Profiling the tackle and its injury characteristics in premier New Zealand club rugby union players over a complete season

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Accepted 15 December 2021

To cite: Takamori S, Hamlin MJ, King D, *et al*. *Br J Sports Med* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/bjsports-2021-104868

ABSTRACT

Objectives RugbySmart is a safe tackle technique education programme. Our objective was to identify whether the RugbySmart-recommended safe tackle technique was exhibited by club rugby players and whether tackle-related injuries showed poor tackle technique characteristics.

Methods The prospective cohort design enabled 28 senior club based amateur male rugby union players from New Zealand to be followed over 18 matches in the 2017 rugby season. Game video analysis by three analysts provided categorisation of tackle technique into type, approach, foot contact, leading foot and rear foot position, face and head position. Injuries were diagnosed by the same sports medicine physician.

Results In the 18 matches, 28 players completed a combined total of 3006 tackles, with only six tackle-related injuries sustained. Notable findings included: (1) forwards complete more tackles than backs; (2) shoulder tackles were the most prevalent tackle; (3) good tackle technique as promoted by RugbySmart was demonstrated in 57.9% of all tackles and (4) of the six tackle-related injuries, two occurred despite RugbySmart desired tackle techniques.

Conclusion This is the first study to investigate whether players were performing the recommended 'safe tackle technique' proposed by New Zealand Rugby's RugbySmart programme. As two of six tackle-related injuries occurred despite the RugbySmart preferred technique being performed, further technique analysis and a larger sample are needed to determine what techniques reduce risk of injury during tackles. As only 57.9% of tackles were performed with RugbySmart head and foot positions, further research and education regarding tackle technique recommendations are needed.

INTRODUCTION

One of the high risk facets of play in rugby union (termed rugby) is the tackle.[1] Tackling is a dynamic and complicated movement[2] that is responsible for 19 injuries per 1000 playing hours.[3] Identifying the characteristics of tackles that result in injuries in rugby, including head impacts, may be useful in reducing the injuries that do occur. Previous research has identified that safety equipment such as head gear and shoulder pads do little to protect the tackler in rugby,[4] and this has placed a greater emphasis on adequate and safe tackling technique in order to avoid injury.

In 2001, New Zealand Rugby (NZR) launched 'RugbySmart' where it became compulsory for all rugby coaches to complete this training programme annually. The RugbySmart programme is a research-based information programme about the risk of injury and possible injury prevention strategies for coaches. The RugbySmart programme which was developed from reviewing tackles and injuries and gaining expert opinion from elite rugby coaches[5] has helped to reduce severe injuries and improve player behaviour in contact areas such as the tackle.[6]

Head placement during the tackle is an important predictor of subsequent injury.[7 8] A recent study found that the incidence of injury was greater if the tackler's head positioning was incorrect (ie, to the front of the ball carrier, 69.4 injuries per 1000 tackles) compared with correct head positioning (ie, behind or to one side of the ball-carrier, 2.7 injuries per 1000 tackles).[9] Having the front foot grounded and close to the ball-carrier (on the same side as the shoulder contact) assists in keeping the tacklers body square to the ball-carrier, while allowing maximum potential for a strong and efficient leg drive during the tackle.[10 11] Previous research indicated that tackles that did not use this safe technique (eg, arm or jersey tackles), increased the risk of an injury occurring.[12] While other tackle characteristics are also known to reduce the risk of injury (eg, number of tacklers, tackler speed),[13] the RugbySmart programme concentrated on tackle characteristics that were thought to make the biggest difference in safety.

To assist coaches and players with safe tackle technique, NZR have identified in RugbySmart that the recommended tackle technique (ie, the tackler's head positioned behind or to the side of the ball-carrier, with their front foot grounded close to the ball-carrier and on the same side as the contact shoulder) could improve tackle safety by having the shoulder contact the ball-carrier first.[14]

While the RugbySmart programme has been successful at reducing New Zealand national insurance injury claims for rugby,[6] to our knowledge it is not reported whether these techniques are being actioned during match competitions. In addition, it has not been investigated whether the injury risk in rugby is reduced due to effects of the specific tackle technique promoted by this programme or other aspects as yet unidentified.

