Lay of the land: narrative synthesis of tackle research in rugby union and rugby sevens

Nicholas Burger, Mike Lambert, Sharief Hendricks

ABSTRACT

Objectives The purpose of this review was to synthesise both injury prevention and performance tackle-related research to provide rugby stakeholders with information on tackle injury epidemiology, including tackle injury risk factors and performance determinants, and to discuss potential preventative measures.

Design Systematic review and narrative synthesis.

Data sources PubMed, Scopus and Web of Science.

Eligibility criteria Limited to peer-reviewed English-only publications between January 1995 and October 2018.

Results A total of 317 studies were identified, with 177 in rugby union and 13 in rugby sevens. The tackle accounted for more than 50% of all injuries in rugby union and rugby sevens, both at the professional level and at the lower levels, with the rate of tackle injuries higher at the professional level (mean 32/1000 player-hours) compared with the lower levels (mean 17/1000 player-hours). A player’s tackle actions and technical ability were identified as major risk factors for injury and a key determinant of performance.

Summary/conclusion Evidence-based education, progressive tackle technique training with a high potential to transfer and law changes have been proposed as key modifiers of player tackle actions and technical ability. Conceivably, all three modifiers working in unison (as opposed to separately) will have a higher potential at reducing tackle injury risk while enhancing performance. With the guidance of tackle injury and performance studies, as well as stakeholder engagement, experiential and explorative tackle research has the potential to inspire innovative injury prevention and performance strategies.

INTRODUCTION

The physical and dynamic nature of rugby union and rugby sevens expose players to high risk of injury. The majority of injuries in these rugby codes, at all levels, occur during the contact events: the tackle, ruck, maul, line-out and scrums. The tackle is the contact event that has the highest injury incidence (injuries per 1000 player-hours), while the ruck and scrum have the second and third highest injury incidences, respectively. Also, while the majority of spinal cord injuries occur in the scrum, the tackle has the highest incidence for the most severe injuries. During the tackle, both the player in possession of the ball (ball carrier) and the player(s) attempting to contest the ball and territory (tacklers) are at risk of injury, although the mechanisms of injury may differ. Although the tackle is a high-injury risk contest, the ability to repeatedly win the contest is also a key performance indicator, with successful teams winning more tackles.

To effectively reduce the risk of injury and optimise performance, it is recommended a sport injury prevention or sport performance process model be followed.

What is known

- The physical and dynamic nature of rugby union and rugby sevens exposes players to high risk of injury.
- The tackle is the contact event that has the highest injury incidence.
- To effectively reduce the risk of injury and optimise performance, it is recommended a sport injury prevention or sport performance process model be followed.

What this study adds

- Tackle injury rates are higher at the professional level compared with the lower levels.
- Tackle injury frequencies are similar between the ball carrier and tackler.
- A major risk factor for tackle injury and a key determinant of tackle performance is the player’s technical ability.
- A player’s technical ability can be improved through boosting coaching competencies. An example of such a coaching competency is how to monitor and progress tackle training to ensure optimum transfer to matches.
the uptake and sustainability of an injury prevention or performance initiative in the ‘real world’. The first stage proposes establishing the extent of the injury problem through injury surveillance studies. Thereafter, the aim is to understand why and how these injuries occur, that is, identifying injury risk factors (stage 2). Stage 3 seeks to develop potential preventive measures for testing in ideal or controlled conditions (stage 4). Stage 5 aims to understand the implementation context, and the final stage (stage 6) monitors the effectiveness of the preventive measure in the real world.

Owing to the high risk of injury and performance demands, the tackle has been a research focus within rugby compared with other contact events. Seemingly, each of these studies have contributed to a stage in the injury prevention or performance process models. However, these studies have not been consolidated to determine the state of tackle-related research at each stage for both injury prevention and performance. For instance, while systematic reviews on injury rates in rugby union and rugby sevens have been published to address stage 1 of injury prevention models, and despite knowing the high incidence of tackle injury, no review to date has synthesised tackle injury frequencies and rates by playing levels and competition, and by role (ball carrier or tackler). Therefore, using the first three stages of the TRIPP model as a guide, the purpose of this review was to consolidate both injury prevention and performance tackle-related research. The intention of this review was to synthesise both injury prevention and performance tackle-related research to provide rugby stakeholders with information on tackle injury epidemiology, including tackle injury risk factors and performance determinants, and to discuss measures that may improve tackle performance and reduce the risk of tackle injuries.

