Injury risks associated with tackling in rugby union

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ABSTRACT
Objective To examine factors associated with tackles in rugby union and to assess their impact on the risk of injury.
Setting 13 English Premiership clubs.
Participants 645 players.
Main outcome measure RR (95% CI) calculated by comparing the frequency of occurrence of risk factors in a cohort of players injured during tackles with their frequency of occurrence in tackles in general play.
Risk factors Playing position; player’s speed, impact force, head position, head/neck flexion and body region struck in the tackle; sequence, direction and type of tackle; and location and type of injury.
Results High-speed going into the tackle, high impact force, collisions and contact with a player’s head/neck were identified as significant (p<0.01) risk factors for ball carriers (BCs) and tacklers. Midfield backs were significantly (p<0.01) more prone to injury when tackling than other players. Relatively few tacklers were penalised by referees for collision tackles (general play: 2.0%; injured players: 3.3%) and tackles above the line of the shoulder (general play: 5.9%; injured players: 16.7%).
Conclusions Advice in national and international injury prevention programmes for reducing the risk of injury in tackles is strongly supported by the results obtained from this study. These programmes should be reviewed, however, to provide specific advice for each type of tackle. Stricter implementation of the Laws of Rugby relating to collisions and tackles above the line of the shoulder may reduce the number of head/neck injuries sustained by BCs.

INTRODUCTION
Rugby union is recognised as a contact team sport with a high incidence of injury (91 injuries/1000 player-match-hours).1 An investigation of contact events in rugby union2 identified that, although tackles were the most common match event (tackle: 221.0/match; collision: 14.8) and were most likely to have been running or diving at the time of injury but concluded that over half the injury events involved tackles from behind the ball carrier’s (BC) line of vision, and where there was a difference in the BC’s and tackler’s speeds, the player with the lower speed was more likely to be injured. However, because neither study investigated the frequencies with which these specific actions occurred during general play, they were not able to comment on the RRs of these factors.5 The potential dangers associated with tackles are recognised by the International Rugby Board, and specific actions, such as a tackler charging without attempting to hold the BC, tackling above the line of the shoulders and tackling when the BC’s feet are off the ground, should be penalised.6 Of particular concern in rugby are tackles with the potential to cause serious head or neck injuries.

METHODS
All first team players at 13 of the 14 English Premiership rugby union clubs during the 2003/04 (11 teams; 434 players) and 2005/06 (10 teams; 401 players) seasons took part in the study. In total, 645 players were included, of whom 190 were involved in both seasons. Players gave their written informed consent for data to be recorded.

Analysis framework
According to the Laws of Rugby,6 ‘a tackle occurs when the ball carrier is held by one or more opponents and is brought to the ground’: in this study, a tackle was considered to be ‘any event where one or more tacklers attempted to stop or impede the BC whether or not the BC was brought to ground.’ Every tackle was assessed by one of four experienced rugby video analysts using a range of categorical variables related to the BC and the first two tacklers (T1 and T2) involved in the event. The variables, which were defined following a series of discussions...
involved a sports epidemiologist, sports physician, biomechanist, rugby players and coaches and video analysts, were grouped into a framework involving three phases; namely, pretackle (0.4 s period (10 frames) preceding the tackle event), the tackle and post-tackle (0.4 s period (10 frames) following the tackle event):

**Pretackle**
- BC, T1 and T2 playing positions (front row—numbers 1, 2, 3; second row—numbers 4, 5; back row—numbers 6, 7, 8; scrum half—number 9; midfield backs—numbers 10, 12, 13; back three—numbers 11, 14, 15);
- speed of BC, T1 and T2 into tackle (fast—running/sprinting; slow—walking/jogging; stationary—standing/minimal movement).

**Tackle**
- Sequence of event (one-on-one—T1 on BC; sequential and simultaneous—T1 and T2 on BC);
- type of tackle (arm—T impedes/stops BC with upper limb(s), figure 1; collision—T impedes/stops BC without use of the arm(s), figure 2; jersey—T holds BC jersey, figure 3; lift—T raises BC hips above BC head, figure 4; shoulder—T impedes/stops BC with shoulder as the first point of contact followed by use of arm(s), figure 5; smother—T uses chest and wraps both arms around BC, figure 6; tap—T trips BC with hand on lower limb below the knee, figure 7);
- T1 and T2 directions of tackle (behind; front; left side; right side—with respect to BC);
- T1 and T2 head positions (above; behind; beside; in front—with respect to BC);
- BC, T1 and T2 head/neck flexion (chin-on-chest—head/neck flexed; head up—head/neck in neutral or extended position);
- BC, T1 and T2 body region struck (BRS) in tackle (head/neck; upper limb; trunk; lower limb);
- impact force of T1 and T2 on BC (high; low—subjective assessment).

**Post-tackle**
- BC, T1 and T2 first BRS on ground after tackle (head/neck; upper limb; trunk; lower limb);
- player injured (BC, T1, T2);
- injury location (head/neck; upper limb; trunk; lower limb);
- injury type (bone; joint (non-bone)/ligament; muscle/tendon; skin; central/peripheral nervous system).

