Tackle Injuries in Professional Rugby Union

Kenneth L. Quarrie,*[†] MPhEd, and Will G. Hopkins,[‡] PhD
From [†]Injury Prevention and Research, New Zealand Rugby Union, Wellington, New Zealand, and the [‡]Exercise Science Department, Institute of Sport and Recreation Research New Zealand, AUT University, Auckland, New Zealand

Background: The tackle is the most dangerous facet of play in rugby union, but little is known about risk factors for tackle injuries.

Purpose: To estimate the injury risk associated with various characteristics of tackles in professional rugby union matches.

Study Design: Descriptive epidemiology study.

Method: All 140 249 tackles in 434 professional matches were coded from video recordings for height and direction of tackle on the ball carrier, speed of tackler, and speed of ball carrier; injuries were coded for various characteristics, including whether the tackler or ball carrier required replacement or only on-field assessment.

Results: There were 1348 injury assessments requiring only on-field treatment and 211 requiring player replacement. The inciting event and medical outcomes were matched to video records for 281 injuries. Injuries were most frequently the result of high or middle tackles from the front or side, but rate of injury per tackle was higher for tackles from behind than from the front or side. Ball carriers were at highest risk from tackles to the head-neck region, whereas tacklers were most at risk when making low tackles. The impact of the tackle was the most common cause of injury, and the head was the most common site, but an important mechanism of lower limb injuries was loading with the weight of another player. Rates of replacement increased with increasing player speed.

Conclusion: Strategies for reducing tackle injuries without radically changing the contact nature of the sport include further education of players about safe tackling and minor changes to laws for the height of the tackle.

Keywords: football; rugby; risk factors; injury; prospective study

Rugby union (rugby), a popular type of full-contact football, is the game from which American football evolved. The worldwide governing body of rugby, the International Rugby Board (IRB), lists 95 countries in its world rankings, although in most countries it is a minor sport. Rugby is most commonly played between 2 teams of 15 players for 2 periods of 40 minutes. The anthropometric and physical characteristics of each position have been described previously.[10,24] In general, forwards (positions 1-8), who are typically taller and heavier than backs,[26] are primarily responsible for contesting possession of the ball. Backs (positions 9-15), who are typically quicker than forwards,[26] are mainly charged with gaining field position and scoring points.[26] Each team is permitted up to 7 replacements, either for injuries or tactical purposes.

The tackle is the most dangerous facet of play in rugby, accounting for up to 58% of all game-related injuries.[2,4,6,9,13,30] Tackles also are associated with a large proportion of the most serious head and spinal injuries.[1,17,25,26] Prospective cohort studies of rugby injury epidemiology have documented that tackle injuries are distributed throughout the body for both carriers and tacklers.[4,13] A recent study of tackle injuries among professional players reported that concussion and cervical nerve root injuries were the most common injuries to tacklers, whereas shoulder injuries resulted in the greatest loss of participation.[6,7] Thigh hematomas were the most common injuries to ball carriers, with anterior cruciate ligament injuries resulting in the greatest amount of missed play.[6]

Factors moderating the risk of injury in the tackle have not been studied extensively, and the findings of the existing research are not always consistent. Tackles to the

*Address correspondence to Kenneth L. Quarrie, Injury Prevention & Research, New Zealand Rugby Union, PO Box 1272, Wellington, New Zealand (e-mail: ken.quarrie@nzrugby.co.nz).

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head/neck region and double tackles (2 players tackling the ball carrier) were identified through early case reports as risk factors for spinal injuries.[27,28] The tackler appeared to be at slightly greater risk than the ball carrier in some studies[5,6,9,15] but not others.[4] In one case series,[15] most injuries occurred in tackles from behind or from the side, but in another case series,[32] tackles from the front, which stopped the ball carrier, produced more injuries. In a prospective study of injuries to professional rugby players, front-on tackles produced most injuries to the tackler, whereas injuries to the ball carrier were most common from side-on tackles.[6]

To date, studies of injuries in tackles have had a number of limitations. First, information about those tackles that do not result in injury has not been provided.[15] Thus, relative rates of injury for specific types of tackle have not been available. In addition, the relatively small scale of the case series studies presented to date[15,32] has meant that a large degree of uncertainty remains with respect to the inciting events, or mechanisms, of tackles that result in injury. No medical information describing the circumstances of injuries in the tackle (eg, site, type, and severity) was provided from these case series studies.[15,32] Among those prospective studies examining tackle injuries that have provided medical information and the effect of injury on subsequent participation, the degree of information about the circumstances of the tackle has been limited.[6,7,14,30] Recognition of these limitations has prompted calls for studies that collect data about all tackles rather than just those that result in injury,[15] for the use of video data to examine the specific circumstances of tackle injuries,[6] and for studies to take into account both the frequency with which injuries occur and their subsequent effect on the participation of players.[12]

To gain a deeper understanding of the impact of tackle injuries in rugby, information is required about (1) how frequently specific characteristics of tackles are associated with injury, (2) how common particular tackle characteristics are in the sport, (3) what inciting events are commonly associated with specific types of injury, and (4) what burden the resulting injuries place on players and teams. The purpose of this study was to provide new knowledge about the risks and circumstances of tackle injuries in rugby by undertaking a large-scale prospective study of tackle injuries using video data. All tackles were coded, thus overcoming one of the main limitations of the work to date. The video data for tackles resulting in injury was cross-linked to medical data to provide information about inciting events and the burden of injuries for a subsample of the tackles.

METHODS

Video Data

To investigate aspects of the tackle thought to modify risk of injury to professional rugby players, we examined all matches in each professional competition in which New Zealand teams competed from 2003 to 2005. These matches represented a convenience sample, with sufficient injuries to allow reasonably narrow confidence intervals (CI) around rate estimates in most cases. A commercial coding company (Verusco Technologies, Palmerston North, New Zealand) used proprietary software with video recordings to code all tackles in the following televised professional rugby match series: New Zealand National Provincial Championship 2003-2005 (n = 144); Super 12, 2003-2005 (n = 207); 2003 Rugby World Cup (n = 47); Tri-Nations 2003-2005 (n = 18); and all other international (test) matches played by the New Zealand national team (the All Blacks) 2003-2005 (n = 18). Coding of the 434 matches included information about date, teams, players, and positions. The resulting video database allowed each tackle to be reviewed on demand by querying any of the coded categories. A selection of examples of tackle injuries from the data for this paper has been provided online at the AJSM website at http://ajs.sagepub.com. The tackle characteristics coded included tackle height and direction (Figure 1), movement type of the ball carrier and tackler

