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Does ball carrier technique influence tackler head injury assessment risk in elite rugby union?

Gregory J. Tierney[1]
gtierne@tcd.ie

Karl Denvir[2]
Karl.Denvir@leinsterrugby.ie

Garreth Farrell[2]
garreth.farrell@leinsterrugby.ie

Ciaran K. Simms[1]
csimms@tcd.ie

[1]Trinity Centre for Bioengineering, Trinity College Dublin, Ireland
[2]Leinster Rugby, Dublin, Ireland

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Corresponding Author:
Gregory Tierney
Trinity Centre for Bioengineering
Trinity College Dublin
Dublin 2
Ireland
gtierne@tcd.ie
+353 89 2381688

Abstract

The aim of this study was to use video evidence of tackles in elite level rugby union to identify ball carrier proficiency characteristics, for both lower and upper body tackles, that have a higher propensity to result in Head Injury Assessments(HIA) for the tackler. HIA (n=74) and non-HIA tackles (n=233) were categorised as either front-on or side-on upper or lower body tackles and scored for ball carrying proficiency characteristics. Side-on tackles included tackles from behind. A Chi-Square test ($p<0.05$) and Cramer's V were calculated to compare proficiency characteristics in HIA and non-HIA cases. For front-on upper body tackles, the ball carrier "fending into contact" ($p<0.01$;ES=Moderate) and "explosiveness on contact" ($p=0.04$;ES=Moderate) had a higher propensity to result in a HIA for the tackler. Fending into contact was exhibited in 47% of all upper body Tackle front-on HIA cases. The fending arm contacted the tackler's head in 67% of these cases. Fending into contact can potentially be dangerous and therefore emphasis should be placed on safe fending during tackle-based training drills. Referees should also be alert to arm-to-head contact during the fend. Given the low number of ball carrier characteristics identified, focus should be placed on tackler characteristics for HIA prevention strategies.

Key Words: Concussion, Head Impact, Tackling, Injury Prevention

1. Introduction

Tackling is the main cause of contact in rugby union (Fuller, Brooks, Cancea, Hall, & Kemp, 2007) with some players making over 30 tackles per game (Deutsch, Kearney, & Rehrer, 2007). Unfortunately, it is also the most common cause of head injuries (Fuller, Laborde, Leather, & Molloy, 2008; Fuller, Taylor, & Raftery, 2015; Quarrie & Hopkins, 2008; Tierney, Lawler, Denvir, McQuilkin, & Simms, 2016). For the sixth consecutive season, concussion was the most commonly reported match injury for English Premiership rugby union (incidence rate of 20.9/1000 player hours, contributing to 22% of all match injuries during the 2016-17 season) (Rugby Football Union, 2018). In one season alone, one study found that 23% of elite level Rugby Union participants suffered a concussion (Shuttleworth-Edwards et al., 2008). It is well understood that both correct tackler and ball carrier technique are necessary for successful and safe participation in rugby union (Hendricks & Lambert, 2010; Hendricks & Lambert, 2014; Tierney, Denvir, Farrell, & Simms, 2018a, 2018c; Tierney, Krosshaug, Wilson, & Simms, 2015), and that incorrect tackle technique is a risk factor for injury (Burger et al., 2016; Hendricks et al., 2015).

Video analysis studies have provided valuable information on injury (Burger et al., 2016; Quarrie & Hopkins, 2008) and concussion (Fuller et al., 2015; Hendricks et al., 2015; Hendricks et al., 2016) risk factors in rugby union. This has also been the case for concussion injury research in other sports such as rugby league (Gardner et al., 2015), ice hockey (Hutchison, Comper, Meeuwisse, & Echemendia, 2013) and soccer (Andersen, Arnason, Engebretsen, & Bahr, 2004). A recent study (Tierney et al., 2016) on direct head impacts in elite level rugby union reported that the tackle phase of play accounted for 60% of direct head impacts and that the tackler was the head impacted player in 97% of these cases.