**Injuries**
Definitions and procedures used to record injuries followed the consensus statement for injury surveillance studies in rugby union.
rugby union. Medical personnel at each club recorded details of time-loss (>1 day’s absence) match injuries resulting from tackle events on a standard report form using the Orchard Sports Injury Classification System; injuries were subsequently grouped for type and location according to the consensus statement. The shoulder was grouped with the upper limb in all body location variables.

Sample size
A sample size calculation was undertaken to determine the number of tackle events required in general play to identify whether differences between the injured and general play groups were statistically significant. The calculation was based on being able to identify a 10% (absolute) difference in the frequency of occurrence of a risk factor in a group of 244 tackle injuries (the sample population available in this study) compared with a 30% frequency of occurrence in the general play group with 90% power and 95% confidence. This calculation indicated that ~6000 tackle events were required; as there were ~235 tackle events per game, 26 games were required. These games were selected randomly from the 264 games played in the two seasons and DVD recordings of the games obtained from the Rugby Football Union.

Data analysis
A detailed assessment manual was prepared and a training programme implemented in order to maximise the level of agreement between the video analysts. Results obtained by the four analysts were compared pairwise (κ statistic) using 12 variables assessed in two games (453 events) selected randomly from the 26 games (6219 events) analysed. K values between 0.40 and 0.75 are considered to represent ‘fair to good’ and values greater than 0.75 ‘excellent’ agreement.

The RR for each risk factor was determined by comparing the frequency of occurrence within the injured population with the frequency of occurrence in general play. An RR=1 indicates that a risk factor has no greater propensity to cause injury than that anticipated by chance; an RR>1 indicates a higher and an RR<1 a lower propensity to cause injury than expected by chance. Differences were considered to be significant if the 95% CI for the RR did not include the value 1.00, and the p value (two-tailed Z test) was <0.01. χ² Tests were used to identify significant differences (p<0.01) between the numbers of cases in the two groups. The κ statistic was used to assess agreement between the body regions injured by BC, T1 and T2, and the players’ body regions struck in the tackle and on the ground.
RESULTS
The injured group comprised 244 (2003/04: 157; 2005/06: 87) injuries sustained in tackles identified on the video recordings. The general play group comprised 6219 (2003/04: 3473; 2005/06: 2746) tackles that occurred in the 26 games (2003/04: 15; 2005/06: 11) selected. The average and range of $\kappa$ values obtained for the inter-rater reliability tests are summarised in table 1: the average values for 11 of the factors were classified as ‘fair to good’ and one as ‘excellent.’

Table 1 Summary of inter-rater reliability tests ($\kappa$ statistic) achieved for 12 tackle risk factors by four video analysts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average</th>
<th>Range</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC playing position</td>
<td>0.90</td>
<td>0.88</td>
<td>0.93</td>
<td></td>
</tr>
<tr>
<td>BC speed</td>
<td>0.52</td>
<td>0.40</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>Sequence of tackle on BC</td>
<td>0.72</td>
<td>0.65</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>BC head/neck flexion</td>
<td>0.43</td>
<td>0.33</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>BC BRS in tackle</td>
<td>0.41</td>
<td>0.34</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>T1 direction of tackle on BC</td>
<td>0.49</td>
<td>0.28</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>T1 impact force</td>
<td>0.45</td>
<td>0.28</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>T1 type of tackle</td>
<td>0.54</td>
<td>0.45</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>T1 head position</td>
<td>0.54</td>
<td>0.49</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>T1 BRS on ground</td>
<td>0.44</td>
<td>0.32</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>T2 direction of tackle on BC</td>
<td>0.48</td>
<td>0.29</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>T2 head position</td>
<td>0.50</td>
<td>0.43</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>All variables</td>
<td>0.54</td>
<td>0.28</td>
<td>0.93</td>
<td></td>
</tr>
</tbody>
</table>

BC, ball carrier; BRS, body region struck; T1, Tackler-1; T2, Tackler-2.

Table 2 Pretackle—RRs of injury as a function of playing position and speed into tackle