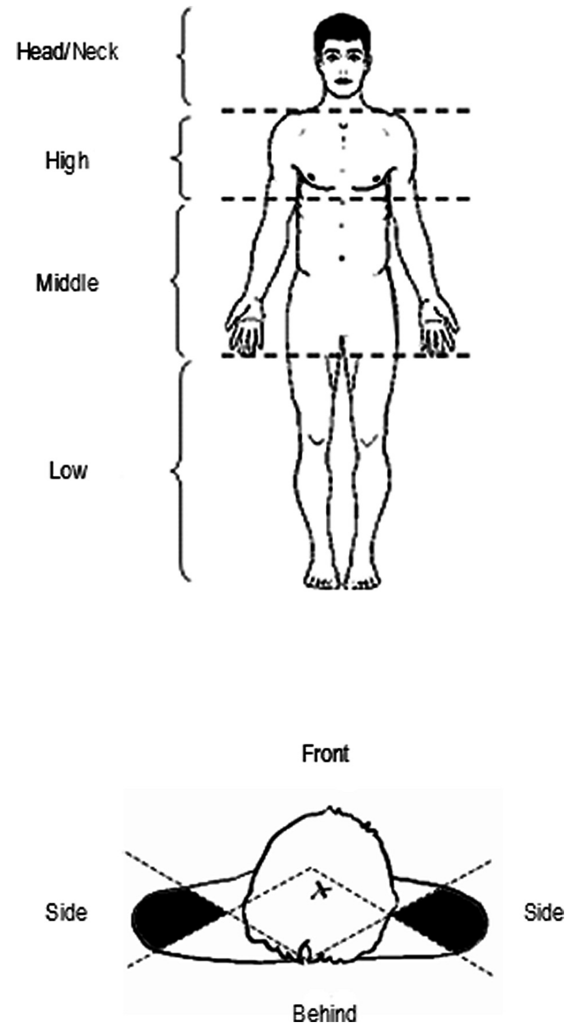

Figure 1. Tackle height and direction coding.

(stationary, walk, jog, run, sprint), and number of players in the tackle. The classification of movement type followed conventions previously described for time-motion analyses of rugby players.[8,11]

The 2002 Super 12 competition was used as a pilot study to train the coders. Sixty-nine matches were coded according to a schema developed specifically for this project. The head coder at Verusco Technologies undertook consistency checking. In cases where the circumstances of the tackle were ambiguous or poorly captured on the video record, the head coder made the final decision about the circumstances of the tackle, for example, the height and direction of the tackle and the relative movement type of the players involved. In professional rugby matches, multiple views of the match are televised, which helps to increase the accuracy of the coding.[20] We selected 6 matches at random following the completion of coding and had them recoded by the head coder to assess the influence of coder reliability. Kappa coefficients (number of tackles = 1986 in each case) were calculated for tackle height ($\kappa = 0.65$; 90% CI: 0.62-0.67), direction ($\kappa = 0.85$; CI: 0.83-0.87), tackler movement ($\kappa = 0.58$; CI: 0.56-0.61), and carrier movement ($\kappa = 0.65$; CI: 0.62-0.67). The lower the κ, the greater the attenuation of the effect. The rate ratios can be corrected for the attenuation resulting from the κ value by raising the rate ratio to the power of 1 over the appropriate κ.

Medical Data

Information captured for medical injuries included injury date, player, phase of play, injury site, type, and severity (days unavailable for selection).[14] Information from the video coding was cross-linked with a purpose-built New Zealand Rugby Union database (RugbyMed) by matching player name, date, and phase of play. There were 738 injury assessments and injury replacements to New Zealand players coded from the video records, 38% of which (281 injuries) were matched to RugbyMed injury claims. For these 281 injuries, the inciting event[16,22] was coded by one of the authors (K. L. Q.) according to whether the injury was the result of an impact between players, loading of the body by other players, the player falling/impacting the ground, or unable to be determined from the video record. Details recorded about impact injuries between players included which body parts were involved in the collision. Injury site was coded according to the categories outlined in the consensus document for injury data collection in rugby union by Fuller et al[14] and subsequently grouped into 3 body regions: the head/neck (head/face/neck/cervical spine); the upper body (shoulder/torso/arm/wrist/hand); and the lower body (hip/groin/thigh/knee/lower leg/ankle/foot).

Tackle and Injury Definitions

For the present study we defined tackles as follows: a *tackle* occurred when a ball carrier was contacted (hit and/or held) by an opponent without reference to whether they went to the ground. This differs from the definition of tackles under the laws of the game,[18] which specify that the ball carrier must be brought to the ground. We included events in which an opponent made substantial contact with a ball carrier or noticeably affected the movement of the ball carrier but did not complete a tackle. We further modified the definition to distinguish between tackles and what we termed "tackle events." A tackle occurred for every tackler contacting a ball carrier, whereas a *tackle event* occurred whenever a ball carrier was contacted by 1 or more opponents; thus, a tackle event could have more than 1 associated tackle.

Injury assessments were defined as tackles or tackle events resulting in a player obtaining medical attention on the field or being treated in the "blood bin" but subsequently continuing to participate in the match. *Injury replacements* were defined as injuries resulting in a player leaving the field for the remainder of the match. *Medical injuries* were defined as those injuries for which medical information for New Zealand-based players was entered into RugbyMed by team physicians. Medical injuries accrued medical costs and thus required an injury claim to be lodged into New Zealand's national injury insurance scheme and included, but were not limited to, those injuries observed on video.

Injury rate was defined as the incidence of injuries either per 1000 player-hours or per 1000 tackles (or tackle events). *Severity* was defined as the number of days an injured player was unavailable for selection for matches.[14] *Injury burden* was calculated as the rate of injury either per 1000 player-hours or per 1000 tackles multiplied by the severity of injury. Whereas Fuller and colleagues have called these measures *risks*,[12] the term risk has a specific meaning in injury epidemiology,[19] we have therefore chosen "injury burden" to avoid confusion as to which meaning of risk was intended.

Statistical Methods

Analyses of injury rates were performed using the generalized linear modeling procedure (Proc Genmod) in SAS (Version 9.1, SAS Institute, Cary, NC). To estimate rates of injury for tacklers per 1000 tackles, each tackle was coded with a binary-dependent variable representing injury replacement. A binomial response distribution was used. Similar analyses were performed to estimate injury rates for ball carriers by coding tackle events rather than tackles. To estimate rate of injury for tacklers or ball carriers per 1000 player-hours, the dependent variable was the sum of tackle injuries for each level of the tackle characteristic per match, and the Poisson response probability distribution was used. Separate analyses were performed for each potential risk factor (tackle height, direction, player movement speed, number of tacklers, player position) as a single main effect. The effect of tackle height, direction, and tackler movement on injury rate to ball carriers was estimated only for tackle events involving a single tackler. A logarithmic link function was used to express effects as rate ratios.

