85 - 2.60)	87% (80% - 92%)
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