Physical Therapy in Sport 38 (2019) 170–178

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Literature Review

Injury surveillance in school Rugby: A systematic review of injury epidemiology & surveillance practices

Therese M. Leahy [a, *], Ian C. Kenny [a, b], Mark J. Campbell [a, c], Giles D. Warrington [a, b], Roisin Cahalan [b, d], Andrew J. Harrison [a], Mark Lyons [a], Liam G. Glynn [e], Thomas M. Comyns [a, b]

[a] Department of Physical Education and Sport Sciences, University of Limerick, Limerick, Ireland
[b] Health Research Institute, University of Limerick, Limerick, Ireland
[c] Lero, The Irish Software Research Centre, University of Limerick, Limerick, Ireland
[d] School of Allied Health, University of Limerick, Limerick, Ireland
[e] Graduate Entry Medical School, University of Limerick, Limerick, Ireland

ARTICLE INFO

Article history:
Received 12 March 2019
Received in revised form
22 May 2019
Accepted 23 May 2019

1. Introduction

Rugby Union (RU) is regarded as one of the world's most popular sports and continues to grow with participation figures achieving 9.1 million players worldwide (World Rugby, 2019). In 2017, over two million children participated in World Rugby's (WR) “Get into Rugby” initiative (World Rugby, 2019). School RU in particular, has increased in popularity and professionalism and these “feeder teams” have played an integral role in the development of the game (Irish Rugby Football Union, 2012).

Recently, injury risk in school RU has come under scrutiny and tackle exposure has been questioned (Carter, 2015; SportCIC Open, 2016; Pollock, 2017; Pollock, White, & Kirkwood, 2017). It has been argued that school-age related characteristics such as body composition, muscle growth, strength, motor skills, flexibility, bone structure and psychological maturity may affect the musculoskeletal injury risk for school players (Halstead & Walter, 2010; Patel, Yamasaki, & Brown, 2017). Countries with substantial injury surveillance systems such as New Zealand (Accident Compensation Cor, 2018) have already implemented injury preventive change; for example, in some parts of the country children are grouped by mass rather than age (McCoy, Piggot, Macafee, & Adair, 1984).

Evaluating injury risk in school RU highlights important implications for child safety, given that children are more susceptible to injuries such as concussion (Halstead & Walter, 2010). The high injury incidence reported in the professional game (81/1000 h) and the identification of the tackle as the most dangerous phase of play (Williams et al., 2013) may be attributing to concerns raised in a recent editorial in The British Journal of Sports Medicine (BJSM), calling for a tackle ban in school Rugby (Pollock, 2017; Pollock et al., 2017). There is an absence of any systematic review of the current medical and scientific literature, evaluating injury incidence in school RU specifically. Reviews evaluating injury incidence in youth Rugby describe players aged 6–21 years across a range of Rugby settings and have reported lower incidence rates of 12–22/1000 h (Bleakley, Tully M Fau - O'Connor, & O'Connor, 2011) and 26.7/1000 h (Freitag, Kirkwood, Scharer, Ofori-Asenso, & Pollock, 2015) in comparison to the professional (81/1000 h) (Williams et al., 2013) and the amateur (46/1000 h) (Yeomans et al., 2018) codes of the game. Large discrepancies in reported incidence rates have been demonstrated in youth Rugby with incidence rates ranging from 3.7 to 217.9/1000 h (Bleakley et al., 2011; Freitag et al., 2015; McIntosh, 2005). It should be noted that these studies demonstrated notable differences in player age, sex, injury definition, Rugby codes and discipline (Bleakley et al., 2011; Freitag et al., 2015; McIntosh, 2005). These methodological inconsistencies create considerable difficulties when attempting to extrapolate and evaluate data specific to individual youth groups such as school, club and academy teams. It has been previously demonstrated that injury risk increases with age (Haseler, Carmont, & England, 2010), therefore pooled injury incidence values must be interpreted with caution, as individual group differences may not be clear. It also further emphasises the importance of cohort specific standardised surveillance practices as recommended by WR (Fuller et al., 2007).