Examination of the influence of the repeated observations on individuals was performed by conducting generalized estimating equation analyses for tackle height, direction, and tackler speed and comparing the CIs obtained with those from the corresponding generalized

TABLE 1
Effect of Tackle Event Characteristics on Ball Carrier Replacement Injuries[a]

	Tackle Events per Match, Mean ± SD	Replacement Rate Per 1000 ...		
		Tackle Events	Player-Hours	Player-Hours as a Percentage, %
Total[b]	203 ± 29	1.1 (1.0-1.3)	5.8 (4.9-6.8)	100
Number of tacklers[b]				
1	99 ± 17	1.2 (1.0-1.5)	3.1 (2.4-3.8)	53 (45-61)
2	84 ± 16	1.2 (0.9-1.5)	2.5 (1.9-3.2)	43 (35-51)
3 or more	19 ± 6	0.5 (0.2-1.2)	0.2 (0.1-0.5)	4 (2-9)
Tackle height[c]				
Head/neck	4 ± 2	4.3 (2.3-7.9)	0.4 (0.2-0.8)	13 (7-23)
High	37 ± 10	1.2 (0.8-1.7)	1.1 (0.8-1.6)	36 (26-47)
Middle	44 ± 9	0.9 (0.6-1.3)	1.0 (0.7-1.5)	32 (23-43)
Low	15 ± 5	1.6 (0.9-2.6)	0.6 (0.3-1.0)	19 (12-29)
Tackle direction[c]				
Front	59 ± 14	1.0 (0.7-1.4)	1.5 (1.1-2.1)	49 (38-60)
Side	35 ± 8	1.4 (1.0-2.0)	1.3 (0.9-1.8)	42 (31-53)
Behind	5 ± 3	2.2 (1.1-4.6)	0.3 (0.1-0.6)	9 (4-18)
Carrier motion[c]				
Stationary	6 ± 3	1.2 (0.5-3.1)	0.2 (0.1-0.5)	6 (2-14)
Walk	17 ± 6	0.8 (0.4-1.6)	0.4 (0.2-0.7)	11 (6-21)
Jog	48 ± 11	1.0 (0.7-1.5)	1.3 (0.9-1.8)	42 (31-53)
Run	24 ± 7	1.3 (0.9-2.1)	0.8 (0.5-1.3)	26 (18-37)
Sprint	4 ± 3	4.5 (2.5-8.1)	0.5 (0.3-0.9)	15 (9-25)
Tackler motion[c]				
Stationary	8 ± 5	0.8 (0.3-2.2)	0.2 (0.1-0.5)	6 (2-15)
Walk	30 ± 9	0.5 (0.2-0.9)	0.4 (0.2-0.7)	11 (6-22)
Jog	43 ± 9	1.1 (0.8-1.6)	1.2 (0.8-1.7)	39 (28-56)
Run	14 ± 5	2.4 (1.6-3.7)	0.9 (0.6-1.3)	28 (18-43)
Sprint	4 ± 2	5.0 (2.8-9.0)	0.5 (0.3-0.8)	16 (9-28)

[a]Data are mean (90% confidence intervals).
[b]Based on 87 494 tackle events; 100 injury replacements in 434 matches.
[c]Based on 43 366 tackle events; 53 injury replacements in 434 matches.

linear models. The differences in CIs were minimal, so we opted for generalized linear models because they required much less computing time.

We expressed uncertainty in the true (infinite-sample) values of statistics as 90% CIs.[29] We compared replacement injury rates by deriving rate ratios and their CIs with Proc Genmod, but for better assessment of magnitude of effects, we also calculated percentage differences in injury rates, as follows: CIs for the injury rate at each level were first converted to standard errors, assuming that the sampling distribution of the rates was normal. Confidence intervals for the differences between the percentage injury rates were then approximated by using partial differentiation to combine the errors for each level into a standard error for the percentage difference: if r_i = the rate of injury per 1000 player-hours for level i, for example, middle, of a tackle characteristic, for example, height; if e_i = the standard error for r_i; and if p_i = the percentage (%) of injuries due to level i = $100\ r_i / \Sigma\ r_i$, then the standard error for $p_1 – p_2 = 100\ \Sigma\ \{[\partial\ (p_1 – p_2)/\partial r_i]\ e_i\}^2$. Confidence intervals for injury burdens were estimated using log transformation to combine factor uncertainty in injury rate with factor uncertainty in days off as independent errors.

We made inferences about true effects by declaring effects clear and interpreting their magnitude if the 90% CI did not include values that were greater than the least clinically important effect in both a positive and negative sense.[3] We assumed the following values of least clinically important effects: for difference in percentages of injury rates per 1000 player-hours, ±10%; for injury rate ratio and injury burden per 1000 tackles or tackle events, ×/÷ 1.10; and for injury severity, Cohen's standardized thresholds of 0.20,[3] representing 0.20 of the standard deviation (SD) in days off expressed as a factor (the factor SD raised to the power of 0.20).

To simplify the large number of comparisons of injury burden, we derived the mean factor CI for pair-wise comparisons of levels of a tackle characteristic and divided it by the smallest factor effect (1.1) to give the smallest ratio in the levels that could be interpreted as a clear outcome. The resulting clear outcomes were ratios in excess of ×/÷ 2.5 for ball carriers and ×/÷ 2.6 for tacklers.

RESULTS

Number of Tackles, Tackle Events, and Injuries

The 140 269 coded tackles represented 293 ± 46 (mean ± SD) successful tackles and 30 ± 8 missed tackles per

TABLE 2
Statistics for Medical Injuries to Ball Carriers Arising From Tackle Events and Resulting in Days Unavailable for Match Selection (New Zealand Players Only)

			Injury Rate per 1000		Injury Burden (Days Off) per 1000	
	No. of Injuries	Days Off, Mean ± SD	Tackle Events[a]	Player-Hours[a]	Tackle Events[a]	Player-Hours[a]
Total	152	35 ± 98	2.9 (2.5-3.3)	15 (13-17)	100 (71-150)	530 (370-760)
Number of tacklers						
1	81	41 ± 118	3.2 (2.6-3.8)	8.1 (6.7-9.7)	130 (79-210)	330 (200-540)
2	62	31 ± 71	2.8 (2.3-3.5)	6.2 (5.0-7.6)	88 (54-140)	190 (120-310)
3 or more	9	14 ± 21	1.9 (1.1-3.3)	0.9 (0.5-1.6)	27 (11-67)	13 (5-31)
Tackle height[b]						
Head/neck	8	23 ± 25	8.5 (4.7-15)	0.8 (0.4-1.4)	190 (89-410)	18 (8.4-39)
High	33	40 ± 71	3.4 (2.6-4.5)	3.3 (2.5-4.4)	140 (80-230)	130 (77-220)
Middle	32	52 ± 173	2.9 (2.1-3.8)	3.2 (2.4-4.3)	150 (64-340)	160 (72-380)
Low	8	21 ± 36	2.1 (1.2-3.8)	0.8 (0.4-1.4)	45 (17-120)	17 (6.4-45)
Tackle direction[b]						
Front	43	29 ± 55	2.8 (2.2-3.6)	4.3 (3.3-5.5)	82 (51-130)	130 (78-200)
Side	33	53 ± 173	3.7 (2.8-4.9)	3.3 (2.5-4.4)	200 (88-440)	180 (79-390)
Behind	5	59 ± 61	3.8 (1.8-7.9)	0.5 (0.2-1.0)	220 (89-560)	29 (12-74)
Carrier speed[c]						
Stationary	4	8 ± 4	1.6 (0.7-3.7)	0.4 (0.2-0.9)	13 (6.2-28)	3.2 (1.5-6.8)
Walk	29	46 ± 91	2.5 (1.9-3.4)	2.9 (2.1-3.9)	120 (63-210)	130 (72-240)
Jog	68	38 ± 125	2.6 (2.1-3.2)	6.8 (5.5-8.3)	97 (54-180)	250 (140-460)
Run	40	29 ± 60	3.7 (2.9-4.9)	4.0 (3.1-5.2)	110 (63-180)	120 (68-200)
Sprint	11	29 ± 34	8.5 (5.2-14)	1.1 (0.7-1.8)	240 (120-480)	31 (16-62)
Tackler speed[b]						
Stationary	3	110 ± 86	1.5 (0.6-3.9)	0.3 (0.1-0.8)	160 (57-470)	33 (11-94)
Walk	11	18 ± 24	1.4 (0.9-2.3)	1.1 (0.7-1.8)	26 (12-53)	20 (9.5-41)
Jog	41	43 ± 154	3.7 (2.8-4.8)	4.1 (3.2-5.3)	160 (71-350)	170 (79-380)
Run	19	41 ± 79	5.1 (3.5-7.4)	1.9 (1.3-2.8)	210 (100-430)	77 (38-160)
Sprint	7	36 ± 41	7.4 (4.0-14)	0.7 (0.4-1.3)	270 (120-620)	25 (11-58)