METHODS
A narrative synthesis format was chosen to review and synthesise the pool of literature. A narrative synthesis is an approach to the systematic review and synthesis of findings from multiple studies that relies primarily on the use of words and texts to summarise and explain the finding of the synthesis. Narrative syntheses can be used to review and assess quantitative and qualitative data and, in contrast to narrative reviews and evidence syntheses, involve a systematic and predefined search strategy with a focus on producing a more textual synthesis versus other types of systematic reviews such as quantitative meta-analyses.

Search strategy
A search was conducted for published studies that reported on tackle-specific factors in rugby union and rugby sevens (rugby league studies were included in the search but removed at the final stage of the selection process). Three electronic databases (PubMed, Scopus and Web of Science) were searched using the keyword combinations ‘rugby’ AND ‘contact’, ‘rugby’ AND ‘tackle’, and ‘rugby’ AND ‘union’ OR ‘league’ OR ‘sevens’ AND ‘injur*’.

Eligibility criteria
The search was limited to peer-reviewed English-only publications between January 1995 (the advent of professionalism in rugby union) and October 2018. Articles that involved quantitative data on rugby union or rugby sevens (including all ages and levels of play, and male and female players) were included. Only studies that included tackle-related testing protocols and match or training data (pertaining to tacklers and/or ball carriers) were included. The studies had to clearly define the tackle or ball carry as part of their analysis and not group the tackle into general contact/collision data.

Overall and/or time-loss tackle injury rates (only studies reporting number of injuries per 1000 exposure) and frequencies (percentages) were tabulated according to rugby code and level of play (tables 1–3). A time-loss injury was defined as an injury that resulted in a player being absent from normal match/training/ recreational activities for more than 24 hours or 7 days (depending on the specific study’s definition) after the incident. Medical attention injuries were injuries that required treatment from a doctor/healthcare professional but resulted in no time away from normal match/training/recreational activities. Overall injuries included both medical attention and time-loss injury events. Injury case studies specific to tackle events were also reviewed (see online supplementary appendix 1). Overall tackle numbers and rates (only studies reporting total number of tackles per match, and/or number of tackles per game or per minute) were tabulated in tables 4 and 5. Narrative literature reviews, systematic reviews, meta-analyses, editorials, journal letters, book chapters, conference proceedings, discussions and qualitative research studies were excluded from the analysis. All other quantitative study types and case studies were accepted for review.

Screening process
A five-step approach was followed to identify the final group of articles that would eventually be included in the final review (figure 1). Two authors (NB and SH) independently screened the titles using the eligibility criteria. The reliability of the authors was assessed by comparing the results of the title-screening process. Disparities in the results were discussed and resolved by the authors. NB continued the screening process of the abstracts and full-text articles. The articles were excluded at each step if they met the exclusion criteria or did not meet the inclusion criteria.

Data interpretation
Only the main findings (relating to tackle events) from each study were presented in this review. Confidence intervals (90% or 95% CIs) and standard deviations (±SDs) were provided in the tables, depending on their availability. All values and percentages were rounded off...
Table 1  Tackle-related injury frequencies and rates in professional rugby union