This study aimed to identify whether the RugbySmart suggested safe tackle technique (head behind or to side of ball-carrier, front foot grounded

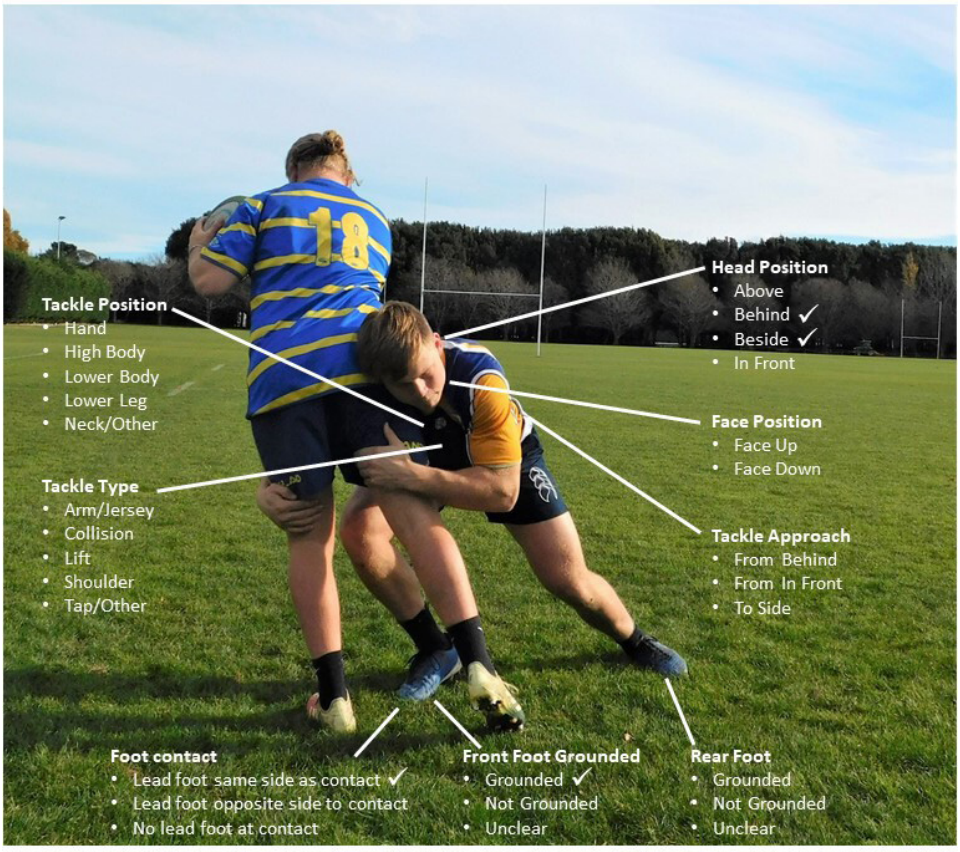

Figure 1 The eight characteristics and 28 categories used to describe the tackle. The tick (✓) indicates those characteristics that are considered desirable according to the NZR RugbySmart programme. NZR, New Zealand Rugby.

and same side as shoulder contact) was exhibited by club rugby players during a competitive season. A second purpose was to assess if tackle techniques being undertaken by players had any influence on the incidence of tackle-related injuries.

METHODS

Ethics

Participants were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

Research design and participants

The study used a prospective cohort design to follow senior club based amateur rugby players from the Christchurch region in New Zealand over 18 matches during the 2017 competition season. Previous research on injury incidence with correct and incorrect head positioning,[9] suggested that at least 2170 (correct head position) and 217 (incorrect head position) tackles would be required in each group to achieve 80% power at an alpha level of 0.05. The 28 male players (21.4±2.0 years, 1.8±0.9 m, 97.1±12.3 kg, mean±SD) from one domestic senior premier division (division 1) rugby team had a high skill level, with 79% selected to play for higher-level representative teams at the end of the season.

Video collection of match data

For each match, players' two-dimensional kinematics were recorded from two views perpendicular to one another. Two cameras, (50 Hz, Panasonic HC-WX970M, Tokyo, Japan) were positioned at a height of ~3 m above the ground; one was situated at the half-way line, and the other between the goal posts at the end of the field. The field of view for both cameras were optimised by zooming in to the play while allowing the entire play to be imaged during the action.

Tackle technique video analysis

Independent game video analysis by three experienced rugby video analysts (KT, RK and TY) provided categorisation of tackle technique into type, approach, foot contact, leading foot and rear foot position, face and head position using a video analysis programme (Sportscode Elite, V.10.3.36, Sportstec, France). The game's coding was checked by an additional video analyst. In instances where the first two analysts did not agree on coding a third analyst discussed the disparate coding with the two analysts to seek a consensus.