[a]Data are mean (90% confidence intervals).
[b]Based on 81 injuries from 25 587 tackle events with a single tackler only in 10 050 player-hours.
[c]Based on 152 injuries from 52 248 tackle events in 10 050 player-hours.

match. The tackles were associated with 87 494 tackle events, of which 49%, 42%, and 9% involved 1, 2, or more than 2 tacklers, respectively. There were 613 nonreplacement injury assessments and 100 replacement injuries to ball carriers. Injury assessments to ball carriers occurred at the rate of 7.0 per 1000 tackle events (35 per 1000 player-hours). The rate of ball carrier replacement was 1.1 per 1000 tackle events (5.8 per 1000 player-hours). There were 735 injury assessments to tacklers and a further 111 injury replacements. Injury assessments to tacklers occurred at the rate of 5.2 per 1000 tackles (42 per 1000 player-hours). The rate of tackler replacements was 0.8 per 1000 tackles (6.4 per 1000 player-hours).

Tackle Event Characteristics and Ball Carrier Injuries

In the following sections, the rates for given levels of a tackle characteristic are presented in the tables, and comparisons between levels (rate ratios and/or percentage differences in percentages) are presented in the text. Table 1 shows the effect of tackle-event characteristics on injury replacement rates for ball carriers. Table 2 shows the burden of injuries to New Zealand ball carriers, which were matched to assessment and replacement events in the video recordings. Carriers were replaced at a higher rate per 1000 tackle events when there was 1 tackler (rate ratio = 2.4; 90% CI: 1.0-5.5) or 2 tacklers (rate ratio = 2.3; 90% CI: 1.0-5.4) than when the event involved 3 or more tacklers. Carriers also had a higher rate of replacement per 1000 player-hours when tackled by 1 (rate ratio = 13; 90% CI: 5.7-31; percentage difference = 49%; 90% CI: 39%-59%) or 2 tacklers (rate ratio = 11; 90% CI: 4.6-25; percentage difference = 39%; 90% CI: 29%-49%) than when tackled by 3 or more. The differences between injury rates in tackle events with 1 tackler and those with 2 tacklers were unclear.

Tackles to the head/neck region resulted in replacement injuries to ball carriers at a higher rate per 1000 tackle events than low (rate ratio = 2.7; 90% CI: 1.2 to 6.1), middle (rate ratio = 4.8; 90% CI: 2.3 to 10), or high (rate ratio = 3.7; 90% CI: 1.8 to 7.6) tackle events. A different pattern was apparent when carrier replacement rate was modeled per 1000 player-hours: high tackles resulted in carrier

TABLE 3
Effect of Tackle Characteristics on Tackler Injuries[a]

	Tackles per Match, Mean ± SD	Replacement Rate per 1000 …		
		Tackles	Player-Hours	Player-Hours as a Percentage, %
Total[b]	323 ± 50	0.8 (0.7-0.9)	6.4 (5.5-7.5)	100
Number of tacklers				
1	99 ±17	1.1 (0.8-1.4)	2.7 (2.1-3.4)	41 (34-49)
2	168 ± 32	0.6 (0.5-0.8)	2.7 (2.1-3.4)	41 (34-49)
3 or more	55 ± 19	0.8 (0.5-1.2)	1.1 (0.8-1.6)	17 (12-24)
Tackle height				
Head/neck	11 ± 5	0.6 (0.2-1.6)	0.2 (0.1-0.5)	3 (1-7)
High	151 ± 29	0.7 (0.5-0.8)	2.5 (1.9-3.2)	39 (30-50)
Middle	131 ± 2	0.7 (0.6-1.0)	2.4 (1.9-3.1)	38 (29-49)
Low	30 ± 10	1.8 (1.3-2.5)	1.3 (0.9-1.9)	21 (15-29)
Tackle direction				
Front	206 ± 39	0.7 (0.5-0.8)	3.4 (2.7-4.2)	53 (45-61)
Side	105 ± 20	0.9 (0.7-1.2)	2.4 (1.8-3.1)	37 (30-45)
Behind	11 ± 4	2.2 (1.3-3.6)	0.6 (0.4-1.0)	10 (6-16)
Carrier motion				
Stationary	14 ± 5	0.5 (0.2-1.3)	0.2 (0.1-0.5)	3 (1-7)
Walk	75 ±19	0.5 (0.3-0.7)	0.9 (0.6-1.4)	14 (10-21)
Jog	165 ± 32	0.7 (0.6-0.9)	2.9 (2.3-3.6)	45 (37-53)
Run	63 ± 16	1.3 (1.0-1.7)	2.0 (1.5-2.7)	32 (25-39)
Sprint	7 ± 4	2.5 (1.3-4.7)	0.4 (0.2-0.8)	6 (3-11)
Tackler motion				
Stationary	28 ± 13	0.4 (0.2-0.9)	0.3 (0.1-0.6)	5 (2-9)
Walk	118 ± 27	0.5 (0.3-0.7)	1.4 (1.0-1.9)	22 (16-29)
Jog	143 ± 29	0.8 (0.6-1.0)	2.8 (2.2-3.6)	44 (37-52)
Run	29 ± 8	1.9 (1.4-2.7)	1.4 (1.0-1.9)	22 (16-29)
Sprint	5 ± 3	4.0 (2.3-6.9)	0.5 (0.3-0.9)	8 (5-14)

[a]Data are mean (90% confidence intervals).
[b]Based on 140 269 tackles, 735 injury assessments (resumed play), and 111 injury replacements in 434 matches.

replacement more frequently than head/neck (rate ratio = 2.6; 90% CI: 1.3 to 5.4; percentage difference = 22%; 90% CI: 6% to 38%) and low (rate ratio = 1.9; 90% CI: 1.0 to 3.6; percentage difference = 17%; 90% CI: 0.1% to 34%) tackles. Middle tackles also resulted in replacement more frequently than head/neck (rate ratio = 2.3; 90% CI: 1.1 to 4.9; percentage difference = 18%; 90% CI: 2.6% to 34%) and low tackles (rate ratio = 1.7; 90% CI: 0.9 to 3.3; percentage difference = 13%; 90% CI: –3.2% to 29%).