It appears that the tackler is at most risk of a direct head impact, and hence concussion, in the tackle. As a result, Tierney et al. (Tierney, Denvir, Farrell, & Simms, 2018b) performed a video analysis study of elite level match play to identify tackler proficiency characteristics that had a lower propensity to result in a Head Injury Assessment (HIA) for the tackler. The HIA was first introduced in 2012 by World Rugby as the pitch side assessment process for concussion injuries (Fuller, Kemp, & Decq, 2014) and has previously been

81 described in detail (Fuller, Kemp, & Raftery, 2017). In brief, the aim of the HIA is to create a standardised
82 tool for the medical assessment of suspected concussion injuries in rugby union (McCrory et al., 2005).
83 During a game, a player enters the HIA protocol by displaying on-field signs and symptoms of concussion
84 (McCrory et al., 2005). The HIA assesses a range of concussive symptoms including memory difficulties,
85 cognitive ability, balance and player discomfort. In the HIA, if a player's score is positive, they are removed
86 from play and must follow the return-to-play protocol (Kemp, Patricios, & Raftery, 2016). Of the 24
87 diagnosed concussions at the 2015 Rugby World Cup, 19 were first suspected on the field using the HIA
88 protocol (Fuller et al., 2017). The remaining 5 were suspected post-match. A total of 39 on-field HIAs were
89 conducted during the 2015 Rugby World Cup (Fuller et al., 2017). It is clear that a reduction in tackle
90 related HIAs would have a strong influence on concussion injury reduction. Tierney et al. (Tierney, Denvir,
91 Farrell, & Simms, 2018b) found several tackler proficiency variables that had a lower propensity to result
92 in a HIA for the tackler, especially "identify/track ball carrier onto shoulder", "head up and forward/face
93 up", "straight back, centre of gravity forward of support base" and "head placement on correct side of ball
94 carrier". The results from the study provided an evidence-base at the elite level to assist coaches in
95 developing and implementing HIA prevention strategies for the tackler.

96 However, this study did not assess ball carrier proficiency characteristics and how these might affect
97 tackler HIA risk. Rapidly changing and dynamic tackle scenarios require tacklers to make split-second
98 decisions when reacting to ball carriers who frequently adjust their speed and direction to avoid or break
99 contact. Part of the skill of ball carrying is to deceive the opposition tackler and thereby ensure an effective
100 tackle cannot be executed, however, it may also jeopardise tackler safety. It is possible that specific ball
101 carrying characteristics are linked to HIA causation for the tackler for both upper body and lower body
102 tackles, the details of which are unknown.

103 Accordingly, the aim of this study is to use match video evidence of tackles in elite level rugby union to
104 identify ball carrier characteristics that result in HIA for the tackler. This study has the potential to further

clarify tackle-related head injury mechanisms. This in turn can allow effective HIA prevention strategies to be developed.

2. Methods

2.1. Research design and data collection

A qualitative observational case-control study design was used on a cohort of professional men rugby union players to identify specific ball carrier characteristics (Table 1-4) associated with HIA and non-HIA tackles. A tackle was defined as "when the ball-carrier was contacted (hit and/or held) by an opponent without reference to whether the ball-carrier went to ground" (Quarrie & Hopkins, 2008). A HIA tackle was defined as "when a player received a direct/in-direct head impact in the tackle and was subsequently removed from play for a HIA and did not return to play for the remainder of the game" (Tierney, Denvir, Farrell, & Simms, 2018b). Only HIA scenarios involving tacklers as the injured player were used for the current study.

Tackles were categorised as either upper body tackles which are defined by the tackler's intended primary contact being above the ball carrier's hip or lower body tackles defined by intended primary contact being at or below the ball carrier's hip (Tierney et al., 2016; Tierney & Simms, 2017a, 2017b). Tackles were also categorised as either front-on or side-on tackles. Tackles initiated outside the ball carriers estimated peripheral vision (roughly ±60 degrees from the direction the ball carrier's head is pointing) were considered side-on tackles (Burger et al., 2016; Garraway et al., 1999). Side-on tackles included tackles from behind (Burger et al., 2016). For side-on tackles, awareness was identified by the ball carrier adjusting their head direction such that the tackler was roughly within the abovementioned ±60 degrees during the pre-contact phase of the tackle (see below).