Tackle technique characteristic definitions and classification

A tackle was defined as 'any event where one or more tacklers (player or players making the tackle) attempted to stop or impede the ball-carrier (player carrying the ball), whether or not the ball-carrier was brought to ground'.[12]

A tackle template of eight categories (a total of 28 items) describing the tackle event and match and player information was developed using previous research[2] which enabled the coding of the tackles as they occurred (see figure 1). Table 1 contains the definitions used for the 28 items.

Characteristics of a good tackle, as promoted by RugbySmart include: (1) The tackler's head positioned behind or to the side

Table 1 Tackle characteristics of amateur senior premier rugby union players in New Zealand for 18 matches in one season

	n	%
Tackle type		
Arm/Jersey-Tackler impedes ball-carrier with upper limbs or holds jersey.	538	18.0
Collision-Tackler impedes ball-carrier without use of arms.	945	31.4
Lift-Tackler raises ball-carrier's hips above ball-carriers head.	12	0.4
Shoulder-Tackler contacts ball-carrier with the shoulder as first point of contact.	1483	49.3
Tap/other-Tackler trips ball-carrier with hand on lower limb/or other tackles.	28	0.9
Front foot grounded		
Yes-Tackler's front foot is grounded and close to ball-carrier.	2521	83.9
No-Tackler's front foot is not grounded.	316	10.5
No foot/unclear-Tackler's has no front foot grounded or it is unclear.	169	5.6
Foot contact		
Same side-Tackler's lead foot on same side at contact.	2043	68.0
Opposite side-Tackler's lead foot on opposite side at contact.	613	20.4
No-No lead foot at contact.	350	11.6
Rear foot		
Grounded-Tackler's rear foot is grounded.	1809	60.2
Off ground-Tackler's rear foot is not grounded.	1027	34.1
Unclear-Tackler's rear foot position is unclear.	170	5.7
Tackle approach		
From behind player-Tackler makes contact with ball-carrier from behind.	238	7.9
From in front of player-Tackler makes contact in front of the ball-carrier.	1684	56.0
To the side of player-Tackler makes contact with ball-carrier's side.	1084	36.1
Tackle position		
Hand-Tackler makes contact with ball-carrier's hand/arm.	51	1.7
High body-Tackler makes contact with ball-carrier from the hip to the shoulder.	2016	67.1
Lower body-Tackler makes contact with ball-carrier between knees and hip.	791	26.3
Lower leg-Tackler makes contact with ball-carrier below the knees.	115	3.8
Neck/other-Tackler makes contact with ball-carrier above the shoulder/other.	33	1.1
Face position		
Face up-Tackler's face is up during contact.	2560	85.2
Face down-Tackler's face is down during contact.	446	14.8
Head position		
Above-Tackler's head is higher than ball-carrier's body during contact.	125	4.1
Behind-Tackler's head is at the back of ball-carrier's body during contact.	1550	51.6
Beside-Tackler's head is next to ball-carrier's body during contact.	1231	41.0
In front- Tackler's head is in front of ball-carrier's body during contact.	100	3.3

Data are tackle numbers and percentages of total tackles made in all games over the season.

Table 2 Tackle completion by rugby position for 28 amateur senior premier rugby players in New Zealand for 18 matches in one season

Player position	Tackle count	Tackle %	Tackle per match (mean±SD)
Forwards*	1982	65.9	22±10
Hooker†, ‡, §, ¶, **, ††, ‡‡, §§	260	8.7	14±6
Prop††, ‡‡, §§, ¶¶, ***	460	15.3	26±8
Lock††, ‡‡, §§, ¶¶, ***	499	16.6	28±7
Flanker††, ‡‡, §§, ¶¶, ***	504	16.8	28±9
Number 8†, ‡, §, ¶, **, ††, ‡‡, §§	259	8.6	14±6
Backs†††	1024	34.1	12±7
Half back††, ‡‡, §§, ¶¶, ***cgjkl	226	7.5	13±5
First five††, ‡‡, §§, ¶¶, ***	228	7.6	13±5
Midfield back¶¶, †, ‡, §, ***, ¶, **, ‡‡, §§	334	11.1	19±8
Wing†, ‡, §, ¶, **, ††, §§, ¶¶, ***	185	6.1	10±6
Full back†, ‡, §, ¶, **, ††, §§, ¶¶, ***	51	1.7	3±2