Tackles from behind resulted in a higher rate of replacement to carriers per 1000 tackle events than did tackles from the front (rate ratio = 2.2; 90% CI: 1.0-4.9) or the side (rate ratio = 1.5; 90% CI: 0.7-3.5). The opposite profile was apparent with respect to rate of carrier replacement by direction per 1000 player-hours: tackles from the front (rate ratio = 5.1; 90% CI: 2.3-11; percentage difference = 39%; 90% CI: 29%-49%) and the side (rate ratio = 4.3; 90% CI: 1.9-9.8; percentage difference = 32%; 90% CI: 23%-41%) were more likely to result in replacement than tackles from behind.

Carriers were replaced at a higher rate per 1000 tackle events when they were sprinting than when moving at lower speeds; rate ratios ranged from 3.4 (90% CI: 1.7-7.1) for running to 5.5 (90% CI: 2.3-13) for walking. There was a different pattern of replacements per 1000 player-hours: the rate was highest when the carrier was jogging and lowest when stationary (rate ratio = 7.3; 90% CI: 2.6-20; percentage difference = 36%; 90% CI: 27%-44%). The effects of tackler motion on injury rates were very similar to those of carrier motion.

Tackle Characteristics and Tackler Injuries

Table 3 shows the effect of tackle characteristics on injury replacement rates for tacklers.

Table 4 shows the burden of injuries to New Zealand tacklers that were matched to assessment and replacement events in the video recordings. The replacement rate per 1000 tackles was higher for tackles with a single tackler than for tackles with 2 tacklers (rate ratio = 1.7; 90% CI: 1.2-2.4). Injury rates per 1000 player-hours were higher for single and double tackles than for tackles involving 3 or more tacklers (rate ratio = 2.4; 90% CI: 1.6-3.8; percentage difference = 24%; 90% CI: 13%-36%).

Tacklers making low tackles were replaced at a higher rate per 1000 tackles than those making high (rate ratio = 2.7; 90% CI: 1.8-4.1) or middle (rate ratio = 2.4; 90% CI: 1.6-3.7) tackles. A different pattern emerged for tackler replacements per 1000 player-hours: the highest rate was for high tackles and the lowest was for the head/neck region (rate ratio = 14; 90% CI: 5.4-38; percentage difference = 36%; 90%

TABLE 4
Statistics for Medical Injuries to Tacklers Resulting in Days Unavailable for Match Selection (New Zealand Players Only)

	No. of Injuries	Days Off, Mean ± SD	Injury Rate per 1000		Injury Burden (Days Off) per 1000 …	
			Tackles	Player-Hours[a]	Tackles	Player-Hours[a]
Total[b]	129	26 ± 78	1.5 (1.3-1.8)	13 (11-15)	40 (26-60)	330 (220-500)
Number of tacklers						
1	56	41 ± 104	2.2 (1.8-2.7)	5.6 (4.5-6.9)	89 (52-150)	230 (130-390)
2	45	20 ± 60	1.0 (0.8-1.3)	4.5 (3.5-5.7)	21 (11-41)	90 (46-180)
3 or more	28	8 ±15	1.8 (1.3-2.5)	2.8 (2.0-3.8)	15 (8-28)	23 (13-43)
Tackle height						
Head/neck	3	14 ± 15	1.0 (0.4-2.7)	0.3 (0.1-0.8)	14 (3.8-52)	4.1 (1.1-15)
High	45	29 ± 92	1.1 (0.9-1.4)	4.5 (3.5-5.7)	33 (16-65)	130 (65-260)
Middle	64	25 ± 77	1.9 (1.5-2.3)	6.4 (5.2-7.8)	47 (27-84)	160 (91-290)
Low	17	26 ± 49	2.2 (1.5-3.3)	1.7 (1.1-2.5)	59 (28-120)	45 (22-93)
Tackle direction						
Front	77	24 ± 74	1.4 (1.2-1.7)	7.7 (6.3-9.2)	34 (20-58)	180 (110-310)
Side	43	19 ± 71	1.6 (1.2-2)	4.3 (3.3-5.5)	30 (14-66)	82 (38-180)
Behind	9	82 ± 127	3.1 (1.8-5.4)	0.9 (0.5-1.6)	260 (110-620)	74 (31-180)
Carrier speed						
Stationary	6	4 ± 4	1.6 (0.8-3.2)	0.6 (0.3-1.2)	6.5 (2.9-14)	2.4 (1.1-5.3)
Walk	15	80 ± 187	0.7 (0.5-1.1)	1.5 (1.0-2.3)	59 (24-150)	120 (48-300)
Jog	71	13 ± 29	1.6 (1.4-2)	7.1 (5.-8.6)	22 (14-34)	95 (62-140)
Run	29	19 ± 26	1.8 (1.3-2.5)	2.9 (2.1-3.9)	35 (22-56)	55 (34-88)
Sprint	8	85 ± 135	5.0 (2.8-9.0)	0.8 (0.4-1.4)	430 (170-1100)	68 (26-180)
Tackler speed						
Stationary	6	9 ± 8	0.9 (0.4-1.7)	0.6 (0.3-1.2)	8.1 (3.6-18)	5.6 (2.5-12)
Walk	37	17 ± 35	1.2 (0.9-1.5)	3.7 (2.8-4.8)	20 (11-34)	61 (35-110)
Jog	57	20 ± 81	1.5 (1.2-1.9)	5.7 (4.6-7.1)	31 (15-64)	120 (55-240)
Run	22	39 ± 98	3.0 (2.1-4.2)	2.2 (1.5-3.1)	120 (52-260)	85 (38-190)
Sprint	7	103 ± 139	5.3 (2.9-10)	0.7 (0.4-1.3)	550 (220-1400)	72 (29-180)

[a]Data are mean (90% confidence intervals).
[b]Based on 129 injuries from 84 755 tackles in 10 050 player-hours.

CI: 27%-45%), while low tackles had an intermediate rate; replacement rate for middle tackles was similar to that for high, but the difference was unclear.

Tackles from behind (rate ratio = 2.0; 90% CI: 1.0-4.1) and from the side (rate ratio = 1.6; 90% CI: 1.2-2.3) resulted in a higher rate of replacement per 1000 tackles than tackles from the front, whereas replacements per 1000 player-hours were much more frequent for front-on (rate ratio = 5.4; 90% CI: 3.1-9.2; percentage difference = 43%; 90% CI: 33%-54%) or side-on (rate ratio = 3.7; 90% CI: 2.1-6.5; percentage difference = 27%; 90% CI: 17%-37%) tackles than tackles from behind.