<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Injury definition</th>
<th>Injury frequency</th>
<th>Injury rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jakoet and Noakes145</td>
<td>1995 RWC teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>56% (29% tackled, 27% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Targett146</td>
<td>Super 12 team</td>
<td>Time-loss (&gt;2 training sessions, &gt;1 match)</td>
<td>46%</td>
<td>N/A</td>
</tr>
<tr>
<td>Doyle and George147</td>
<td>England Women’s team</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>30% tackling</td>
<td>N/A</td>
</tr>
<tr>
<td>Best et al23</td>
<td>2003 RWC teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>40% (19% tackled, 21% tackling)</td>
<td>38.9/1000 hours (18.7/1000 hours tackled [95% CI 12.6 to 24.7]; 20.2/1000 hours tackling [95% CI 13.9 to 26.5])</td>
</tr>
<tr>
<td>Brooks et al148</td>
<td>England 2003 RWC team</td>
<td>Time-loss (&gt;1 day)</td>
<td>36% (23% tackled, 13% tackling)</td>
<td>50/1000 hours (tackled only)</td>
</tr>
<tr>
<td>Holtzhausen et al149</td>
<td>Super 12 South African teams</td>
<td>Time-loss (&gt;1 day or special treatment)</td>
<td>61% (46% tackled, 15% tackling)</td>
<td>33.8/1000 hours (25.7/1000 hours tackling, 8.1/1000 hours tackling)</td>
</tr>
<tr>
<td>Fuller et al20</td>
<td>English Premiership teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>63%</td>
<td>33.9/1000 hours (95% CI 30.3 to 37.9)</td>
</tr>
<tr>
<td>Fuller et al24</td>
<td>2007 RWC teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>29.2/1000 hours (22.4/1000 hours tackled [95% CI 16.6 to 30.2]; 6.8/1000 hours tackling [95% CI 3.9 to 11.7])</td>
</tr>
<tr>
<td>Quarrie and Hopkins10</td>
<td>Professional New Zealand men’s teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>12.2/1000 hours (5.8/1000 hours tackled [90% CI 4.9 to 6.8]; 6.4/1000 hours tackling [90% CI 5.5 to 7.5])</td>
</tr>
<tr>
<td>Schick et al150</td>
<td>2006 Women’s RWC teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>63% (36% tackled, 27% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Fuller et al151</td>
<td>Super 14 teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>68% (41% tackled [95% CI 35.5 to 47.2]; 27% tackling [95% CI 21.5 to 32])</td>
<td>N/A</td>
</tr>
<tr>
<td>Fuller et al151</td>
<td>Vodacom Cup teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>64% (33% tackled [95% CI 21.3 to 44.3]; tackling 31% [95% CI 19.9 to 42.6])</td>
<td>N/A</td>
</tr>
<tr>
<td>Taylor et al27</td>
<td>2010 Women’s RWC teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>38% (33% tackled [95% CI 18.5 to 48.1]; 5% tackling [95% CI 0 to 12.1])</td>
<td>N/A</td>
</tr>
<tr>
<td>Fuller et al25</td>
<td>2011 RWC teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>44%</td>
<td>40.1/1000 hours (21.9/1000 hours tackled [95% CI 16.2 to 29.6]; 18.2/1000 hours tackling [95% CI 13.1 to 25.4])</td>
</tr>
<tr>
<td>Schwellnus et al153</td>
<td>Super Rugby South African teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>49% (23% tackled, 26% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Fuller et al26</td>
<td>2015 RWC teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>46% (25% tackled [95% CI 18.2 to 31.2]; 21% tackling [95% CI 15.0 to 27.3])</td>
<td>N/A</td>
</tr>
<tr>
<td>Williams et al152</td>
<td>English Premiership team</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>29.2/1000 hours (18.0/1000 hours tackled; 11.2/1000 tackling)</td>
</tr>
<tr>
<td>Schwellnus et al153</td>
<td>Super Rugby South African teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>54% (23% tackled, 27% tackling, 4% unspecified)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Continued
to a maximum of two decimal places where necessary. Results are organised according to the first three stages of the TRIPP model.

RESULTS

Injury epidemiology and tackle frequencies

General rugby union and sevens injury studies provided details pertaining to one or more tackle-related factors, including but not limited to limited injury rates, player injured (ie, ball carrier or tackler), injury location (eg, head/neck, lower-limb or upper-limb), injury type/diagnosis (eg, concussion, fracture or bruise/contusion), tackle direction (eg, front-on or from behind) and player running speed prior to injury.6–11 18–52 The tackle consistently accounted for more than 50% of all injuries in rugby union and rugby sevens, both at the professional level and at the lower levels. The rate of tackle injuries is higher at the professional level (mean 32/1000 player-hours) compared with the lower levels (mean 17/1000 player-hours). At all levels, the frequency of injury between the ball carrier and tackler were not largely dissimilar.

Certain studies also focused on niche areas including head injuries and concussions,31 40 53–70 spinal and neck injuries,51 58 69 71–73 shoulder injuries,34 80–88 knee and ankle injuries,89–95 and the influence of tackle technique on injuries.61 64 65 69 94–96 Overall and time-loss injury frequencies and rates for rugby union (tables 1 and 2) and sevens (table 3) were tabulated (all injury types included). Tackle-related injury case studies were also summarised for all levels of rugby union and sevens from 1995 to 2018 (see online supplementary appendix 1).

The total number of tackles per match and tackle rates (tackles per game or per minute) for all levels of play for rugby union and sevens are summarised in tables 4 and 5, respectively. Successful and unsuccessful tackles were also included.

Injury risk factors and performance determinants

In matches, proper contact technique during the tackle, for both the ball carrier and tackler, has been identified as a key injury risk factor and performance determinant.61 64 65 69 94–96 For example, ball carrier and tacklers that fail to ‘leg drive’ after contact have a higher risk of injury and a reduced chance of winning the tackle.56 94–96 In another example, ball carriers fending the tackler on contact have a reduced risk of injury and are more likely to offload or break the tackle.48 98 Not surprisingly, high, dangerous and illegal tackles are also a major risk factor for tackle injuries. A match contextual factor that has also been identified as a risk factor for injury is match quarter. Tackle injuries are reported to occur more frequently during the latter stages of matches,15 16 which are attributed to a decrease in tackle technique. The physical and physiological demands of the tackle during matches, such as tackle velocity and muscle damage, have also been reported.99–123

Players’ and coaches’ knowledge, attitudes and behaviours pertaining to the tackle have been studied, including risk factors for injury and determinants of performance, both in training and matches.68 124–130 For instance, players who rated tackle training to prevent injuries important (player attitude) and who spent more time on technique training to prevent injuries (player behaviour) reported safer behaviours for the tackle during matches. Also, coaches seem to be aware of the risk of injury in the tackle and the importance of coaching of proper technique.131 However, this positive knowledge and attitudes from the coaches did not transfer into tackle training (coach behaviour).