*Significant difference (p<0.05) with backs.
†Significant difference (p<0.05) with prop.
‡Significant difference (p<0.05) with lock
§Significant difference (p<0.05) with flanker
¶Significant difference (p<0.05) with half back
**Significant difference (p<0.05) with first five
††Significant difference (p<0.05) with midfield back
‡‡Significant difference (p<0.05) with wing
§§Significant difference (p<0.05) with full back
¶¶Significant difference (p<0.05) with hooker
***Significant difference (p<0.05) with number 8
†††Significant difference (p<0.05) with forwards

of the ball-carrier; (2) The front foot grounded close to the ball-carrier and (3) The front foot on the same side as the contact shoulder (https://www.rugbysmart.co.nz/improving-performance/tackle-technique/). These characteristics were developed though the review of tackles and tackle related injuries.[1 15] In addition, it is considered good technique to have the face position up (ie, the tackler's face is facing forwards towards the oncoming ball-carrier, rather than downwards with the ball-carrier out of view), the rear foot grounded, and a high body tackle position. As such we classified tackle technique using the count of the desired tackle characteristics from the three RugbySmart promoted categories. We considered less than 3/3 as poor tackle technique.

Match injuries

Match injuries were recorded by a registered sport medicine physician (ST) using the 2007 consensus statement of the International Rugby Board's (now World Rugby's) definition of injury (ie, physical insult that occurred during the rugby match that resulted in the player being unable to take full part in future rugby training or match play for longer than 24 hours).[16] The sports medicine physician attended every match and training session and followed the injured players throughout their recovery process.

Statistical analyses

A game was randomly selected to determine the accuracy of tackle information from the three video analysts. The inter-rater percentage of agreement and the Cohen's kappa (κ) was utilised for inter-rater reliability (IRR) between video evaluators on the coding of tackles. Cohen's kappa effect sizes of <0.01, 0.01–0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80 and 0.81–1.00 were considered as no agreement, none to slight, fair, moderate, substantial and almost perfect agreement. Proc Freq in the Statistical Analysis System (V.9.3 SAS Institute) was used to estimate the differences in frequencies of events and were reported as a χ^2 statistic. The student's t-test was used to compare differences across the tackle characteristics. Cohen's effect size (d) was used to calculate practically meaningful differences between playing positions and injury sites. Effect sizes of <0.19, 0.20–0.60, 0.61–1.20 and >1.20 were considered trivial, small, moderate and large, respectively.[17] The incidence of injury was calculated as the number of injuries per 1000 tackles.[1]