Tacklers were replaced at a higher rate per 1000 tackle events when carriers were sprinting than when moving at lower speeds: rate ratios ranged from 2.0 (90% CI: 1.0-3.9) for running to 5.1 (90% CI: 2.4-11) for walking. Tacklers were also at higher risk when they were sprinting: rate ratios varied from 2.1 (90% CI: 1.1-4.0) compared with running through to 9.8 (90% CI: 3.9-25) compared with stationary. There was a different pattern of replacements per 1000 player-hours: the rate was highest when jogging and lowest when stationary for carrier movement (rate ratio = 17; 90% CI: 6.3-44; percentage difference = 42%; 90% CI: 34%-51%) and tackler movement (rate ratio = 9.8; 90% CI: 4.5-21; percentage difference = 40%; 90% CI: 30%-49%). Tackles in which a single tackler was involved also resulted in higher injury burdens to tacklers per 1000 tackles and per 1000 player-hours than tackles in which multiple tacklers were involved.

Effect of Playing Position

The effects of player position on numbers of tackle events, tackles, and replacement injuries are shown in Figures 2 and 3. Backs were replaced at about twice the rate as forwards per 1000 tackle event when they were ball carriers (rate ratio = 2.0; 90% CI: 1.4-3.3) and per 1000 tackles when making tackles (rate ratio = 1.7; 90% CI: 1.3-2.5).

Inciting Events

There were 281 medical injuries to New Zealand players matched to video records via the RugbyMed database, of which 152 were injuries to ball carriers and 129 were injuries to tacklers. In the results to follow, the percentages presented are the percentage of injuries caused by a given

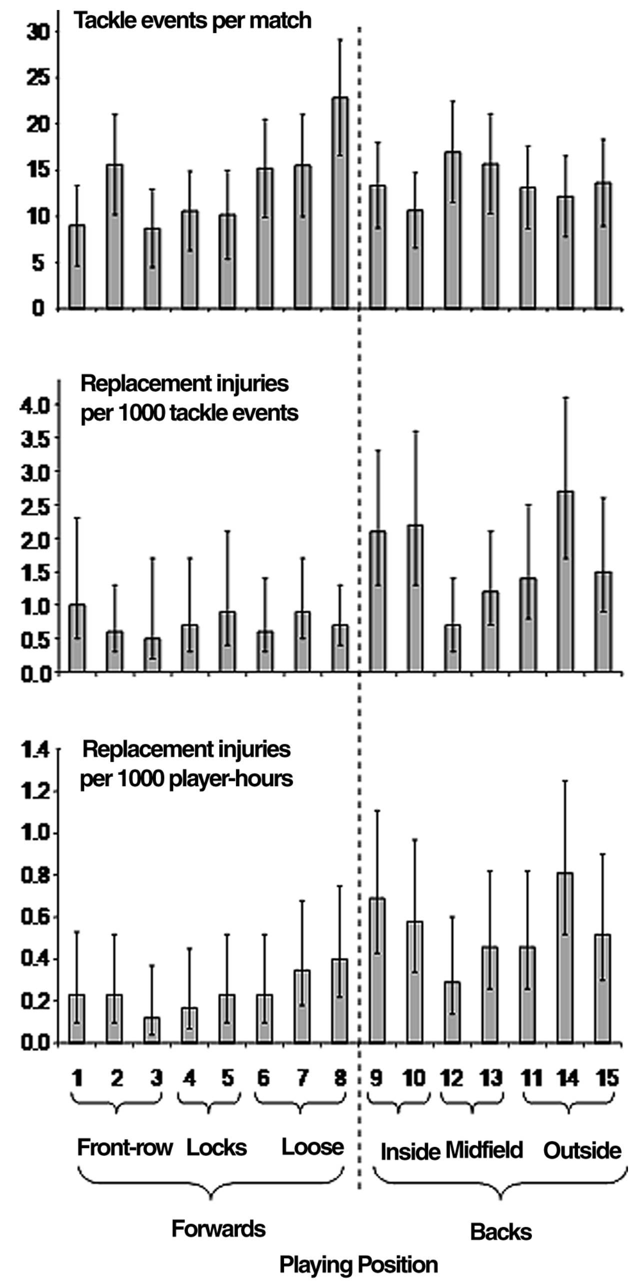

Figure 2. Tackle event and injury rates for ball carriers by position.

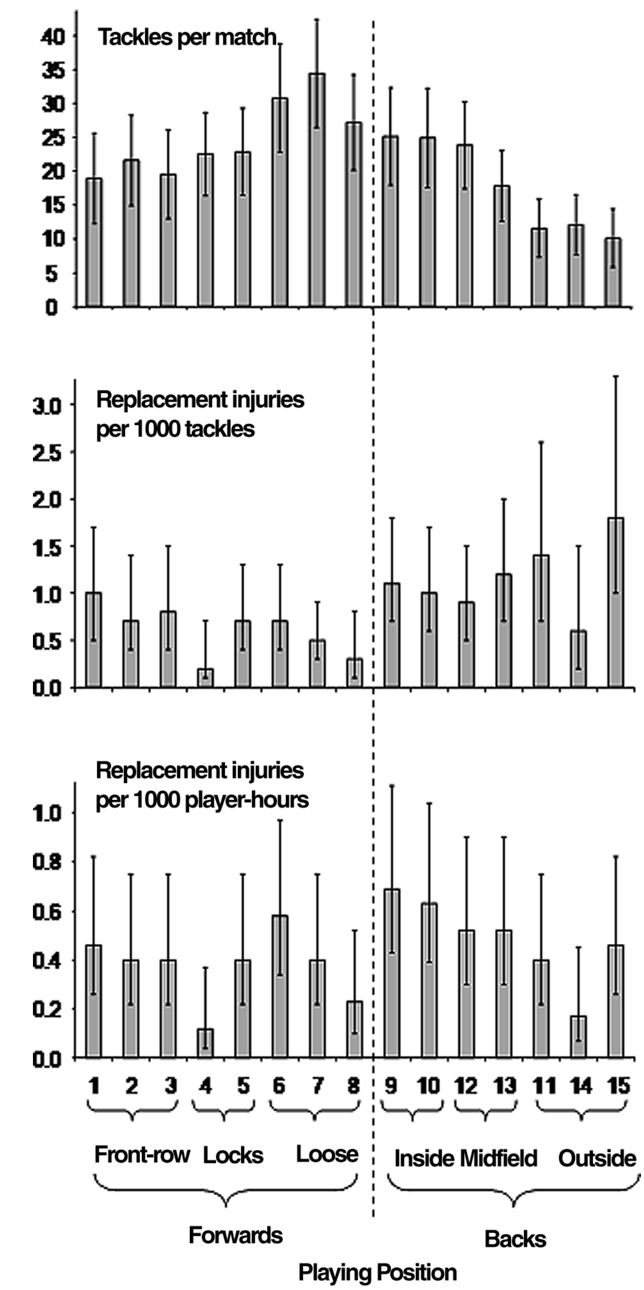

Figure 3. Tackle and injury rates for tacklers by position.