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>No of events in group (%)</th>
<th>RR</th>
<th>(Ratio (95% CI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>General play</td>
<td>Injured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ball carrier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All forwards (8)</td>
<td>2722 (45.5)</td>
<td>0.91 (0.70 to 1.19)</td>
<td>0.484</td>
</tr>
<tr>
<td>Front (3)</td>
<td>734 (12.3)</td>
<td>1.04 (0.84 to 1.28)</td>
<td>0.865</td>
</tr>
<tr>
<td>Back (3)</td>
<td>1374 (22.9)</td>
<td>0.95 (0.66 to 1.37)</td>
<td>0.787</td>
</tr>
<tr>
<td>All backs (7)</td>
<td>3266 (54.5)</td>
<td>1.08 (0.86 to 1.35)</td>
<td>0.529</td>
</tr>
<tr>
<td>Scrum half (1)</td>
<td>551 (9.2)</td>
<td>0.57 (0.27 to 1.21)</td>
<td>0.142</td>
</tr>
<tr>
<td>Midbacks (3)</td>
<td>1352 (22.6)</td>
<td>1.33 (0.67 to 2.82)</td>
<td>0.703</td>
</tr>
<tr>
<td>Back three (3)</td>
<td>1363 (22.8)</td>
<td>1.00 (0.72 to 1.48)</td>
<td>0.897</td>
</tr>
<tr>
<td>Tackler-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All forwards (8)</td>
<td>3186 (53.5)</td>
<td>0.76 (0.55 to 1.06)</td>
<td>0.107</td>
</tr>
<tr>
<td>Front (3)</td>
<td>872 (14.6)</td>
<td>0.60 (0.38 to 0.91)</td>
<td>0.167</td>
</tr>
<tr>
<td>Back (3)</td>
<td>817 (13.7)</td>
<td>0.45 (0.28 to 0.72)</td>
<td>0.056</td>
</tr>
<tr>
<td>All backs (7)</td>
<td>2789 (46.5)</td>
<td>1.06 (0.60 to 1.85)</td>
<td>0.005</td>
</tr>
<tr>
<td>Scrum half (1)</td>
<td>479 (8.0)</td>
<td>0.72 (0.30 to 1.34)</td>
<td>0.472</td>
</tr>
<tr>
<td>Midbacks (3)</td>
<td>1415 (23.8)</td>
<td>1.19 (1.16 to 2.34)</td>
<td>0.003</td>
</tr>
<tr>
<td>Back three (3)</td>
<td>875 (14.7)</td>
<td>0.95 (0.54 to 1.68)</td>
<td>0.857</td>
</tr>
<tr>
<td>Tackler-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All forwards (8)</td>
<td>1591 (26.6)</td>
<td>0.93 (0.56 to 1.74)</td>
<td>0.772</td>
</tr>
<tr>
<td>Front (3)</td>
<td>471 (19.1)</td>
<td>1.25 (0.56 to 2.81)</td>
<td>0.582</td>
</tr>
<tr>
<td>Back (3)</td>
<td>737 (15.3)</td>
<td>1.04 (0.89 to 1.28)</td>
<td>0.906</td>
</tr>
<tr>
<td>All backs (7)</td>
<td>870 (35.4)</td>
<td>0.66 (0.22 to 1.36)</td>
<td>0.358</td>
</tr>
<tr>
<td>Scrum half (1)</td>
<td>148 (6.0)</td>
<td>0.85 (0.52 to 1.43)</td>
<td>0.017</td>
</tr>
<tr>
<td>Midbacks (3)</td>
<td>491 (20.0)</td>
<td>0.60 (0.19 to 1.87)</td>
<td>0.379</td>
</tr>
<tr>
<td>Back three (3)</td>
<td>231 (9.4)</td>
<td>2.16 (0.88 to 5.17)</td>
<td>0.095</td>
</tr>
<tr>
<td>Ball carrier speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast</td>
<td>1280 (20.7)</td>
<td>1.60 (1.18 to 2.16)</td>
<td>0.002</td>
</tr>
<tr>
<td>Slow</td>
<td>4398 (71.0)</td>
<td>0.67 (0.70 to 1.08)</td>
<td>0.004</td>
</tr>
<tr>
<td>Stationary</td>
<td>514 (8.3)</td>
<td>0.63 (0.30 to 1.34)</td>
<td>0.030</td>
</tr>
<tr>
<td>Tackler-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast</td>
<td>744 (12.1)</td>
<td>1.85 (1.18 to 2.92)</td>
<td>0.008</td>
</tr>
<tr>
<td>Slow</td>
<td>4544 (73.7)</td>
<td>0.88 (0.67 to 1.15)</td>
<td>0.337</td>
</tr>
<tr>
<td>Stationary</td>
<td>880 (14.3)</td>
<td>0.91 (0.50 to 1.64)</td>
<td>0.749</td>
</tr>
</tbody>
</table>

*Statistically significant difference (p<0.01).

Pretackle
The results for playing position and speed into the tackle are presented in table 2. In general play, BC was significantly (p<0.001) more likely to be a back than a forward, and while there was no significant difference (p=0.795) for T1, T2 was significantly (p<0.001) more likely to be a forward. In terms of injury, BC was significantly (p=0.006) more likely to be a back, but there were no significant differences between forwards and backs for T1 (p=0.019) or T2 (p=0.504). Of the grouped playing positions, only midfield backs showed a significantly higher propensity to be injured when tackling as T1. BC, T1 and T2 were significantly more likely to be injured when approaching the tackle event at high speed; however, there was no greater chance that the slower player into a tackle was more likely to be injured (BC: RR=1.03; 95% CI 0.61 to 1.75, p=0.904; T1: RR=1.18, 95% CI 0.78 to 1.78, p=0.430).

Tackle
The results for the sequence and direction of tackle are summarised in table 3. In general play, there were significantly more one-on-one tackles than double-tackles (p<0.001); however,
there were no significant differences in the propensity for any of the sequences or directions of tackle to result in an injury. There was also no indication that double-tackles from opposing directions were significantly more likely to result in injury to BC than double-tackles from the same direction (RR=1.23, 95% CI 0.61 to 2.47, p=0.562). However, BC was significantly more likely to be injured (RR=2.21, 95% CI 1.60 to 3.06, p<0.001) if the impact forces of either T1 in on-one-on tackles or T1 or T2 in double-tackles were high. In over 98% of tackle events, BC, T1 and T2 went into the tackle with their head/neck in the ‘head-up’ position; only three players (all BCs) sustained an injury when their head was in the ‘chin-on-chest’ position, and none of these involved injuries to the players’ head/neck.