Full details on the case-control cohort are available in Tierney et al. (Tierney, Denvir, Farrell, & Simms, 2018b). In brief, videos of HIA cases were obtained from elite level competitions/test series including the

Pro 12 (2014-2017), European Rugby Champions Cup (2014-2017), RBS 6 Nations (2014-2017), Guinness Autumn Test Series (2013-2016), the 2015 Rugby World Cup and the 2017 British and Irish Lions Tour. A total of 74 HIA cases were identified (19 upper body and 19 lower body for front-on tackles and 23 upper body and 13 lower body for side-on tackles). A direct head impact was identified in every video even though a HIA can result from an impact to the body (McCrory et al., 2005).

The non-HIA cases consist of tackles from three randomly selected European Rugby Champions Cup games. As a result of this approach, a total of 92 upper body tackles and 30 lower body tackles for front-on tackles and 75 upper body tackles and 36 lower body tackles for side-on tackles were analysed as control cases. Ethical permission was not required as all the data was freely available online similar to other rugby union video analysis studies on head impacts/injury (Montgomery et al., 2016; Tierney et al., 2016).

2.2. Technical proficiency criteria

The ball carrier technique characteristics are based on the work of Burger et al. (2016) (Burger et al., 2016). These technical based characteristics were created for front- and side-on tackles based on studies that analysed tackling proficiency in collision sports (Gabbett & Kelly, 2007; Gabbett & Ryan, 2009; Gabbett, 2008; Hendricks, Matthews, Roode, & Lambert, 2014). The criteria were further developed by a specialist group of rugby union coaches, medical personnel and sport scientists.

Each video was analysed by two reviewers together (a Senior Sports Physiotherapist and a Biomechanist). Any differences between reviewers were resolved by a review and discussion until a consensus was reached. Video analysis was conducted by utilising Sports Code (Version 8) which allowed frame-by-frame viewing of the tackle. Reviewers watched the clips as many times as necessary and a minimum of two camera views (25 fps) were available for every tackle. The technical proficiency characteristics were assigned to the three main phases of the tackle (Hendricks et al., 2014); pre-contact (0.5 s preceding contact), contact (first instance of contact) and post-contact. If a player exhibited a characteristic, they would score 1 for that particular characteristic, otherwise they would score 0.

2.3. Statistical Analysis

Statistical analysis was conducted using SPSS (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). For each ball carrier proficiency characteristic, Pearson's Chi-Square and Cramer's V were calculated (Altman, 1990). Statistical significance was set at $p<0.05$. Statistically significant tackle technique characteristics are regarded as having a higher propensity to result in a HIA for the tackler than that anticipated by chance. A Cramer's V value less than 0.1, between 0.1 and less than 0.3, between 0.3 and less than 0.5 and 0.5 or greater were considered indicative of trivial, small, moderate and large Effect Sizes (ES) respectively (Cohen, 1988).

2.4. Reliability

Thirty tackles (Fifteen front-on and fifteen side-on tackles, including HIA and non-HIA cases) were selected randomly using a number generator (http://www.random.org/). For intra-rater reliability, the two reviewers reanalysed these 30 cases, for each ball carrier proficiency characteristic, at least one week after conducting the initial analysis. For inter-rater reliability, an external reviewer (ex-player) analysed the same 30 cases using the same protocol as the two main reviewers. Intra-rater and inter-rater reliability were assessed using Cohen's Kappa (K). A Cohen's Kappa value higher than 0.8 indicates almost perfect agreement (Landis & Koch, 1977). For front-on tackles, a Cohen's Kappa value of 0.93 and 0.81 were calculated for intra- and inter-rater reliability, respectively. For side-on tackles, a Cohen's Kappa value of 0.95 and 0.86 were calculated for intra-rater reliability and inter-rater reliability, respectively.

3. Results

For front-on upper body tackles (Table 1) only the contact phase influenced HIA causation. The ball carrier characteristics "Explosiveness on contact" ($p=0.03$; ES=Small) and "fending into contact" ($p<0.01$, ES=Moderate) had a higher propensity to result in a HIA for the tackler. Fending into contact was exhibited in almost half of all upper body tackle front-on HIA cases (47%). Additional analysis found that in 67% of these cases it was the fending arm (upper arm, elbow and forearm), and not the palm of the hand, that

contacted the tackler's head. Furthermore, the ball carrier was not legally leading with the palm of the hand in these cases. None of these cases resulted in a foul being given.