A critical review of the existing literature is therefore crucial to establish injury epidemiology and aetiology, to improve the quality and impact of future injury surveillance studies. Differences in

* Corresponding author.
E-mail address: therese.leahy@ul.ie (T.M. Leahy).

https://doi.org/10.1016/j.ptsp.2019.05.005

injury incidence are evident between the professional and amateur codes of the game (Williams et al., 2013; Yeomans et al., 2018). Furthermore, differences have also been demonstrated between schools, clubs and academies; Palmer-Green et al. (Palmer-Green et al., 2013) reported a larger incidence rate of 47/1000 h for academy players in comparison to 35/1000 h for school players. However, the academy players were significantly taller ($P = 0.02$) and heavier ($P = 0.01$) than the school players and considered of a higher skill proficiency. Similar discrepancies, this time in skill level were demonstrated by Barden and Stokes (Barden & Stokes, 2018) where the tackle injury rate was more than double for the elite school league in comparison to the non-elite school league (Barden & Stokes, 2018). Although there are limited data on body mass trends in school RU players, research suggests that body mass has significantly increased in the professional game since 1995, and this increase is attributed to the development in professionalism and level of play (Hill et al., 2018).

Although concerns expressed over the safety of school RU players have merit, currently the true injury risk is unclear (Tucker, Raftery, & Verhagen, 2016). WR (Fuller et al., 2007) published an injury consensus guideline in 2007 in an attempt to improve the quality of injury surveillance research. These data have important implications for WR who identified "player welfare" to be an integral part of their 2016–2020 strategic plan with a key emphasis on injury surveillance (World Rugby, 2016–2020). Evaluating injury risk for school Rugby is fundamental for schools, coaching and medical staff in terms of injury prevention, education and player safety. van Mechelen (van Mechelen, Hlobil, & Kemper, 1992) acknowledged that to effectively inform risk management and identify appropriate interventions, injury surveillance must first be undertaken, as recognised by the Translating Research into Practice Model (TRIPP) (Finch, 2006). Modifiable risk factors identified by injury surveillance data may then be addressed through targeted interventions such as education and injury prevention programmes.

The purpose of this review therefore is to address the current gaps in the existing literature by providing an up to date evaluation of injury incidence in schools Rugby.

The objectives of this review were:

1. To identify, compare and synthesise the epidemiological research on injury incidence in school Rugby Union.
2. To critically appraise the injury surveillance procedures and methods used in these studies, establish the potential for error in injury data and to inform the future development of injury surveillance systems for this cohort.

2. Methods

A systematic review was conducted while adhering to the Preferred Reporting Guidelines for Systematic Reviews (PRISMA) (Moher D, Tetzlaff, & Altman, 2009) to determine injury incidence in school RU.

During September and October 2018, a comprehensive literature search was undertaken of the following databases, "PubMed", "Scopus", "SportsDiscuss" (EBSCO) and "Google Scholar" between the years January 1996 to October 2018. The search strategy consisted of the following key words combined using Boolean operators; "Rugby" OR "Rugby UNION" AND ""YOUTH" OR "ADOLESCENT" OR "SCHOOL" OR "STUDENT" OR "CHILD" AND "INJUR*". The search was supplemented with a manual search of bibliographies and reference lists of injury surveillance reviews and articles. The search was limited to publications in the English language.

Types of Studies: Prospective cohort studies of at least one season duration were included. Retrospective cohort studies were excluded except those in which the injury surveillance data were collected on a prospective basis and accessed retrospectively by the author. Systematic reviews and editorials were excluded to reduce recall bias.

Participants: Inclusion was limited to male RU players participating in school Rugby competitions, aged 9–19 years inclusive. This age range was chosen so that studies reporting injury incidence figures for middle/secondary school players were captured. Study selection was limited to male school RU players only, in an attempt to limit parameters in body mass, level of competition and skill proficiency. The inclusion of female RU players would make comparison capabilities difficult and influence overall injury rates. Mixed Rugby code and mixed sport studies not reporting individual injury incidence data for school RU were excluded. Studies reporting data for mixed sexes were included where it was possible to extract the male only data.