Table 3 Tackle characteristic frequencies for each of the tackle types

	Shoulder 49.3% (1483)	Collison 31.4% (945)	Arm/ Jersey 18% (538)	Lift 0.4% (12)	Tap/ other 0.9% (28)	All tackles 100% (3006)
RugbySmart: Tackler's head positioned behind or to the side of the ball carrier						
Behind*	61.7% (915)[bce]	46.5% (439)[ac]	34.4% (185)[ab]	25.0% (3)	28.6% (8)[a]	51.6% (1550)
Beside*[23]	28.4% (421)[bcde]	47.0% (444)[ac]	63.0% (339)[ab]	75.0% (9)[a]	64.3% (18)[a]	41.0% (1231)
Above[1]	4.1% (61)[c]	5.3% (50)[c]	2.2% (12)[ab]	–	7.1% (2)	4.1% (125)
In front[1]	5.8% (86)[bc]	1.2% (12)[a]	0.4% (2)[a]	–	–	3.3% (100)
RugbySmart: Front foot grounded close to the ball carrier						
Yes*	88.5% (1313)[c]	83.7% (791)[c]	72.1% (388)[ab]	66.6% (8)	75.0% (21)	83.9% (2521)
No	9.3% (138)[c]	11.3% (107)	12.5% (67)[a]	8.4% (1)	10.7% (3)	10.5% (316)
No foot/unclear	2.2% (32)[bcde]	5.0% (47)[acde]	15.4% (83)[ab]	25.0% (3)[ab]	14.3% (4)[ab]	5.6% (169)
RugbySmart: Front foot on the same side as the contact shoulder						
Front foot on same side at contact*	73.1% (1084)[bc]	62.6% (592)[a]	64.3% (346)[a]	50.0% (6)	53.6% (15)	68.0% (2043)
Front foot on opposite side at contact	19.8% (294)[bc]	24.2% (229)[ac]	15.1% (81)[ab]	8.3% (1)	28.6% (8)	20.4% (613)
No lead foot at contact	7.1% (105)[bcde]	13.2% (124)[acd]	20.6% (111)[ab]	41.7% (5)[ab]	170.8% (5)[a]	11.6% (350)
Rear foot						
Grounded	63.6% (943)[ce]	65.0% (614)[ce]	43.7% (235)[ab]	75.0% (9)[e]	28.6% (8)[acd]	60.2% (1809)
Off ground	34.3% (508)[ce]	30.0% (284)[ce]	40.7% (219)[ab]	–	57.1% (16)[a]	34.1% (1027)
No foot/unclear	2.1% (32)[bcde]	5.0% (47)[acde]	15.6% (84)[ab]	25.0% (3)[ab]	14.3% (4)[ab]	5.7% (170)
Tackle approach						
From in front of player	56.4% (837)[bc]	65.8% (622)[ace]	38.7% (208)[abd]	75.0% (9)[ce]	28.6% (8)[bd]	56.0% (1684)
To the side of player	37.2% (551)[bce]	27.2% (257)[ace]	47.5% (256)[ab]	25.0% (3)	60.7% (17)[ab]	36.1% (1084)
From behind player	6.4% (95)[c]	7.0% (66)	13.8% (74)[a]	–	10.7% (3)	7.9% (238)
Tackle position						
Hand	0.2% (3)[bc]	0.7% (7)[ac]	7.6% (41)[ab]	–	–	1.7% (51)
High body	50.6% (750)[bc]	96.6% (913)[ace]	63.2% (340)[abe]	50.0% (6)	25.0% (7)[bc]	67.1% (2016)
Lower body	44.5% (660)[bce]	1.0% (9)[acd]	21.6% (116)[abe]	41.6% (5)[be]	3.6% (1)[acd]	26.3% (791)
Lower leg[5]	4.6% (68)[e]	–	5.2% (28)	–	67.8% (19)[a]	3.8% (115)
Neck	0.1% (2)[bc]	0.7% (7)[a]	1.1% (6)[a]	–	–	0.5% (15)
Other[4]	–	1.0% (9)[d]	1.3% (7)[d]	8.4% (1)[bc]	3.6% (1)	0.6% (18)
Face position						
Face up	75.7% (1123)[bc]	98.0% (926)[a]	87.9% (473)[a]	91.6% (11)	96.4% (27)	85.2% (2560)
Face down	24.3% (360)[bce]	2.0% (19)[ac]	12.1% (65)[ab]	8.4% (1)	3.6% (1)[a]	14.8% (446)

Data given as percentage of tackles (number of tackles in brackets).
Significant difference ($p<0.05$) than: (a)=shoulder; (b)=collision; (c)=arm/Jersey; (d)=lift; (e)=tap/other; (1)=beside head position; (2)=front head position; (3)=above head position; (4)=lower Leg tackle position; (5)=other tackle position.
*Method prescribed by RugbySmart.

IRR of tackle data extraction

The level of agreement (accuracy) between the three video analysts for classification of the tackle information was high (from 92% to 94% for the 28 tackle characteristic items). The Cohen's kappa coefficients indicated substantial and acceptable IRR (κ=0.75–0.80).

RESULTS

Tackle types and technique characteristics

In the 18 matches, 28 players completed a combined total of 3006 tackles (see table 2). Forwards completed significantly more tackles than backs (1982 vs 1024; $\chi^2_{(1)}$=305.3; p<0.0001), with flankers, locks and props completing nearly half (48.7%) of the total tackles made.

Tackle type

The most common tackle types were the shoulder (49.3%) and the collision tackle (31.4%) (see table 3). The shoulder tackle also had the highest frequency of two out of the three good tackle characteristics promoted by RugbySmart (ie, front foot grounded and on the same side as contact).

Tackle completion

The flanker recorded the highest number of tackles for the forwards (n=504; 16.8%) and the midfield back recorded the highest number of tackles for the backs (n=334; 11.1%) over the duration of the study (see table 2). There were more tackles recorded for the flanker than the hooker ($\chi^2_{(1)}$=77.9; p<0.0001) and number 8 ($\chi^2_{(1)}$=78.7; p<0.0001). In the backs there were more tackles recorded for the midfield back than the halfback ($\chi^2_{(1)}$=20.8; p<0.0001), wing ($\chi^2_{(1)}$=42.8; p<0.0001) and full-back ($\chi^2_{(1)}$=208.0; p<0.0001). Over the duration of the study forwards recorded more tackles than backs (1982 vs 1024; $\chi^2_{(1)}$=305.3; p<0.0001).