No characteristics for side-on upper body tackles (Table 2) had a higher propensity to result in a HIA for the tackler. In 35% (n=8) of side-on upper body tackles, it was another tackler from the same team that impacted the tackler's head as both team mates collided while attempting to tackle the same ball carrier. In one case, both tacklers received HIAs.

For front-on lower body tackles (Table 3), only "explosiveness on contact" (p=0.04; ES=Moderate) had a higher propensity to result in a HIA for the tackler. No characteristics for side-on lower body tackles (Table 4) had a higher propensity to result in a HIA for the tackler. In one side-on lower body Tackle, it was another tackler from the same team that impacted the other tackler's head.

Insert Table 1 near here

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Insert Table 4 near here

4. Discussion

4.1. General

This study utilised match video evidence to identify ball carrier characteristics that have a higher propensity to result in a HIA for the tackler. The results from this study provide an evidence-base at an elite level to assist with the development of strategies to prevent head impacts which result in a HIA. Only two ball carrier proficiency variables that contribute to a high HIA risk for the tackler were identified. In particular, no side-on ball carrier characteristics were identified as having a higher propensity to result in a HIA for the tackler. Tierney et al. (Tierney, Denvir, Farrell, & Simms, 2018b) found a number of tackler characteristics that were associated with a high tackler HIA risk. This highlights the importance of effective

and safe tackler proficiency characteristics and that focus should be placed on tackler characteristics for prevention strategies, particularly for side-on tackles.

Previous studies have shown that fending has a positive effect on ball carrier tackle outcomes (Hendricks et al., 2014; Tierney, Denvir, Farrell, & Simms, 2018c; Wheeler & Sayers, 2009). One study found that a moderate fend increased the chance of offloading (Hendricks et al., 2014) whilst another study reported that a strong fend compromised the quality of the tackler's positioning (Wheeler & Sayers, 2009). However, the same study (Wheeler & Sayers, 2009) also found that the type of fend (e.g. moderate, strong etc) influenced outcomes such as tackle breaks and offloads. In addition to these studies, fending has also been shown to reduce the risk of ball carrier injury (Burger et al., 2016).

Fending into contact was exhibited in almost half of all upper body tackle front-on HIA cases (47%) and in 67% of these cases it was not legally executed. According to Law 7 of rugby union, the ball carrier is only permitted to fend off an opponent by using the palm of the hand (Rugby, 2017). As of November 2016, World Rugby added a reckless tackle sanction to the laws of the game by stating that "A player is deemed to have made reckless contact during a tackle or attempted tackle or during other phases of the game if in making contact, the player knew or should have known that there was a risk of making contact with the head of an opponent, but did so anyway. This sanction applies even if the tackle starts below the line of the shoulders. This type of contact also applies to grabbing and rolling/ twisting around the head/ neck area even if the contact starts below the line of the shoulders (Rugby, 2016)." The minimum and maximum sanction for a reckless tackle is a yellow and red card, respectively. The results of this study agree with this addition to the laws and illustrates the importance of its enforcement. With regards to HIA prevention, coaches should place focus on safe fending during tackle based training drills and referees should be alert to arm-to-head contact during the fend.

"Explosiveness on contact" was a ball carrier characteristic identified as having a higher propensity to result in a HIA for the tackler for both upper and lower body front-on tackles. This is consistent with a

previous study that identified energy transfer in the tackle as a risk factor for HIAs (Tucker et al., 2017). It is difficult to mitigate against this risk as explosivity is a desirable trait amongst players.