Studies reporting injury incidence data for schoolboy RU over the minimum period of one season were included. Data relating to severity and nature of injuries were also included if available. Studies reporting injury incidence per 1000 player hours or where this could be calculated were included. Studies focussing on a particular injury type without reporting overall match injury incidence were excluded. Injury was defined as per WR's consensus guidelines where; "Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a Rugby match or Rugby training, irrespective of the need for medical attention or time loss from Rugby activities" (Fuller et al., 2007); p 193). Provided an injury was described as per the consensus guidelines, no restriction was placed on variation of injury definitions, methods of reporting, duration of follow up and verification of injury. Studies without full text availability were excluded.

The initial database search was completed by the primary researcher (TL). All possible studies identified by the initial search were independently assessed at abstract stage by TL and a second reviewer (TC) against the inclusion and exclusion criteria (Fig. 1). In cases of uncertainty, the full-text was retrieved, and a third reviewer (IK) mediated. Full-text articles were retrieved for all identified studies and were confirmed against the inclusion/exclusion criteria. The final selection of studies was collated using a MS Excel sheet and key characteristics were extracted and organised under key headings for evaluation and assessment (Table 1).

3. Results

Seven articles were identified that met the inclusion/exclusion criteria and are displayed in Table 1.

3.1. Injury incidence

Overall injury incidence rates reported across the seven studies ranged from 23.7 to 129.8/1000 h for players aged 9–18 years (Archbold et al., 2017; Barden & Stokes, 2018; Durie & Munroe, 2000; Junge et al., 2004; Leung et al., 2017a, 2017b; Palmer-Green et al., 2013). Injury incidence rates for injuries >24 h' time loss ranged from 28.3 to 35/1000 h (aged 14–18 years) excluding the "Academic and Sporting Excellence league" (AASE) data from Barden and Stokes (77/1000 h) (Archbold et al., 2017; Barden & Stokes, 2018; Junge et al., 2004; Palmer-Green et al., 2013). Studies utilising WR's medical attention definition reported injury incidence rates of 23.7/1000h (Leung et al., 2017a) and 31.8/1000h (Leung et al., 2017b) for players aged 9–18 years and 11–18 years respectively.