Tackle technique characteristics

The majority (92.6%) of tackles that were recorded had the tackler's head in the RugbySmart recommended position (behind the tackler-51.6%; beside the tackler-41.0%). Over the study there was an observable difference that the tackler's head position was beside (41.0%) the ball-carrier more often than when compared with being in front (3.3%; $t_{(2)}$=11.5; p=0.0075; d=6.64) or above (4.1%; $t_{(3)}$=3.2; p=0.0514; d=1.57) the ball-carrier for

Table 4 The number of tackles with characteristics of a good tackle as promoted by RugbySmart

	n	%
Tackles made with 1/3 advised good tackle characteristics		
[a] front foot grounded	2,521[234567]	83.8
[b] front foot same side	2,043[13457]	67.9
[c] head behind/beside	2,781[124567]	92.5
Tackles made with 2/3 advised good tackle characteristics		
[a+b] front foot grounded+front foot same side	1,846[1235]	61.4
[a+c] front foot grounded+head behind/beside	2,367[123467]	78.7
[b+c] front foot same side+head behind/beside	1,921[1357]	63.9
Tackles made with 3/3 advised good tackle characteristics		
[a+b+c] front foot grounded+front foot same side+head behind/beside	1,741[12356]	57.9

Significant difference (p<0.05) than (1)=a; (2)=b; (3)=c; (4)=a+b; (5)=a+c; (6)=b+c; (7)=a+b+c.

all tackle types (see table 3). There was a noticeable difference that the tacklers head was behind the ball-carrier more often in the shoulder tackle (n=915) than in the collision (n=439; $\chi^2_{(1)}$=24.1; p<0.0001) and arm/jersey (n=185; $\chi^2_{(1)}$=54.1; p<0.0001) tackle situations. The front foot was more commonly seen grounded close to the ball-carrier in the shoulder tackle (n=1313) than the collision (n=945; $\chi^2_{(1)}$=9.1; p=0.0025) and arm/jersey (n=538; $\chi^2_{(1)}$=4.3; p=0.0380) tackle type. More tackles were approached from the front of the player in the shoulder tackle (n=837) than the collision (n=622; $\chi^2_{(1)}$=8.5; p=0.0036) and arm/jersey (n=208; $\chi^2_{(1)}$=24.1; p<0.0001) tackle types. The tackle position occurred on the high body position more often in the collision (n=913) tackle type than the shoulder (n=750; $\chi^2_{(1)}$=178.6; p<0.0001), arm/jersey (n=340; $\chi^2_{(1)}$=11.7; p=0.0006) and tap/other (n=7; $\chi^2_{(1)}$=14.8; p=0.0001) tackle positions.

More than half (57.9%) of the tackles recorded showed three of the RugbySmart desired techniques (see table 4). More tackles were recorded with the front foot grounded and head behind/beside (n=2367; 78.7%) when compared with front foot grounded and front foot same side (n=1846; 61.4%; $\chi^2_{(1)}$=104.3; p=0.0001) and front foot grounded and front foot same side and head behind/beside (n=1741; 57.9%; $\chi^2_{(1)}$=24.1; p<0.0001).

Tackle related injuries

Only six injuries (see table 5) occurred because of the tackle (2.0 per 1000 tackles): two sport-related concussions (ie, sport-originated brain injuries; SOBI)[18] (0.7 per 1000 tackles), two knee injuries (0.7 per 1000 tackles), one brachial plexus/stinger (0.3 per 1000 tackles) and one shoulder injury (0.3 per 1000 tackles). Given the low number of injuries, the intended analyses by tackle characteristics could not be performed with adequate power.

All injuries occurred during shoulder tackles where the players had their front foot grounded. All but one of the injuries involved the rear foot being grounded, with the tackle approach from in front of the player. All but one of the injuries involved a high body tackle position. Four of the tackles involved a face up position.

The most variations in the tackle technique that was observed were in the head position (three behind, then one each for above, beside and in front) and the foot contact (three lead foot on opposite side at contact, two lead foot on same side at contact and one no lead foot at contact). This meant that four of the six injuries involved the head positioned behind or to the side of the ball-carrier as promoted by RugbySmart. Only two of the six injuries involved the lead foot on the same side at contact as promoted by RugbySmart. Two of the injuries occurred despite the tackles showing 3/3 of the desired tackle characteristics promoted by RugbySmart.