4.2. Limitations

The tackle is a dynamic and open phase of play and this must be appreciated when analysing tackling characteristics (Burger et al., 2016; Garraway et al., 1999). The HIA definition utilised in this study was based on a player being removed from the game for a HIA and subsequently not returning to the field of play. This can be considered a strong indication of concussion, but without access to player medical notes, cannot be used as a concussion diagnosis. Access to player medical notes would have clarified this. The control cases only utilised three games and only one team was analysed, meaning the results could be team specific. The non-HIA cases were from elite level club competition match play (European Champions Cup) whereas the HIA dataset includes both elite level club and international match play. Ideally both elite level club and international match play would be included in the control dataset. The analysis was conducted on elite level rugby union games. Although there are no HIAs in amateur and youth level rugby union, the findings may be applicable to this level of play to prevent significant direct head impacts (Tierney, Lawler, Denvir, McQuilkin, & Simms, 2016). However, further research on tackle characteristics in amateur and youth level rugby union is needed to clarify this. Further work could also model the combination and interaction of other technical characteristics and match situation characteristics, such as tackle speed (Gabbett & Kelly, 2007; Tucker et al., 2017) and tackle height (Tierney & Simms 2018a, 2018b) to allow for an even greater understanding of HIA risk. In order to fully understand the mechanism of head injury, further work should investigate the biomechanics of head impacts (Tierney et al., 2016; Tierney et al., 2018; Tierney, Richter, Denvir, & Simms, 2018).

5. Conclusion

Fending into contact is a ball carrier characteristic than can potentially be dangerous for the tackler. This characteristic was exhibited in 47% of all upper body Tackle front-on HIA cases. In 67% of these cases, it was the fending arm (upper arm, elbow and forearm), and not the palm of the hand, that contacted the

tacklers head. The results from this study provide an evidence-base at an elite level to assist with the development of HIA prevention strategies. In particular, coaches should place focus on safe fending during tackle based training drills and referees should be alert to arm-to-head contact during the fend. "Explosiveness on contact" was a ball carrier characteristic identified as having a higher propensity to result in a HIA for the tackler for both upper and lower body front-on tackles, though it is difficult to mitigate against this risk. Much fewer ball carrier proficiency variables that result in a HIA for the tackler were identified in comparison to tackler proficiency characteristics that were identified in an earlier study. In particular, no side-on ball carrier characteristics were identified as having a higher propensity to result in a HIA for the tackler. This highlights the importance of effective and safe tackler proficiency characteristics and that focus should be placed more on tackler characteristics for HIA prevention strategies.

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TABLE 1

Ball carrier Upper Body Tackle front-on proficiency results for HIA and non-HIA tackles (includes % occurrence, p values, Cramer's V and interpretations).

	HIA (n=19)	Non-HIA (n=92)	p value	Cramer's V	Interpretation
Pre-contact					
Eyes Focused on tackler	13 (68%)	76 (83%)	0.16	0.13	Small
Shifting the ball away from contact	5 (26%)	43 (47%)	0.10	0.16	Small
Body position - Upright to low	6 (31%)	44 (48%)	0.20	0.12	Small
Body Position-Straight back	15 (79%)	73 (79%)	0.97	<0.01	Trivial
Head up and forward, eyes open	14 (74%)	59 (64%)	0.42	0.08	Trivial
Shuffle or evasive manoeuvre	3 (16%)	19 (21%)	0.63	0.05	Trivial
Contact					
Fending into contact	9 (47%)	14 (15%)	**<0.01**	0.30	Moderate
Side-on into contact	4 (21%)	12 (13%)	0.37	0.09	Trivial
Explosiveness on contact	11 (58%)	29 (31%)	**0.03**	0.21	Small
Body position- from low body position up into contact	3 (16%)	18 (20%)	0.70	0.04	Trivial
Ball protection	17 (90%)	90 (98%)	0.08	0.17	Small
Post-contact					
Leg drive on contact	11 (58%)	48 (52%)	0.65	0.03	Trivial
Arm and shoulder usage	9 (47%)	40 (44%)	0.76	0.03	Trivial
Go to ground and present ball/offload	17 (90%)	89 (97%)	0.16	0.13	Small

TABLE 2

Ball carrier Upper Body Tackle side-on proficiency results for HIA and non-HIA tackles (includes % occurrence, p values, Cramer's V and interpretations).