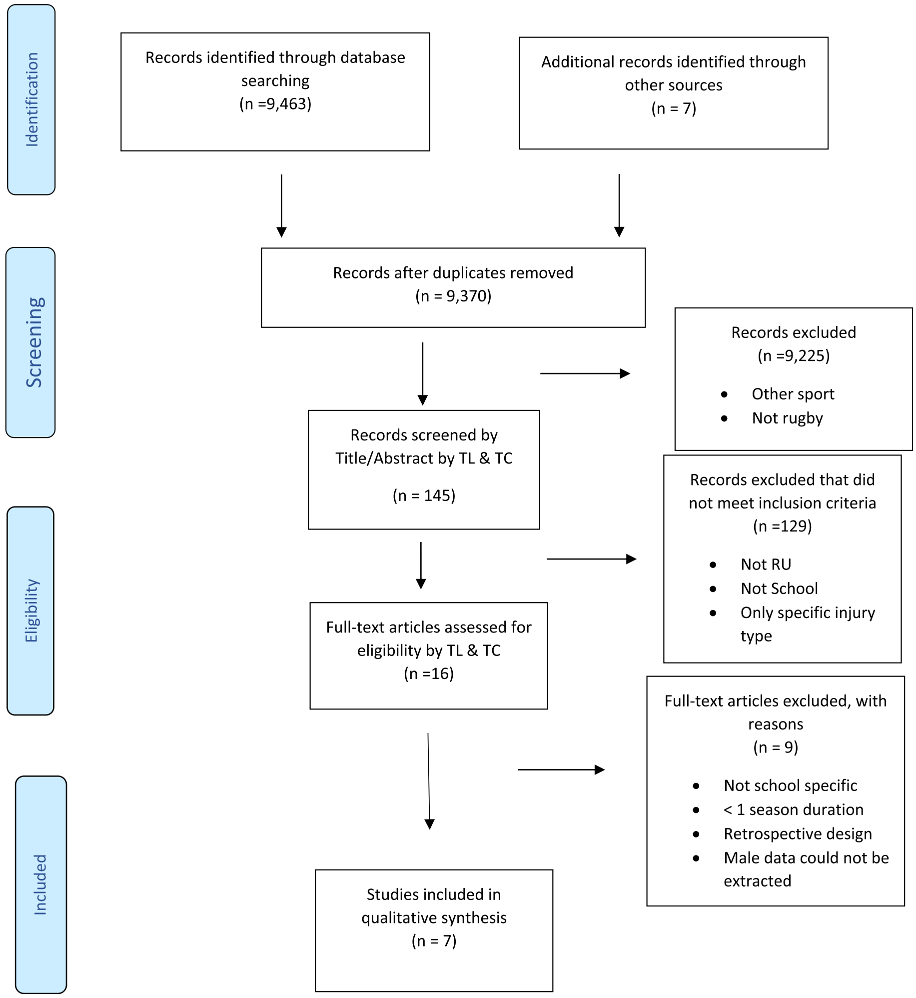

Fig. 1. Identification and selection of studies (PRISMA).

The highest incidence of 129.8/1000 h was reported by Junge et al. (Junge et al., 2004), for all injuries irrespective of medical attention or time loss (14–18 years) whilst Durie and Munroe (Durie & Munroe, 2000) reported an overall incidence rate of 27.5/1000 h using a modified medical attention injury definition (U13s-U18). A significant linear increase trend in injury incidence between age groups was also reported by Durie and Munroe (Durie & Munroe, 2000) (chi-squared = 10.4 on 1df, $p = 0.0013$). Barden and Stokes (Barden & Stokes, 2018) reported separate injury incidence figures for "AASE" and "non-AASE" teams with reported incidence rates of 77/1000 h and 34/1000 h respectively. The "non-AASE" group referred to a lower standard competition or friendly matches.

3.2. Definition of injury

Three studies adhered to WR's time loss >24 h injury definition (Archbold et al., 2017; Barden & Stokes, 2018; Palmer-Green et al., 2013) whilst two utilised WR's medical attention definition (Leung et al., 2017a, 2017b). One study adopted a modified medical attention definition where all physical complaints sustained during a match or training were referred to a weekly clinic for recording (Durie & Munroe, 2000). The remaining study recorded all injuries irrespective of medical attention or time loss (Junge et al., 2004) but also reported data for injuries resulting in absence >1day.

3.3. Severity of injury

Injury severity data are presented in Table 2. Five of the seven studies reported injury severity data (Archbold et al., 2017; Barden & Stokes, 2018; Durie & Munroe, 2000; Junge et al., 2004; Palmer-Green et al., 2013) with one study reporting (Archbold et al., 2017) as per the WR consensus (Fuller et al., 2007) classification, where injuries are grouped as slight (0–1 days), minimal (2–3 days), mild (4–7 days), moderate (8–28 days), severe (>28 days). Durie and Munroe (Durie & Munroe, 2000) and Junge et al. (Junge et al., 2004) self-classified injury severity using similar time loss parameters to the WR Consensus (Fuller et al., 2007), categorising into minor, moderate and severe injuries. Two studies reported overall mean number of days' time loss but did not classify severity individually (Barden & Stokes, 2018; Palmer-Green et al., 2013) whilst the remaining two studies (Leung et al., 2017a, 2017b) did not report severity data. Injury severity data are reported for match injuries only with the exception of one study (Junge et al., 2004) which also included training injuries.

3.4. Classification of injury

Data on injury classification and distribution where available were extracted and analysed as a percentage of overall injury incidence. Original raw data were requested where only incidence

Table 1
Characteristics of study selection.