inciting event, along with the 90% CI of the percentage. The injuries to ball carriers arose from impact between players (45%; 90% CI: 39%-52%), tackler(s) loading the ball carrier's body with their weight (29%; 90% CI: 24%-36%), and the ball carrier falling/impacting the ground (19%; 90% CI: 15%-25%); 7% (90% CI: 5%-12%) were unable to be determined. There were 39 ball-carrier injuries to the head/neck region, of which 29 were to the head and face. The most common inciting event for injuries to the head/neck was impact between players, of which 7 of 25 (28%; 90% CI: 17%-46%) were the result of impact between the carrier's head and tackler's head—all of which caused injuries to the head/face. A further 41 injuries to ball carriers were reported to the upper body; 49% (90% CI: 37%-62%) of these were to the shoulder/clavicle. There were 72 ball carrier injuries to the lower body, of which 33% (90% CI: 25%-43%) were to the knee, 31% (90% CI: 23%-41%) were to the ankle, and 14% (90% CI: 9%-22%) were to the lower leg/Achilles tendon. Loading of the ball carrier's body by the tackler(s) was the most common inciting event for lower limb injuries to ball

TABLE 5
Injury Severity (Days Off) and Injury Burden (Days Off per 1000 Player-Hours) for Injuries to Different Body Regions Arising From Different Inciting Events for Ball Carriers and Tacklers (New Zealand Players Only)

Body Region	Inciting Event	No. of Events	Days Off, Mean ± SD	Injury Burden (Days Off) per 1000 Player-Hours[a]
Ball carrier				
Head/neck	Falling/hitting ground	8	6 ± 6	5 (2.3-11)
	Impact between players	25	19 ± 51	47 (21-110)
	Loading	1	0	–
	Uncertain	5	6 ± 7	3.1 (1.1-8.8)
Upper body	Falling/hitting ground	8	13 ± 20	10 (3.7-27)
	Impact between players	19	30 ± 45	56 (30-110)
	Loading	11	74 ± 95	81 (38-170)
	Uncertain	3	20 ± 26	6 (1.3-27)
Lower body	Falling/hitting ground	13	12 ± 19	16 (7.6-34)
	Impact between players	24	19 ± 52	46 (20-100)
	Loading	32	83 ± 190	260 (140-500)
	Uncertain	3	3 ± 3	0.80 (0.22-2.8)
Total		152	35 ± 98	530 (370-760)
Tackler				
Head/neck	Falling/hitting ground	2	0	–
	Impact between players	53	8 ± 9	42 (30-58)
	Loading	1	14	–
	Uncertain	5	7 ± 5	3.2 (1.3-7.8)
Upper body	Falling/hitting ground	8	27 ± 59	22 (6.7-71)
	Impact between players	19	26 ± 52	49 (23-100)
	Loading	1	81	–
	Uncertain	4	12 ± 14	4.9 (1.5-16)
Lower body	Falling/hitting ground	5	42 ± 34	21 (8.3-52)
	Impact between players	17	53 ± 94	89 (43-190)
	Loading	9	80 ± 200	72 (21-240)
	Uncertain	5	44 ± 28	22 (9.4-52)
Total		129	26 ± 78	330 (220-500)

[a]Data are mean (90% confidence intervals).

carriers (32 injuries of 72 [44%]; 90% CI: 36%-55%). Of the loading injuries, 38% (90% CI: 26%-53%) were to the ankle, 28% (90% CI: 18%-44%) were to the knee, and 22% (90% CI: 13%-37%) were to the lower leg/Achilles tendon region. A breakdown of body region injured by inciting event for ball carriers and tacklers is shown in Table 5.

The tackler injuries resulted from impact between players (69%; 90% CI: 63%-75%), the carrier loading the tackler's body (9%; 90% CI: 6%-13%), and the tackler falling/impacting the ground (12%; 90% CI: 8%-17%); 11% (90% CI: 8%-16%) were unable to be determined. There were 61 tackler injuries to the head/neck, of which 47 (77%; 90% CI: 68%-85%) were to the head/face. Of the 53 tackler injuries to the head/neck resulting from impacts between players, 28% (90% CI: 20%-40%) occurred through a collision between the tackler's head and the ball carrier's head, 23% (90% CI: 15%-34%) were the result of the tackler's head hitting the ball carrier's body, and in 17% (90% CI: 10%-28%) of cases the tackler's head collided with the head of another tackler. Impacts were also the most common inciting event for tackler injuries to the lower limb, accounting for 47% (90% CI: 35%-61%) of the 36 injuries. A further quarter of lower limb injuries to tacklers (25%; 90% CI: 16%-39%) were the result of loading of the tackler with the weight of the carrier during the tackle.

Ball carriers (47%; 90% CI: 41%-54%) sustained a greater percentage of injuries to the lower limb than did tacklers (28%; 90% CI: 22%-35%). The inciting event that resulted in the greatest injury burden (days unavailable per 1000 player-hours; 90% CI) for ball carriers was loading of the body (340; 90% CI: 200-580), followed by impact between players (150; 90% CI: 95-230). For tacklers, impact (190; 90% CI: 120-290) was the inciting event resulting in the greatest burden, followed by loading (88; 90% CI: 30-250).

DISCUSSION

Injury Risk Factors, Inciting Events and Injury Burden in Rugby Tackles

Injuries can be conceptualized as resulting from a transfer of energy that exceeds the ability of the body to maintain its structural or functional integrity.[14] Whether a particular rugby tackle results in injury depends on the amount of energy transferred, the size of the area over which the force is distributed, the direction(s) of the forces, and the biomechanical properties of the body structures to which the energy is transferred.

In general, the most common types of tackles and tackle events resulted in the most injuries and highest injury burden per 1000 player-hours. Thus, ball carriers were most frequently replaced after receiving high or middle tackles to the front or side, and tacklers were most often replaced after high or middle tackles made to the front or side of the ball carrier. Certain types of tackles that resulted in injury at relatively high rates per event occurred at low frequencies in the sport, which meant that they did not contribute substantially to the overall morbidity related to the tackle situation; examples are the injuries associated with the movement speed of either ball carriers or tacklers. Per occurrence, tackles in which players were sprinting resulted in injuries at 3 to 5 times the rate of injury of tackles in which players were moving at lower speeds. The average days missed per injury from tackles in which players were sprinting were also higher than for those in which players were moving at lower speeds. The relative rarity of tackles in which players were sprinting, however, meant that they accounted for a much lower proportion of injuries overall than tackles in which players (either the ball carrier or the tackler) were jogging. The injury burden per 1000 hours of play was also higher for tackles in which players were jogging than when they were sprinting, especially for ball carriers.

A previous study of rugby injuries noted similar differences in the distribution of injuries between tacklers and ball carriers.[13] Given that the direction and points of application of energy differ between the tackler and ball carrier, it is not surprising that there are differences between tacklers and ball carriers in the distribution of injuries across the body and the proportion of injuries resulting from the various types of inciting events.