Studying the tackle in controlled settings

Within lab settings, the physiological and biomechanical loads of the tackle have been studied.99 101–113 These studies suggest that the movement patterns and the production of force are weaker on the non-dominant shoulder.105 117 For example, Seminati et al reported a 13% higher impact force from the non-dominant shoulder.105 117 Players seem to have poorer shoulder positional sense of their non-dominant shoulder while tackling and adopt a more passive biomechanical strategy to generate the drive needed to stop a ball carrier.132 As such, tackles on the dominant shoulder produce higher impact forces on contact, whereas the non-dominant shoulder produces force over longer durations.132 In addition, tackles on the non-dominant shoulder were characterised by less control of head movement, which had a more flexed and laterally bent position compared with tackles on the dominant shoulder.132

DISCUSSION

It is well established that a player’s tackle actions and technical ability are major risk factors for injury and key determinants of performance.51 64 65 69 94–96 The question is how can we modify player action and improve tackle technique? One answer to this question is player, coach...
Table 2  Tackle-related injury frequencies and rates in semiprofessional, amateur and youth rugby union

<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Injury definition</th>
<th>Injury frequency</th>
<th>Injury rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comstock and</td>
<td>USA women's teams</td>
<td>Overall and time-loss (&gt;7 days)</td>
<td>58% (30% tackled, 28% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Fields</td>
<td></td>
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<tr>
<td>Collins et al</td>
<td>Girls' US high school club teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>61% (29% tackled, 32% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Collins et al</td>
<td>Boys' US high school club teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>59% (31% tackled, 28% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Kerr et al</td>
<td>US collegiate teams (men)</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>48%</td>
<td>8.2/1000 hours (4.53/1000 hours tackled, 3.62/1000 hours tackling)</td>
</tr>
<tr>
<td>Kerr et al</td>
<td>US collegiate teams (women)</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>53%</td>
<td>9.1/1000 hours (5.5/1000 hours tackled; 3.6/1000 hours tackling)</td>
</tr>
<tr>
<td>Schneiders et</td>
<td>New Zealand premier amateur club teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>48% (19% tackled, 29% tackling)</td>
<td>N/A</td>
</tr>
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<td>al</td>
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<tr>
<td>Haseler et al</td>
<td>English youth community club teams (9–17 years)</td>
<td>Time-loss (&gt;1 day)</td>
<td>59%</td>
<td>14/1000 hours (95% CI 8.0 to 19.8)</td>
</tr>
<tr>
<td>Nicol et al</td>
<td>Scottish school teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>62% (40% tackled, 22% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Fuller and</td>
<td>International under-20 teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>45% (26% tackled, 19% tackling)</td>
<td>N/A</td>
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<tr>
<td>Molloy</td>
<td></td>
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<tr>
<td>Palmer-Green et</td>
<td>English Premiership youth academy teams (16–18 years)</td>
<td>Time-loss (&gt;1 day)</td>
<td>51% (30% tackled, 21% tackling)</td>
<td>21/1000 hours (12/1000 hours tackled [95% CI 8 to 17]; 9/1000 hours tackling [95% CI 5 to 13])</td>
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<tr>
<td>al</td>
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<tr>
<td>Palmer-Green et</td>
<td>English senior school teams (16–18 years)</td>
<td>Time-loss (&gt;1 day)</td>
<td>57% (32% tackled, 25% tackling)</td>
<td>18/1000 hours (10/1000 hours tackled [95% CI 7 to 13]; 8/1000 hours tackling [95% CI 5 to 11])</td>
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<tr>
<td>al</td>
<td></td>
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<tr>
<td>Roberts et al</td>
<td>English community-level teams</td>
<td>Time-loss (&gt;7 days)</td>
<td>50%</td>
<td>8.4/1000 hours (95% CI 7.8 to 9.0) (4.8/1000 hours tackled [95% CI 4.3 to 5.2]; 3.6/1000 hours tackling [95% CI 3.2 to 4.0])</td>
</tr>
<tr>
<td>Archbold et al</td>
<td>Irish grammar school teams (16.8±0.8 years)</td>
<td>Time-loss (&gt;1 day)</td>
<td>48% (20% tackled, 28% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>al</td>
<td></td>
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<tr>
<td>Swain et al</td>
<td>Australian amateur club teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>69% (34% tackled [95% CI 25.6 to 42.1]; 35% tackling [95% CI 26.4 to 42.9])</td>
<td>N/A</td>
</tr>
<tr>
<td>Burger et al</td>
<td>South African under-18 provincial Craven Week teams</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>50%</td>
<td>27/1000 hours (95% CI 21 to 33)</td>
</tr>
<tr>
<td>Burger et al</td>
<td>South African under-18 provincial Craven Week teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>11/1000 hours (95% CI 8 to 15)</td>
</tr>
<tr>
<td>Leung et al</td>
<td>Australian Associated Independent Colleges interschool competition teams: year 5 teams (9–10 year olds) to open grades (17–18 year olds)</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>55% (27% tackled, 28% tackling)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Continued
The tackle is a highly technical and physical skill and, like any skill, should be developed through training. Despite this, research comparing training and matches suggests that tackle contact preparation during training is not adequate to meet the demands of tackle contact during matches. Implementation research in sport argues that the ability to coach technique depends on how competent the coaches believe they are to do so; this is also true for coaching tackle technique. From a behaviour change perspective, to increase the likelihood of a desired behaviour requires a specific concept known as ‘boosting’. In line with these arguments, a group of rugby researchers and practitioners designed a tackle contact skill framework and training plan based on skill acquisition and skill development literature. The framework describes measurements that can be used to monitor and progress tackle training to ensure optimum transfer to matches. Although the efficacy and effectiveness of such a tackle training programme has yet to be studied, the framework and training plan serves as a starting point to design tackle training programmes and further develop tackle training concepts such as contact readiness (when introducing players to rugby), contact readiness as part of match warm-up, return to contact (for players returning from injury), contact capacity (maintaining proper technique while fatigued) and contact efficiency (highly proficient contact technique with minimal physical effort). Also, how other forms of physical preparation, for example, resistance training, influences tackle ability is yet to be investigated. Finally, most of what we know about tackle training is based on questionnaire studies; therefore, to better understand the implementation context, as well as