Table 5 Tackle characteristics for the six tackle-related injuries during the 18 matches in one season

	Tackle injury ID					
Tackle characteristic	**1**	**2**	**3**	**4**	**5**	**6**
Tackle rating according to RugbySmart (desired technique where poor is<3/3)	2	1	1	3	3	2
RugbySmart: Tackler's head positioned behind or to the side of the ball carrier						
Behind*	x			x		x
Beside*					x	
Above		x				
In front			x			
RugbySmart: Front foot Grounded close to the ball carrier						
Yes*	x	x	x	x	x	x
No						
No foot/unclear						
RugbySmart: Front foot on the same side as the contact shoulder						
Front foot on same side at contact*				x	x	
Front foot on opposite side at contact	x	x				x
No lead foot at contact			x			
Rear foot						
Grounded		x	x	x	x	x
Off ground	x					
Tackle approach						
From in front of player		x	x	x	x	x
To the side of player	x					
From behind player						
Tackle position						
Hand						
High body	x	x		x	x	x
Lower body			x			
Lower leg						
Neck/other						
Face position						
Face up	x			x	x	x
Face down		x	x			
Tackle type						
Shoulder	x	x	x	x	x	x
Arm/jersey						
Collision						
Lift						
Tap/other						

*indicates a desired tackle characteristic as indicated by the RugbySmart programme.

DISCUSSION

Tackling is the most common match event in Rugby Union[19] and is responsible for the most injuries.[19] This is the first study to investigate whether players were performing the recommended 'safe tackle technique' proposed by NZR's RugbySmart programme during a season of competition. This study has found in a cohort of senior club based amateur rugby players: (1) forwards complete more tackles than backs; (2) shoulder tackles were the most prevalent tackle; (3) good tackle technique

as promoted by RugbySmart was shown in just over half of all tackles and (4) even when good tackle technique was followed injury could still occur.

Tackle completion

Similar to previous research,[20] significantly more tackles were completed by forwards compared with backs, particularly props, locks and flankers. This additional contact demand by these players should be considered by strength, conditioning and coaching staff in weekly contact training sessions. The tackle load found in our players (167/match), was lower than English premiership players (221/match),[19] but remains a considerable part of the game and requires appropriate training, conditioning and coaching.

Tackle technique characteristics

The results of this study indicate the importance of head positioning in the tackle with 7.4% of tacklers using non-recommended head positioning (ie, head 'above' or 'in front' during tackle). Putting the head to the side or behind the ball-carrier helps to align the shoulders and legs for an effective tackle and reduces the likelihood of any heavy contact to the head. As two of the six tackle-related injuries occurred despite the RugbySmart's preferred characteristics being performed, further technique analysis is needed to determine what techniques reduce risk of injury during tackles. For example, in all six tackle injuries, the front foot was grounded and close to the ball-carrier which is a characteristic of the desired tackle technique as promoted by RugbySmart and yet resulted in injury (table 5). Having the front foot grounded and close to the ball-carrier is thought to help square-up the tackler's body to the ball-carrier and allow for a strong position to drive with the leg during the tackle.[11] It may be, that having the tackler's front foot grounded close to the ball-carrier is less important than other tackle characteristics in reducing injury (ie, creating efficient forward momentum by producing strong leg drive into the tackle to counter the ball-carriers momentum, avoiding the ball-carriers fend etc). However, this will remain speculative until further research on large numbers of tackle scenarios along with subsequent injury rates can be completed.

Our results indicated the shoulder tackle was the most prevalent tackle made (49.3%), however, previous research in similar-level players found that the shoulder tackle was secondary (35.4%) to the smother or collision tackle (36.3%).[13] It has been established that the shoulder tackle is the most effective at decreasing the chances of an offload and/or tackle break by the ball-carrier[2] and is also the least likely tackle type to result in injury[13] which may explain the lower injury rate in our players. Our players approached the tackle from in front of the ball-carrier 56% of the time, which is considerably less than previously reported (36%),[21] however, van Rooyen *et al* collected data on teams playing in the Six Nations Championship which is composed of international players in a higher level of competition and therefore may not be directly comparable. In addition, van Rooyen *et al* had a separate category for tackles made at a slight angle somewhere between front on and side on (labelled oblique tackle approach) which was not a category used in the current study, and again not directly comparable.