Injury Prevention Opportunities

From an injury prevention perspective, understanding the rates and time unavailable for selection as a result of injury, both per event and per unit of exposure time, is useful. As noted in a recent paper outlining risk management strategies in sport,[12] frequent injuries of moderate severity may carry the same overall injury burden to participants in a sport as rare but severe injuries. In addition, once risks in a sport have been estimated, decisions need to be made about whether the risks are acceptable or unacceptable to the stakeholders of the sport.[12] In either case, information about the risk should be communicated to the sports community, but where risks are deemed to be unacceptably high, injury prevention strategies need to be implemented.[12] The views of stakeholders (ie, fans, the medical community, administrators, and players) on whether a particular level of risk is acceptable may vary widely. Within rugby, if the overall level of injury from tackles was considered acceptable to stakeholders, then targeting those tackle circumstances that occur infrequently but carry disproportionately high rates and burdens of injury per event would be a logical area on which to focus injury-prevention efforts. This would result in the least disruption to the structure of the sport. On the other hand, if the overall frequency and costs of injury from tackles were deemed to be unacceptably high, then focusing injury-prevention efforts on those tackles that result in the greatest burden of injury per 1000 hours of play would be expected to bring about the greatest reduction in player morbidity. Because the tackles associated with the highest burden of injury per unit of player exposure are among the most common in the sport (height: high or middle; direction: front or side; carrier speed: jogging; tackler speed: jogging), substantial changes to these would result in major modifications to the constitution of the sport.

Changing the laws of the game is an important potential strategy for preventing tackle injuries in rugby union. There were examples of injuries to ball carriers where the initial impact from the tackler was below the shoulder line, that is, at legal height, but the direction of the tackler led to the tackler's shoulder impacting the head of the ball carrier, which resulted in injury. Calls to lower the height of the tackle line from the top of the shoulders to the axillae (armpits) have been made by previous researchers.[23,31] Subsequent to the submission of this paper for review, the IRB set out a change to the interpretation of the laws regarding dangerous tackles, which stated that a tackle which made contact with the ball carrier above the line of the shoulders was dangerous regardless of whether the head or neck was the point of the first or subsequent contact. Presumably, this change will reduce the risk of tackles that start at the level of the chest connecting with the head of the ball carrier, and lower the risk of head-to-head contact. Whether this change will modify the risk of injuries for tacklers is worth monitoring, as the risk per tackle for tacklers was similar for head/neck, high, and middle tackles, but higher for low tackles. If the change to the legal tackle height results in tacklers making a greater proportion of low tackles, they might sustain a greater number of injuries.

Educational initiatives that focus on technique, physical conditioning, and the wearing of protective equipment are another avenue for reducing injury in rugby.[26] The use of incorrect technique has been identified as a risk factor for tackle injuries among schoolboy players,[21] and injury prevention efforts in amateur New Zealand rugby have focused on the correct technique for ball carriers and tacklers to adopt when being tackled or tackling.[26] Even among professional players, however, we observed a number of instances in which poor technique was a contributing factor to the injury occurring. Dropping the chin forward into the contact appears to increase the risk of head/neck injury through hyperflexion of the cervical spine.[23] Head-to-head contacts, either between the tackler and the ball carrier or between 2 tacklers who concurrently tackled the ball carrier from either side, comprised a substantial proportion (40%) of inciting events to the head/neck in the current study. Education measures that focus on teaching players to keep their chins off their chests, their eyes open, and to be aware of the location of other players as they move into the tackle situation may help reduce the risk of this type of injury. In American football, tackles in which tacklers impacted the opponent with the top of the head (spear tackles) were banned because they carried a high risk of spinal injury to the tackler. In rugby there is no censure for tackles that put the tackler at risk of serious spinal injury.

On reviewing the inciting events for injuries, it was notable that a number of the more severe injuries to the lower limbs resulted from the loading of a player's body with the weight of an opponent. In instances where the tackler jumped on the ball carrier from the side or behind and the ball carrier attempted to continue running, the ball carrier appeared to be at particular risk of severe knee, lower leg, and ankle injuries. Tacklers were also at risk of injury via such tackles, especially when their legs became tangled with those of the ball carrier, although tacklers were injured less frequently than ball carriers from this mechanism. Reducing the risk of tackles such as these, which result in major consequences to the player and the team in terms of the player's ongoing participation, but are permitted within rugby, may require greater attention via education-based injury prevention than has been the case previously. For example, teaching ball carriers to go to ground immediately when they feel the weight of the tackler may be a means of reducing risk of injury to ball carriers. The trade-off for players and coaches is that of gaining a meter or two of field position from a particular run versus having a player unavailable through injury for an extended period.

The fact that backs had a higher rate of injuries than forwards is likely to be due in part to the typical movement speed of players (and subsequent impact forces) from various positions.[6] Backs made a greater proportion of their tackles while running or sprinting compared to forwards. The finding that higher movement speeds resulted in higher injury rates has implications for the lawmakers of rugby. Current proposals to change the laws of the game, including increasing the distance between the 2 backlines in an attempt to allow players greater time and space before reaching the tackle zone, will probably increase the risk of injury by increasing energy transfer between tackler and ball carrier (assuming the total number of tackles per match remains relatively constant).

Strengths and Limitations of the Study

The strengths of this prospective study include a large sample size, a long monitoring period, the coding of all tackles and tackle events in each match, and the matching of injury events on the field with medical records. We believe that one of the strengths of the collection of information from video records is that it typically yields more accurate information about the circumstances associated with the injury than is available from player recall of the event or direct observation of data collectors, for example, physicians on the sidelines of matches. When combined with medical information about the injuries, systematic video analysis provides a powerful approach to identifying risk factors for injuries in sport. By analyzing injury statistics with event and player-hour denominators, we have been able to draw inferences about the relative and absolute contribution to the injury rates and burden of the various kinds of tackles.[15] Our findings will help administrators, sports medicine specialists, and participants develop and implement targeted injury-prevention strategies.

A limitation was the fact that medical information regarding injury site, type, and severity was available only for those injuries occurring to New Zealand-based players. While it would have been ideal to have this information for all injuries, the subsample of New Zealand-based players was sufficiently large to allow useful inferences about inciting events and the corresponding burden of injury to be drawn. Many of the limitations associated with capturing data from video recordings have been outlined previously.[20] Specifically, not all injuries that occur during the matches can be seen on video, although the tackle situation is often better able to be examined than scrums, rucks, or mauls, which have bodies massed together. Likewise, not all on-field injury assessments result in a player seeking further medical attention following the match. The tackle situation is dynamic, and cases in which player actions are obscured can increase the likelihood of misclassification of categories; thus, much depends on the quality of match coverage. Injury events, especially those that resulted in the player being replaced or receiving extended medical attention on the field, were often replayed on multiple camera views, which assisted in the coding of the circumstances and inciting events of those tackles that resulted in injury.

CONCLUSION

The most common tackles in rugby are responsible for the greatest number of injuries, but certain types of tackle carry a higher degree of risk. Prevention of tackle injuries needs to balance the frequency and severity of injuries sustained with the desire of rugby participants (including players, administrators, and supporters) to maintain the full-contact nature of the sport.

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