<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Injury definition</th>
<th>Injury frequency</th>
<th>Injury rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leung et al 132</td>
<td>Australian greater private school competition teams: under-11 teams (10–11 year olds) to open grades (17–18 year olds)</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>39%</td>
<td>N/A</td>
</tr>
<tr>
<td>Barden and Stokes 52</td>
<td>English elite under-18 schoolboy teams: AASE league matches</td>
<td>Time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>42/1000 hours (95% CI 26 to 59) (20/1000 hours tackled [95% CI 9 to 32]; 22/1000 hours tackling [95% CI 10 to 34])</td>
</tr>
<tr>
<td>Barden and Stokes 52</td>
<td>English elite under-18 schoolboy teams: general (non-AASE) matches</td>
<td>Time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>19/1000 hours (95% CI 12 to 25) (12/1000 hours tackled [95% CI 7 to 17]; 7/1000 hours tackling [95% CI 3 to 11])</td>
</tr>
<tr>
<td>Barden and Stokes 52</td>
<td>English elite under-18 schoolboy teams (AASE and non-AASE matches)</td>
<td>Time-loss (&gt;1 day)</td>
<td>55%</td>
<td>N/A</td>
</tr>
<tr>
<td>Sewry et al 160</td>
<td>South African provincial Youth Week teams: under-13, under-16 and under-18</td>
<td>Time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>11.4/1000 hours (4/1000 hours tackled [95% CI 3.2 to 4.9]; 7.4/1000 hours tackling [95% CI 6.3 to 8.5])</td>
</tr>
<tr>
<td>Sewry et al 60</td>
<td>South African Western Cape premier league under-16 school teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>N/A</td>
<td>18.3/1000 hours (11.3/1000 hours tackled [95% CI 5.2 to 17.5]; 7/1000 hours tackling [95% CI 2.1 to 11.8])</td>
</tr>
</tbody>
</table>

AASE, Achieving Academic and Sporting Excellence; N/A, not applicable.

and referee education. Using evidence from tackle injury mechanism and performance determinant studies, national injury prevention programmes such as New Zealand’s Rugby Smart and South Africa’s BokSmart programmes aim to educate rugby stakeholders on safe and effective tackle techniques. These educational tools are intended to modify player, coach and referee attitudes and behaviours, both in training and during matches. While these national injury prevention programmes have shown positive changes in player, coach and referee knowledge, this may not be enough to drive positive behaviour change. Indeed, Hendricks et al showed that even though a sample of youth coaches were aware of the high risk of injury during the tackle and the importance of proper tackle technique, this knowledge did not transfer into their actual tackle training sessions. Therefore, the next logical step is to apply the knowledge gained from tackle injury mechanism and performance determinant studies to improve tackle training.