	HIA (n=23)	Non-HIA (n=75)	p value	Cramer's V	Interpretation
Pre-contact					
Aware of tackler (attunement)	15 (65%)	45 (60%)	0.65	0.05	Trivial
Shifting the ball away from contact	13 (56%)	35 (47%)	0.41	0.08	Trivial
Body position - Upright to low	5 (22%)	13 (17%)	0.63	0.05	Small
Body Position-Straight back	21 (91%)	66 (88%)	0.66	0.04	Trivial
Head up and forward, eyes open	15 (65%)	61 (81%)	0.11	0.16	Small
Shuffle or evasive manoeuvre	2 (9%)	17 (23%)	0.14	0.15	Small
Contact					
Fending away from contact	2 (9%)	14 (19%)	0.26	0.11	Small
Explosiveness away from contact	9 (39%)	25 (33%)	0.61	0.05	Trivial
Ball protection	22 (96%)	67 (89%)	0.36	0.09	Trivial
Post-contact					
Leg drive on contact	8 (35%)	31 (41%)	0.57	0.06	Trivial
Go to ground and present ball/offload	21 (91%)	66 (88%)	0.66	0.04	Trivial

384 **TABLE 3**

385 **Ball carrier Lower Body Tackle front-on proficiency results for HIA and non-HIA tackles (includes %**

386 **occurrence, p values, Cramer's V and interpretations).**

	HIA (n=19)	Non-HIA (n=30)	p value	Cramer's V	Interpretation
Pre-contact					
Eyes Focused on tackler	18 (95%)	27 (90%)	0.56	0.08	Trivial
Shifting the ball away from contact	10 (53%)	18 (60%)	0.61	0.07	Trivial
Body position - Upright to low	12 (63%)	13 (43%)	0.18	0.19	Small
Body Position-Straight back	15 (79%)	28 (93%)	0.13	0.21	Small
Head up and forward, eyes open	17 (90%)	27 (90%)	0.95	<0.01	Trivial
Shuffle or evasive manoeuvre	7 (37%)	10 (33%)	0.80	0.04	Trivial
Contact					
Fending into contact	4 (21%)	3 (10%)	0.28	0.15	Small
Side-on into contact	5 (26%)	8 (27%)	0.98	<0.01	Trivial
Explosiveness on contact	10 (53%)	7 (23%)	**0.04**	0.30	Moderate
Body position- from low body position up into contact	2 (11%)	4 (13%)	0.77	0.04	Trivial
Ball protection	18 (95%)	29 (97%)	0.74	0.05	Trivial
Post-contact					
Leg drive on contact	7 (37%)	11 (37%)	0.99	<0.01	Trivial
Arm and shoulder usage	5 (26%)	4 (13%)	0.25	0.16	Small
Go to ground and present ball/offload	18 (95%)	28 (93%)	0.84	0.03	Trivial

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TABLE 4

Ball carrier Lower Body Tackle side-on proficiency results for HIA and non-HIA tackles (includes % occurrence, p values, Cramer's V and interpretations).

	HIA (n=13)	Non-HIA (n=36)	p value	Cramer's V	Interpretation
Pre-contact					
Aware of tackler (attunement)	11 (85%)	29 (81%)	0.75	0.05	Trivial
Shifting the ball away from contact	8 (62%)	25 (69%)	0.60	0.07	Trivial
Body position - Upright to low	2 (15%)	4 (11%)	0.69	0.06	Trivial
Body Position-Straight back	12 (92%)	35 (97%)	0.44	0.11	Small
Head up and forward, eyes open	13(100%)	33 (92%)	0.28	0.16	Small
Shuffle or evasive manoeuvre	4 (31%)	20 (56%)	0.13	0.22	Small
Contact					
Fending away from contact	1 (8%)	10 (28%)	0.14	0.21	Small
Explosiveness away from contact	7 (54%)	13 (36%)	0.27	0.16	Small
Ball protection	13(100%)	33 (92%)	0.28	0.16	Small
Post-contact					
Leg drive on contact	4 (31%)	14 (39%)	0.60	0.07	Trivial
Go to ground and present ball/offload	13(100%)	32 (89%)	0.21	0.18	Small