Tackle-related injuries

Previous research has indicated that poor tackle technique is a major risk factor for injury.[8 22 23] The unusually low number of injuries per tackle found in this study (2.0 per 1000 tackles) is at odds with previous research. For example, McIntosh *et al* reported 10 injuries per 1000 tackles in senior men's grade rugby union players, which increased to 15 injuries per 1000 tackles in Super Rugby and international-level players. Previous research has also reported that elite players are more likely to be higher skilled at tackling and execute more effective and safer tackles than younger less skilled players.[13] In addition, elite players tend to complete more multiplayer tackles which may reduce the injury risk for the tackler compared with single player tackles.

We postulate that the low injury prevalence in the players in this study, compared with international studies, may be associated with prior RugbySmart education and player experience. Almost all (26/28 or 93%) the players in this study had been involved in higher levels of rugby competition throughout their lives (ie, were selected for higher-level representative teams). This would increase the player's exposure to more qualified and experienced coaches and aid in their tackling efficiency. Being exposed to quality coaches over a long period of time probably improved player skill-level in all facets of the game including tackle technique. The RugbySmart programme may have helped to improve coaches' knowledge and awareness around injury prevention and has resulted in improved player tackling technique over the years leading to fewer tackle-related injuries being recorded. The coaches of the team in this study followed the teaching principles of the RugbySmart programme with a major emphasis on safety first. Countries without such education programmes show a higher injury prevalence occurring during the tackle phase of the game of rugby union.[9] In such countries without formal rugby education programmes like RugbySmart (eg, Japan), coaches rely on their own personal experience and knowledge of the tackle technique.

Out of 3006 coded tackles over the 2017 season, only two resulted in SOBIs (0.7 per 1000 tackle events). Estimating the incidence of SOBI from this data indicates the players in this study had a relatively low incidence of SOBI during matches (3.6/1000 player-hours). Recent research suggests the incidence of SOBI in rugby players is higher for elite men (4.6 per 1000 match-hours)[24] elite world cup women (6.2 per 1000 match-hours),[25] professional premier (8.9 per 1000 player-hours),[26] and amateur domestic women (16.1 per 1000 match-hours).[27] The reduced SOBI incidence in the New Zealand players in this study may be due to lower fatigue and subsequently maintained technical skill during matches, better tackle technique or possibly better decision making. Further research is required to understand these relationships.

This study analysed tackles during a season of rugby in senior club-based amateur players. Many of these players had a high level of training and rugby coaching and had played at representative level, therefore, the results of this study may not be representative of lower levels of playing ability. Technical skills in team sports (ie, tackling) are also influenced by many other factors such as quality of opposition, area on the field, time in a match etc,[28] therefore, the results of this tackle study must be considered with other game performance demands on players. Finally, rugby is a complex, fast-moving, confrontational game and not all collisions occur at the tackle, therefore a number of contact and collision characteristics (those not related to the tackle) were not considered in this study.

CONCLUSION

As only 57.9% of tackles were performed with RugbySmart head and foot positions, further research and education regarding tackle technique recommendations are needed. Given 32% of

tackles were not performed according to RugbySmart good tackle technique, research to confirm what techniques are less likely to result in injury are needed. This recommendation is supported given two of the six tackle-related injuries occurred despite the RugbySmart reported tackle characteristics being performed.

What are the findings?

- Only 57.9% of tackles during the season demonstrated currently prescribed good tackle technique.
- Even when using the currently prescribed good tackle technique, injuries can occur.

How might it impact on clinical practice in the future?

- A greater understanding of the various factors of the tackle that result in injury are required.

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Acknowledgements The authors thank the rugby players and their coaches for their assistance. We also acknowledge Richard Deuchrass for his help with this project.

Contributors According to the definition given by the International Committee of Medical Journal Editors (ICMJE), the authors listed qualify for authorship based on making one or more of the substantial contributions to the intellectual content of the manuscript. ST, MJH, DK and PAH contributed in conception and design. MJH gained ethics. ST acquired the data. ST, MJH, PAH, DK, KT, RK and TY contributed in analysis and interpretation of data. ST, MJH, DK and PAH participated in drafting of the manuscript. ST, MJH, DK, PAH, KT, RK and TY were involved in critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published, and all authors are in agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Where: ST, DK, TY, MJH, MH and PAH. Guarantor: MJH.

Funding Funding was received from Lincoln University, New Zealand Rugby and the Yokohama Minami Kyousai Hospital Sports Centre.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained directly from patient(s)

Ethics approval This study was approved by Lincoln University Human Ethics Committee ID 2017-04.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The dataset for this article is not publicly available, however, requests to access the dataset can be directed to MJH (mike.hamlin@lincoln.ac.nz).

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