The tackle is a highly technical and physical skill and, like any skill, should be developed through training. Despite this, research comparing training and matches suggests that tackle contact preparation during training is not adequate to meet the demands of tackle contact during matches. Implementation research in sport argues that the ability to coach technique depends on how competent the coaches believe they are to do so; this is also true for coaching tackle technique. From a behaviour change perspective, to increase the likelihood of a desired behaviour requires a specific action plan and the fostering of competencies, a concept known as ‘boosting’. In line with these arguments, a group of rugby researchers and practitioners designed a tackle contact skill framework and training plan based on skill acquisition and skill development literature. The framework describes measurements that can be used to monitor and progress tackle training to ensure optimum transfer to matches. Although the efficacy and effectiveness of such a tackle training programme has yet to be studied, the framework and training plan serves as a starting point to design tackle training programmes and further develop tackle training concepts such as contact readiness (when introducing players to rugby), contact readiness as part of match warm-up, return to contact (for players returning from injury), contact capacity (maintaining proper technique while fatigued) and contact efficiency (highly proficient contact technique with minimal physical effort). Also, how other forms of physical preparation, for example, resistance training, influences tackle ability is yet to be investigated. Finally, most of what we know about tackle training is based on questionnaire studies; therefore, to better understand the implementation context, as well as
Table 3  Tackle-related injury frequencies and rates in rugby sevens (all levels of play)

<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Injury definition</th>
<th>Injury frequency</th>
<th>Injury rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuller et al(^{61})</td>
<td>International World Sevens Series teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>52% (34% tackled, 18% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Lopez et al(^{46})</td>
<td>US amateur rugby union sevens teams (including women)</td>
<td>Overall and time-loss (&gt;1 day)</td>
<td>75% (95% CI 60 to 85)</td>
<td>40.4/1000 hours (95% CI 28.6 to 55.6)</td>
</tr>
<tr>
<td>Fuller et al(^{14})</td>
<td>International World Sevens Series teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>54% (32% tackled [95% CI 27.1 to 37.6]; 22% tackling [95% CI 17.1 to 26.3])</td>
<td>N/A</td>
</tr>
<tr>
<td>Fuller et al(^{33})</td>
<td>International World Sevens Series teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>55% (33% tackled, 22% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Ma et al(^{47})</td>
<td>US women’s rugby union sevens teams (under-19 to professional)</td>
<td>Time-loss (&gt;1 day)</td>
<td>72%±8.5% (41% tackled, 31% tackling)</td>
<td>N/A</td>
</tr>
<tr>
<td>Rizi et al(^{162})</td>
<td>Hong Kong University rugby teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>65% (29% tackled, 29% tackling, 7% tackle collision, ie, no use of arm)</td>
<td>N/A</td>
</tr>
<tr>
<td>Cruz-Ferreira et al(^{63})</td>
<td>Tier 1 and tier 2 Portuguese national senior male rugby teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>57.1% (38.1% tackled [95% CI 17.6% to 60.0%]; 19% tackling [95% CI 4.8% to 38.1%])</td>
<td>N/A</td>
</tr>
<tr>
<td>Cruz-Ferreira et al(^{63})</td>
<td>Tier 1 Portuguese national senior male rugby Sevens teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>57.2% (42.9% tackled [95% CI 15.4% to 70.0%]; 14.3% tackling [95% CI 0% to 35.7%])</td>
<td>N/A</td>
</tr>
<tr>
<td>Cruz-Ferreira et al(^{63})</td>
<td>Tier 2 Portuguese national senior male rugby Sevens teams</td>
<td>Time-loss (&gt;1 day)</td>
<td>57.2% (28.6% tackled [95% CI 0% to 66.7%]; 28.6% tackling [95% CI 0% to 66.7%])</td>
<td>N/A</td>
</tr>
</tbody>
</table>

N/A, not applicable.

barrier and facilitators to implementing a tackle training programme, coach engagement and systematic observations of tackle training sessions are required.

Another strategy to modify player tackle action during matches is through changing the laws of the game. To specifically reduce head injuries during the tackle, the sport’s governing body, World Rugby, have recently recommended stronger sanctioning of reckless and high tackles and proposed a reduction in tackle height of a legal tackle\(^{61}\) from above the line of the shoulders to above the line of the armpit. These law changes are seemingly based on the behavioural principle known as ‘nudging’, that is, changing the external environment to achieve a predicable outcome\(^{141}\). Changing tackle laws also has a more immediate effect compared with education and training programmes. With that said, the actual effect of these law changes on tackle injury risk and player tackle actions is yet to be published.