Over 90% of all T1 and T2 tackles involved an arm (55.0%), shoulder (22.5%) or smother (14.7%) tackle; Table 4 shows the RRs of injury associated with each type of tackle for BC, T1 and T2. There were significantly higher propensities for BC to be injured in collisions during one-on-one and double-tackles and for T1 and T2 to be injured in collisions during double-tackles.

Table 4  Tackle—RRs of injury as a function of the sequence and type of tackle

<table>
<thead>
<tr>
<th>Sequence and type of tackle</th>
<th>No of tackles in general play (%)</th>
<th>BC</th>
<th>T1</th>
<th>T2</th>
<th>RR (95% CI), p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-on-one tackles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tackler-1 (all)</td>
<td>3558 (100)</td>
<td>60 (100)</td>
<td>41 (100)</td>
<td>–</td>
<td>0.49 (0.29 to 0.83), 0.008*</td>
</tr>
<tr>
<td>Arm</td>
<td>1690 (47.5)</td>
<td>14 (23.3)</td>
<td>17 (41.5)</td>
<td>–</td>
<td>3.09 (1.97 to 4.84), &lt;0.001*</td>
</tr>
<tr>
<td>Collision</td>
<td>384 (10.8)</td>
<td>20 (33.3)</td>
<td>1 (2.4)</td>
<td>–</td>
<td>0.00 (–), –</td>
</tr>
<tr>
<td>Jersey</td>
<td>93 (2.6)</td>
<td>0 (0)</td>
<td>4 (9.8)</td>
<td>–</td>
<td>1.36 (0.87 to 2.15), 0.180</td>
</tr>
<tr>
<td>Lift</td>
<td>16 (0.4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>–</td>
<td>0.00 (–), –</td>
</tr>
<tr>
<td>Shoulder</td>
<td>826 (23.2)</td>
<td>19 (31.7)</td>
<td>17 (41.5)</td>
<td>–</td>
<td>0.79 (0.37 to 1.66), 0.555</td>
</tr>
<tr>
<td>Smother</td>
<td>526 (14.8)</td>
<td>7 (11.7)</td>
<td>2 (4.9)</td>
<td>–</td>
<td>0.00 (–), –</td>
</tr>
<tr>
<td>Tap</td>
<td>23 (0.6)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>–</td>
<td>0.00 (–), –</td>
</tr>
</tbody>
</table>

| Double-tackles              |                                  |    |    |    |                      |
| Tackler-1 (all)             | 2512 (100)                       | 72 (100) | 42 (100) | – | 1.14 (0.85 to 1.52), 0.390 |
| Arm                         | 1443 (57.4)                      | 47 (65.3) | 18 (42.9) | – | 10.47 (2.88 to 38.03), <0.001* |
| Collision                   | 10 (0.4)                         | 3 (4.2) | 5 (11.9) | – | 0.00 (–), – |
| Jersey                      | 86 (3.4)                         | 0 (0) | 0 (0) | – | 0.00 (–), – |
| Lift                        | 11 (0.4)                         | 0 (0) | 0 (0) | – | 0.98 (0.64 to 1.52), 0.936 |
| Shoulder                    | 746 (29.7)                       | 21 (29.2) | 17 (40.5) | – | 0.00 (–), – |
| Smother                     | 209 (8.3)                        | 0 (0) | 2 (4.8) | – | 0.00 (–), – |
| Tap                         | 7 (0.3)                          | 1 (1.4) | 0 (0) | – | 4.98 (0.61 to 40.51), 0.14 |

| Tackler-2 (all)             | 2515 (100)                       | 71 (100) | 24 (100) | – | 0.07 (0.63 to 1.19), 0.326 |
| Arm                         | 1589 (63.2)                      | 39 (64.9) | 11 (45.8) | – | 17.71 (7.15 to 43.88), <0.001* |
| Collision                   | 14 (0.6)                         | 7 (9.9) | 4 (16.7) | – | 3.22 (0.76 to 13.69), 0.114 |
| Jersey                      | 22 (0.9)                         | 2 (2.8) | 0 (0) | – | 0.00 (–), – |
| Lift                        | 3 (0.1)                          | 0 (0) | 0 (0) | – | 0.00 (–), – |
| Shoulder                    | 358 (14.2)                       | 11 (15.5) | 8 (33.3) | – | 1.90 (0.60 to 1.98), 0.779 |
| Smother                     | 527 (21.0)                       | 12 (16.9) | 1 (4.2) | – | 0.00 (–), – |
| Tap                         | 2 (0.1)                          | 0 (0) | 0 (0) | – | 0.00 (–), – |

*Statistically significant difference (<0.01).
BC, ball carrier; T1, Tackler-1; T2, Tackler-2.

Arm/arm, arm/shoulder and arm/smother tackles were the most common tackle combinations and were also responsible for the most injuries (table 5); however, none of these tackle combinations showed a greater propensity to cause injury to any of the players.

Only 27 (0.4%) T1 and three (0.1%) T2 tackles during general play were classified as ‘lift’ tackles, and none of these involved a double-lift tackle by T1 and T2; nor were any of the tackles classified as ‘spear’ tackles: no injuries were caused by lift tackles. Detailed assessments of the RRs for BC to be injured in double-tackles when T1 used an arm action (cause of the greatest number of injuries) and of BC being injured in one-on-one collision tackles by T1 (action with the highest propensity to cause injury) are presented in tables 6, 7, respectively.

Tacklers were more likely to be injured in a tackle if their heads were in front (T1: RR=1.77, 95% CI 1.09 to 2.86, p=0.020; T2: RR=2.44, 95% CI 1.09 to 5.49, p=0.031) and less likely to be injured if above (T1: RR=0.68, 95% CI 0.34 to 1.36, p=0.271; T2: RR=0.56, 95% CI 0.21 to 1.50, p=0.250) or beside (T1: RR=0.65, 95% CI 0.60 to 1.20, p=0.347; T2: RR=0.47, 95% CI 0.21 to 1.50, p=0.250) of the sequences or directions of tackle to result in an injury.
Table 5  Tackle—RRs of injury as a function of the sequence and most common combinations of double (sequential and simultaneous) tackles

<table>
<thead>
<tr>
<th>Tackle combination</th>
<th>No of tackles in general play (%)</th>
<th>BC</th>
<th>T1</th>
<th>T2</th>
<th>No of injuries (%)</th>
<th>RR (95% CI), p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm/arm</td>
<td>942 (37.9)</td>
<td>23 (32.9)</td>
<td>11 (26.8)</td>
<td>6 (25.0)</td>
<td>0.87 (0.57 to 1.31), 0.497</td>
<td>0.71 (0.39 to 1.28), 0.254</td>
</tr>
<tr>
<td>Arm/shoulder</td>
<td>668 (26.8)</td>
<td>25 (35.7)</td>
<td>17 (41.5)</td>
<td>8 (23.3)</td>
<td>1.33 (0.69 to 1.99), 0.159</td>
<td></td>
</tr>
<tr>
<td>Arm/smother</td>
<td>361 (14.5)</td>
<td>9 (12.9)</td>
<td>6 (14.6)</td>
<td>3 (12.5)</td>
<td>0.99 (0.46 to 1.71), 0.719</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>2485 (100)</td>
<td>70 (100)</td>
<td>41 (100)</td>
<td>24 (100)</td>
<td>1.00 (0.45 to 2.26), 0.984</td>
<td></td>
</tr>
</tbody>
</table>

BC, ball carrier; T1, Tackler-1; T2, Tackler-2.

Table 6  Tackle—RR of injury for BC during T1 arm double-tackles

<table>
<thead>
<tr>
<th>Tackle risk factor</th>
<th>No of events in group (%)</th>
<th>BC</th>
<th>RR (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player</td>
<td>General play: 750 (53.6)</td>
<td>30 (63.8)</td>
<td>1.19 (0.83 to 1.72)</td>
<td>0.347</td>
</tr>
<tr>
<td></td>
<td>BC injured: 650 (46.4)</td>
<td>17 (36.2)</td>
<td>0.78 (0.48 to 1.26)</td>
<td>0.308</td>
</tr>
<tr>
<td>Speed into tackle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast</td>
<td>BC: 274 (19.1)</td>
<td>6 (12.8)</td>
<td>0.670 (0.30 to 1.50)</td>
<td>0.332</td>
</tr>
<tr>
<td>Slow</td>
<td>BC: 1163 (80.9)</td>
<td>41 (87.2)</td>
<td>1.08 (0.79 to 1.47)</td>
<td>0.638</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRS in tackle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head/neck</td>
<td>BC: 45 (3.2)</td>
<td>3 (6.5)</td>
<td>2.03 (0.63 to 6.52)</td>
<td>0.234</td>
</tr>
<tr>
<td>Upper limb</td>
<td>BC: 622 (44.5)</td>
<td>16 (34.8)</td>
<td>0.78 (0.48 to 1.29)</td>
<td>0.332</td>
</tr>
<tr>
<td>Trunk</td>
<td>BC: 540 (38.6)</td>
<td>17 (37.0)</td>
<td>0.96 (0.59 to 1.55)</td>
<td>0.857</td>
</tr>
<tr>
<td>Lower limb</td>
<td>BC: 192 (13.7)</td>
<td>10 (21.7)</td>
<td>1.58 (0.84 to 2.99)</td>
<td>0.156</td>
</tr>
<tr>
<td>Tackler-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Player</td>
<td>General play: 606 (43.6)</td>
<td>20 (50.0)</td>
<td>1.15 (0.73 to 1.79)</td>
<td>0.549</td>
</tr>
<tr>
<td></td>
<td>BC injured: 783 (56.4)</td>
<td>20 (50.0)</td>
<td>0.89 (0.57 to 1.38)</td>
<td>0.596</td>
</tr>
<tr>
<td>Speed into tackle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast</td>
<td>BC: 92 (6.4)</td>
<td>6 (12.8)</td>
<td>2.00 (0.87 to 4.56)</td>
<td>0.101</td>
</tr>
<tr>
<td>Slow</td>
<td>BC: 1346 (93.6)</td>
<td>41 (87.2)</td>
<td>0.93 (0.68 to 1.27)</td>
<td>0.660</td>
</tr>
<tr>
<td>Impact on BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>BC: 102 (7.1)</td>
<td>7 (14.9)</td>
<td>2.10 (0.98 to 4.52)</td>
<td>0.057</td>
</tr>
<tr>
<td>Low</td>
<td>BC: 1338 (92.9)</td>
<td>40 (85.1)</td>
<td>0.92 (0.67 to 1.25)</td>
<td>0.582</td>
</tr>
<tr>
<td>Direction on BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behind</td>
<td>BC: 127 (8.8)</td>
<td>3 (6.4)</td>
<td>0.72 (0.23 to 2.27)</td>
<td>0.575</td>
</tr>
<tr>
<td>Front</td>
<td>BC: 486 (33.7)</td>
<td>18 (38.3)</td>
<td>1.14 (0.71 to 1.92)</td>
<td>0.589</td>
</tr>
<tr>
<td>Side</td>
<td>BC: 628 (41.5)</td>
<td>26 (55.3)</td>
<td>0.86 (0.65 to 1.42)</td>
<td>0.849</td>
</tr>
</tbody>
</table>