Although results from lab-based studies may have limited applicability to match situations due to its controlled nature, studying the tackle in the lab allows for experimental and exploratory study designs. Experimental and exploratory study designs may offer deeper insights into the demands and movement patterns of the tackle (eg, tackle biomechanics)\(^{165}\) as well as test the effects of different conditions (eg, physical fatigue) and interventions (video feedback)\(^{148}\) on tackle technique. Not all research on the tackle needs to have a direct application, and experimental and exploratory work is important to inspire innovative tackle injury prevention and performance strategies\(^{144}\). Having said that, findings from tackle injury and performance studies in matches, as well stakeholder engagement, should guide the questions and design of lab-based studies.

**CONCLUSION**

The purpose of this review was to synthesise both injury prevention and performance tackle-related research to offer rugby stakeholders (researchers, practitioners, policymakers and coaches) with tackle-specific injury epidemiology and frequencies, an overview of tackle injury risk factors and performance determinants, discuss measures to improve tackle performance and reduce the risk of tackle injuries. The tackle consistently accounted for more than 50% of all injuries in rugby union and rugby sevens, both at the professional level and at the lower levels, with the rate of tackling injuries higher at the professional level (mean 32/1000 player-hours) compared with the lower levels (mean 17/1000 player-hours). Also, the frequencies of injury between the ball carrier and tackler were not largely dissimilar; A player’s tackle technique and technical ability has been identified as a major risk factor for injury and a key determinant of performance. Evidence-based education has been used, and progressive tackle technique training with a high potential to transfer and law changes have been
<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Rate definition</th>
<th>Tackle rate</th>
</tr>
</thead>
</table>
| Duthie et al<sup>164</sup> | Super 12 teams             | Tackling/game                          | Front-row forwards: 10±8  
Back-row forwards: 13±5  
Inside backs: 11±6  
Outside backs: 7±4 |
| Deutsch et al<sup>165</sup> | Super 12 team              | Tackles (tackling and tackled)/game    | Front-row forwards: 9.5±3  
Back-row forwards: 23±6  
Inside backs: 20±4.5  
Outside backs: 11±6.5 |
| Eaton and George<sup>166</sup> | English Premiership team   | a) Tackling/game                        | Props: 8±4<sup>a</sup>, 5±3<sup>b</sup>  
Hooker: 8±4<sup>a</sup>, 7±4<sup>b</sup>  
Lock forwards: 11±3,<sup>a</sup> 4±2<sup>b</sup>  
Loose forwards: 13±6,<sup>a</sup> 8±5<sup>b</sup>  
Scrum halves: 11±4,<sup>a</sup> 9±4<sup>b</sup>  
Inside backs: 9±4,<sup>a</sup> 5±3<sup>b</sup>  
Outside backs: 6±3,<sup>a</sup> 5±3<sup>b</sup> |
| Eaton and George<sup>166</sup> | English Premiership team   | b) Tackled/game                         |                                                                 |
| Fuller et al<sup>20</sup>    | English Premiership teams  | Total match tackles (tackling and tackled) | 221 (95% CI 215.9 to 226.2) |
| Quarrie and Hopkins<sup>167</sup> | Bledisloe Cup teams        | Total match tackles (tackling and tackled) | 1995: 160±32  
2004: 270±25 |
| Roberts et al<sup>168</sup>   | English Premiership team   | Tackling/game                           | Tight forwards: 12±3  
Loose forwards 16±4  
Inside backs: 13±3  
Outside backs: 8±2 |
| Smart et al<sup>99</sup> | New Zealand National Provincial Championship team | a) Tackling/game                        | Forwards: 13.6±7.5,<sup>a</sup> 3.2±2.4<sup>b</sup>  
Backs: 6.5±4.7,<sup>a</sup> 0.7±0.9<sup>b</sup> |
| Smart et al<sup>99</sup> | New Zealand National Provincial Championship team | b) Tackled/game                         |                                                                 |
| Austin et al<sup>169</sup> | Super 14 team              | Tackles (tackling and tackled)/game     | Front-row forwards: 20±4  
Back-row forwards: 19±4  
Inside backs: 25±13  
Outside backs: 20±7 |
| Coughlan et al<sup>170</sup> | International players (one forward and back) | a) Tackling/game                        | Forward: 10,<sup>a</sup> 5<sup>b</sup>  
Back: 12,<sup>a</sup> 4<sup>b</sup> |
| van Rooyen<sup>170</sup> | International teams        | Total match tackles (tackling and tackled) | Six Nations: 165±28  
Tri Nations:141±24  
2011 Rugby World Cup:156±47 |
| Hendricks et al<sup>171</sup> | Super 14 teams             | Total match tackles (tackling and tackled) | 114±20 |
| Villarejo et al<sup>172</sup> | 2007 RWC teams             | Tackling/game                           | Front-row forwards: 10.04  
Lock forwards: 10.94  
Back-row forwards: 14.25  
Scrum halves: 12.48  
Inside backs: 10.46  
Outside backs: 5.9 |
| Hendricks et al<sup>168</sup> | Super 14 teams             | Total match tackles (tackling and tackled) | 116±20 |
| Jones et al<sup>101</sup>  | European Cup team          | a) Tackling/game                        | Forwards: 5±3,<sup>a</sup> 5±2<sup>b</sup>  
Backs: 4±3,<sup>a</sup> 5±3<sup>b</sup> |
|                          |                             | b) Tackled/game                         |                                                                 |
Table 4  Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Rate definition</th>
<th>Tackle rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>van Rooyen et al173</td>
<td>Six Nations team</td>
<td>Total match tackles (tackling and tackled)</td>
<td>191±32</td>
</tr>
</tbody>
</table>
| Lindsay et al174   | Super 15 team                   | c) Tackling/minute                                    | Front-row forwards: 0.14±0.07, c 0.06±0.05d  
|                  |                                  | d) Tackled/minute                                     | Lock forwards: 0.16±0.09, c 0.1±0.02d  
|                  |                                  |                                                     | Loose forwards: 0.17±0.09, c 0.09±0.06d  
|                  |                                  |                                                     | Inside backs: 0.14±0.12, c 0.11±0.07d  
|                  |                                  |                                                     | Outside backs: 0.07±0.07, c 0.12±0.06d |
| Roberts et al16    | Amateur English community-level teams | Total match tackles (tackling and tackled)            | 140.9 (95%CI 136.7 to 145.2) |
| Villarejo et al175 | 2011 RWC teams                  | Tackling/game                                         | Front-row forwards: 9.96  
|                  |                                  |                                                     | Lock forwards: 10.9  
|                  |                                  |                                                     | Back-row forwards: 14.36  
|                  |                                  |                                                     | Scrum halves: 12.44  
|                  |                                  |                                                     | Inside backs: 10.35  
|                  |                                  |                                                     | Outside backs: 5.95  |
| Brown et al176     | South African under-18 provincial Craven Week teams | Total match tackles (tackling and tackled)            | 123±17          |
| Hendricks et al177 | Six Nations teams               | Total match tackles (tackling and tackled)            | 175±21          |
| Hendricks et al177 | Rugby Championship teams        | Total match tackles (tackling and tackled)            | 154±36          |