BC, ball carrier; BRS, body region struck.

0.18 to 1.27, p=0.156) the BC, but none of these results reached statistical significance.

Post-tackle

Table 8 shows the RRs of BC, T1 and T2 being injured as a function of the BRS in the tackle.

BCs and tacklers were all significantly more likely to sustain an injury if they were struck on the head/neck during a tackle; the majority of these injuries were concussions or cervical nerve root injuries (BC: 50.0%; T1: 71.4%; T2: 66.7%). For BC, 70.0% of the head/neck injuries were sustained during tackles from the front. Overall, however, there were only weak associations (BC: K=0.215; T1: K=0.277; T2: K=0.240) between the body region injured and the player’s BRS in the tackle (table 9).

Table 10 shows the types of injury sustained as a function of the BRS in the tackle.

Of 13 concussion and cervical nerve root injuries sustained by T1, significantly more (eight injuries, 61.5%, p<0.001) were experienced by midfield backs. Results presented in table 11 showed that there were also no associations between the locations of players’ injuries and the first body region striking the ground following the tackle (BC: K=0.015; T1: K=0.014; T2: K=0.018).

Table 12 presents the RRs of injury for midfield backs, who had the greatest propensity of all players to be injured, when tackling.

Table 13 shows the RRs associated with head/neck injuries sustained by BC and T1 in all tackles; of the eight head/neck injuries sustained by T1 following contact with the BC’s lower limb, four (50.0%) were a result of direct contact with the tackler’s head/neck.

Referees considered 2.0% (eight in 394) of collisions in general play and 3.3% (one in 30) of injuries caused by collisions to involve foul play. Tacklers were penalised in 5.9% (14 in 238) of incidents in general play where the BC was struck on the head/neck.

DISCUSSION

The κ values for the inter-rater reliability tests confirmed that values for the risk factors were, on average, all greater than 0.8.
Table 8  Post-tackle—RRs of injury for BC, T1 and T2 as a function of the player’s body region struck in the tackle

<table>
<thead>
<tr>
<th>Body region struck in tackle</th>
<th>No of events in group (%)</th>
<th>RR</th>
<th>Ratio (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC (all)</td>
<td>5948 (100)</td>
<td>129 (100)</td>
<td>2.71 (1.58 to 4.65)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Head/neck</td>
<td>238 (4.0)</td>
<td>14 (10.9)</td>
<td>1.96 (1.13 to 3.42)</td>
<td>0.036</td>
</tr>
<tr>
<td>Upper limb</td>
<td>2364 (39.7)</td>
<td>40 (31.0)</td>
<td>0.78 (0.57 to 1.07)</td>
<td>0.119</td>
</tr>
<tr>
<td>Trunk</td>
<td>2273 (38.2)</td>
<td>45 (34.9)</td>
<td>0.91 (0.68 to 1.23)</td>
<td>0.542</td>
</tr>
<tr>
<td>Lower limb</td>
<td>1073 (18.0)</td>
<td>30 (23.3)</td>
<td>1.29 (0.90 to 1.85)</td>
<td>0.171</td>
</tr>
<tr>
<td>Tackler-1 (all)</td>
<td>6082 (100)</td>
<td>83 (100)</td>
<td>22.30 (12.26 to 40.57)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Head/neck</td>
<td>64 (0.8)</td>
<td>14 (16.9)</td>
<td>0.85 (0.67 to 1.09)</td>
<td>0.194</td>
</tr>
<tr>
<td>Upper limb</td>
<td>5604 (92.1)</td>
<td>65 (78.3)</td>
<td>0.95 (0.73 to 1.24)</td>
<td>0.265</td>
</tr>
<tr>
<td>Trunk</td>
<td>357 (5.9)</td>
<td>2 (2.4)</td>
<td>1.95 (0.48 to 7.96)</td>
<td>0.347</td>
</tr>
<tr>
<td>Lower limb</td>
<td>75 (1.2)</td>
<td>2 (2.4)</td>
<td>1.95 (0.48 to 7.96)</td>
<td>0.347</td>
</tr>
<tr>
<td>Tackler-2 (all)</td>
<td>2530 (100)</td>
<td>24 (100)</td>
<td>28.75 (8.02 to 103.05)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Head/neck</td>
<td>11 (0.4)</td>
<td>3 (12.5)</td>
<td>0.95 (0.54 to 1.34)</td>
<td>0.490</td>
</tr>
<tr>
<td>Upper limb</td>
<td>2348 (92.8)</td>
<td>19 (79.2)</td>
<td>0.85 (0.54 to 1.34)</td>
<td>0.490</td>
</tr>
<tr>
<td>Trunk</td>
<td>161 (64.4)</td>
<td>0 (0)</td>
<td>0.85 (0.54 to 1.34)</td>
<td>0.490</td>
</tr>
<tr>
<td>Lower limb</td>
<td>10 (0.4)</td>
<td>2 (8.3)</td>
<td>21.08 (4.62 to 96.23)</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*Statistically significant difference (<0.01).

BC, ball carrier.

Table 9  Post-tackle—locations of injuries sustained by BC, T1 and T2 as a function of the player’s BRS during the tackle

<table>
<thead>
<tr>
<th>Location of injury, no (% injuries resulting from BRS in tackle)</th>
<th>BRS in tackle</th>
<th>All (129 (100))</th>
<th>Head/neck (14 (100))</th>
<th>Upper limb (40 (100))</th>
<th>Trunk (45 (100))</th>
<th>Lower limb (30 (100))</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC, ball carrier; BRS, body region struck.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10  Post-tackle—types of injuries sustained by BC, T1 and T2 as a function of the player’s BRS during the tackle

<table>
<thead>
<tr>
<th>Type of injury, no (percentage of injuries resulting from BRS in tackle)</th>
<th>BRS in tackle</th>
<th>All (129 (100))</th>
<th>Head/neck (14 (100))</th>
<th>Upper limb (40 (100))</th>
<th>Trunk (45 (100))</th>
<th>Lower limb (30 (100))</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC, ball carrier; BRS, body region struck; CPNS, central and peripheral nervous system.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11  Post-tackle—locations of injuries sustained by BC, T1 and T2 as a function of the BRS on the ground following the tackle

<table>
<thead>
<tr>
<th>Location of injury, no (percentage of injuries resulting from BRS on ground)</th>
<th>BRS on ground</th>
<th>All (107 (100))</th>
<th>Head/neck (25 (100))</th>
<th>Upper limb (3 (100))</th>
<th>Trunk (1 (50.0))</th>
<th>Lower limb (2 (100))</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC, ball carrier; BRS, body region struck.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12  Post-tackle—RRs of injury for midfield backs when tackling as T1

<table>
<thead>
<tr>
<th>Risk factor in tackle</th>
<th>No of events involving midfield backs</th>
<th>RR (95% CI), p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>General play</td>
<td>BC, ball carrier; BRS, body region struck.</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant difference (<0.01).

BC, ball carrier; BRS, body region struck; T1, Tacker-1.
0.40, which was regarded as the minimum acceptable level of performance for the study. Use of multiple regression analysis was considered to evaluate potential associations between tackle variables and outcomes and use of structural equation modelling for the development of a conceptual framework to explain the risks associated with the tackle. These options were discounted for a number of reasons, including the need to account for multiple outcome measures (injury incidence, frequency of occurrence: there were no specific factors that created this higher risk of injury. Collisions, on the other hand, had the greatest propensity for ball carriers and tacklers to be injured (table 14).

These results confirmed previous observations that injured players were more likely to be running just prior to their injuries. There was no evidence, however, to support previous contentions that BCs were more prone to injury if they were tackled from behind or from the front, or that the slower player going into the tackle was more likely to be injured. Arm tackles, although having a low propensity to cause injury, were responsible for most injuries, simply because of their high frequency of occurrence: there were no specific factors that created this higher risk of injury. Collisions, on the other hand, had the greatest propensity for injury for BCs; significant risk factors