a, tackling/game; b, tackled/game; c, tackling/minute; d, tackled/minute; RWC, Rugby World Cup.

proposed, as key modifiers of player tackle actions and technical ability. Conceivably, all three modifiers working in unison (as oppose to separately) will have a higher potential at reducing tackle injury risk while enhancing performance. With the guidance of tackle injury and performance studies, as well as stakeholder engagement, experiential and explorative tackle research also has potential to inspire innovative tackle injury prevention and performance strategies.

Twitter Nicholas Burger @it_is_burger, Mike Lambert @MikeLambert 01 and Sharief Hendricks @Sharief_H

Contributors NB conducted the search and review, NB and SH cowrote the first draft, and all authors provided input to the final version.

Table 5  Tackle numbers and rates in rugby sevens (all levels of play).

<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Rate definition</th>
<th>Tackle rate</th>
</tr>
</thead>
</table>
| Suarez-Arrones et al177 | Professional Spanish League team               | Tackles (tackling and tackled)/game                  | Forwards: 7.4±1.8 (first half: 3.3±1.3, second half: 4.1±1.8)  
|                  |                                  |                                                     | Backs: 4.1±2.4 (first half: 2.3±1.8, second half: 1.9±1.4)  |
| Ross et al178    | New Zealand provincial rugby sevens championship teams | Tackling/minute                                      | 0.19±0.13       |
| Ross et al178    | International Sevens World Series team            | Tackling/minute                                      | 0.2±0.15        |
| Ross et al179    | International Sevens World Series team            | a) Tackling/game                                     | Forwards: 2.68±2.59, a 1.59±2.24b  
|                  |                                  | b) Tackled/game                                      | Backs: 2.41±2.52, a 1.79±2.85b   |

a, tackling/game; b, tackled/game.
REFERENCES