---

**Table 13** Post-tackle—RRs of BC and T1 sustaining a head/neck injury

<table>
<thead>
<tr>
<th>Risk factor in tackle</th>
<th>No of events in group (%)</th>
<th>Pretackle</th>
<th>Post-tackle</th>
<th>BC (95% CI), p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BC</strong></td>
<td></td>
<td>General play</td>
<td>BC injured</td>
<td>T1 injured</td>
</tr>
<tr>
<td>Player</td>
<td></td>
<td>Back</td>
<td>3266 (54.5)</td>
<td>16 (50.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forward</td>
<td>2723 (45.5)</td>
<td>16 (50.0)</td>
</tr>
<tr>
<td>Speed into tackle</td>
<td></td>
<td>Fast</td>
<td>1260 (20.4)</td>
<td>13 (40.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slow/stationary</td>
<td>4910 (79.6)</td>
<td>19 (59.4)</td>
</tr>
<tr>
<td>BRS in tackle</td>
<td></td>
<td>Head/neck</td>
<td>238 (4.0)</td>
<td>10 (33.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper limb</td>
<td>2364 (39.7)</td>
<td>10 (33.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trunk</td>
<td>2273 (38.2)</td>
<td>6 (20.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower limb</td>
<td>1073 (18.0)</td>
<td>4 (13.3)</td>
</tr>
<tr>
<td>Tackler-1</td>
<td></td>
<td>Player</td>
<td>2769 (46.5)</td>
<td>10 (34.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speed into tackle</td>
<td>3166 (53.5)</td>
<td>19 (65.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fast</td>
<td>744 (12.1)</td>
<td>6 (18.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slow/stationary</td>
<td>5424 (87.9)</td>
<td>26 (81.3)</td>
</tr>
<tr>
<td>Impact on BC</td>
<td></td>
<td>High</td>
<td>1253 (20.3)</td>
<td>19 (59.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>4918 (79.6)</td>
<td>13 (40.6)</td>
</tr>
<tr>
<td>Direction on BC</td>
<td></td>
<td>Behind</td>
<td>833 (13.6)</td>
<td>3 (9.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Front</td>
<td>2107 (34.3)</td>
<td>15 (46.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Side</td>
<td>3200 (52.1)</td>
<td>14 (43.8)</td>
</tr>
<tr>
<td>Tackle type</td>
<td></td>
<td>Arm</td>
<td>3136 (51.6)</td>
<td>13 (41.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collision</td>
<td>394 (6.5)</td>
<td>5 (16.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jersey</td>
<td>179 (2.9)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lift</td>
<td>27 (0.4)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shoulder</td>
<td>1572 (25.9)</td>
<td>10 (32.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smother</td>
<td>735 (12.1)</td>
<td>2 (6.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anklet tap</td>
<td>30 (0.5)</td>
<td>1 (3.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Head/neck</td>
<td>46 (0.8)</td>
<td>2 (6.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper limb</td>
<td>5604 (92.1)</td>
<td>27 (90.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trunk</td>
<td>357 (5.9)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower limb</td>
<td>75 (1.2)</td>
<td>1 (3.3)</td>
</tr>
</tbody>
</table>

*Statistically significant difference (<0.01). BC, ball carrier; BRS, body region struck; T1, Tackler-1.

---

**Table 14** Summary of tackle factors significantly (p<0.01) increasing the propensity for ball carriers and tacklers to be injured

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Aspect of risk factor increasing the player’s propensity for injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretackle</td>
<td>Ball carrier Tacklers</td>
</tr>
<tr>
<td>Speed into tackle</td>
<td>High</td>
</tr>
<tr>
<td>Type</td>
<td>Collision</td>
</tr>
<tr>
<td>Body region struck</td>
<td>Head/neck</td>
</tr>
<tr>
<td>Impact force</td>
<td>High</td>
</tr>
</tbody>
</table>
for this type of event were the impact force of T1 and contact with a player's head/neck. BCs and tacklers were at a greater risk of sustaining a head/neck injury in high impact tackles and if there was head/neck contact in the tackle; tacklers also had a greater propensity to sustain head/neck injuries when using shoulder tackles. Midfield backs were the most injury-prone and were at greatest risk when tackling BCs travelling at high speeds, in high-impact tackles, when striking their head/neck in the tackle or when making contact with the BC's lower limbs.

The Laws of the Game and guidance on reducing the risks associated with tackles emphasise the importance of avoiding tackles above the line of the shoulder and head/neck contact. The challenge for BCs and tacklers to achieve this consistently is, however, complex. RugbySmart and SharkSmart injury prevention programmes comment that the best way for BCs to reduce tackle injuries is to avoid big hit tackles and tackles at speed, and to keep the head/neck in the right position. While the advice presented in these training programmes is strongly supported by the results obtained in this study, the advice is general and is not specific to each type of tackle. Additionally, it is not possible to avoid tackles at all times, as they form an integral and important aspect of rugby, in terms of stopping an opponent's forward movement and gaining ball possession. It is essential, therefore, that referees protect BCs by consistently penalising collisions and tackles above the line of the shoulder, as these events are more likely to result in injury and are specifically identified in the Laws of Rugby as foul play. It is essential, also, that research be conducted into the nature and biomechanics of high-impact tackles to develop more specific advice on how to execute and resist this type of tackle. Furthermore, injury-prevention resources should be reviewed to ensure they address all tackle types and provide advice from the BC's and tackler's perspectives.

Acknowledgements The authors would like to acknowledge the contributions of A McIntosh and T Savage (University of New South Wales) and E Crawford and N Redman (Rugby Football Union, Coaching Department) during discussions about the characterisation of tackle events. The contribution made by the medical staff at Premiership clubs in recording match injuries is also recognised.

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Competing interests None.

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Patient consent Obtained.

Provenance and peer review Not commissioned; peer reviewed.

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Injury risks associated with tackling in rugby union

Colin W Fuller, Tony Ashton, John H M Brooks, Rebecca J Cancea, John Hall and Simon P T Kemp

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