Reference	Injury Definition	Injury Recorder	Injury Severity	Recurrent Injuries	No. of Participants	**Age (years)**	Duration	Match Incidence	Country
Durie and Munroe. (Durie & Munroe, 2000)	"Any physical complaint sustained during training/ match or reported afterwards was recorded at weekly injury clinic".	Author assessed players weekly injury clinic	Minor <7 days, moderate 1–3 weeks, severe > 3 weeks	No	442	13–18	1 season	27.5/1000 h (overall) 1st XV 65.8/1000hrs 2nd XV 35/1000hrs 3rd XV 28/1000hrs 4th XV 35.6/1000hrs 5th XV 25.6/1000hrs	New Zealand
Junge et al. (Junge, Cheung, Edwards, & Dvorak, 2004)	"Any complaint or injury that occurred in practice/match irrespective of time loss"	Independent physician visited weekly	Time loss days as per NAIRS (National Injury Registration System)	Yes	123 (RU group)	14–18	1 season	129.8/1000hrs for (all injuries), 28.3/1000hrs (time loss >1 day)	New Zealand
Palmer-Green et al. (Palmer-Green et al., 2013)	"Any injury resulting in time loss >24hrs" (WR consensus)	Medic/nurse/ physiotherapist	As per World Rugby consensus	Yes	222 (school's group)	16–18	2 seasons	35/1000hrs	England
Leung et al. (Leung et al., 2017a)	"Any physical complaint that required medical attention" (WR consensus)	Designated first aid provider	Not reported	No	3585	9–18	1 season	23.7/1000hrs (9–18yrs) 14.8/1000hrs (U18) 34.9/1000hrs (U16) 35.9/1000hrs (U15) 49.2/1000hrs (U14) 9.7/1000hrs (U13) 9.1/1000hrs (U12) 12.3/1000hrs (U11) 15.5/1000hrs (U10)	Australia
Leung et al. (Leung, Franettovich, Melinda, & Hides, 2017b)	"Any physical complaint that required medical attention" (WR consensus)	Physiotherapists/ sports trainers	Not reported	Yes	480	10–18	1 season	31.8/1000hrs (10–18yrs) 56.2/1000hrs (U18) 45.9/1000hrs (U16) 23.3/1000hrs (U15) 33.5/1000hrs (U14) 22.7/1000hrs (U13) 16.7/1000hrs (U12) 21.8/1000hrs (U11)	Australia
Archbold HA et al. (Archbold et al., 2017)	"Any injury resulting in time loss >24hrs" (WR consensus)	Data champion (qualification varied from HCP to coach)	As per World Rugby consensus	No	825	mean 16.8 ± 0.8 (range not reported)	1 season	29.06/1000hrs	Northern Ireland
Barden and Stokes (Barden & Stokes, 2018)	"Any injury resulting in time loss >24hrs" (WR consensus)	Medical team at match or follow up in clinic	As per World Rugby Consensus	No	132	mean 17.5 ± 0.6 (range not reported)	3 seasons	77/1000hrs for elite (elite Academic and Sporting Excellence (AASE) School league competition) 34/1000hrs for non-elite (regular school league competition non-AASE)	England

Table 2
Classification of injury severity data.

Reference:	Minor	Mild	Moderate	Severe	Overall Mean [Median] days' time loss
Durie and Munroe (Durie & Munroe, 2000)	<7 days: n = 136 (74%)	*N/A*	1–3 weeks: n = 59 (22%)	>3 weeks: n = 12 (%4)	*N/A*
Junge et al. (Junge et al., 2004)[a]	<1day n = 269 (79.1%)	1–7 days: n = 37 (10.9%) or 5.3/1000hrs	8–21days: n = 26 (7.6%) or 3.78/1000hrs	>21 days: n = 8 (2.4%) or 1.16/1000hrs	*N/A*
Palmer-Green et al. (Palmer-Green et al., 2013)	*N/A*	*Not Reported*	*Not Reported*	*Not Reported*	30 days [13]
Leung et al. (Leung et al., 2017a)	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Leung et al. (Leung et al., 2017b)	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Archbold et al. (Archbold et al., 2017)	N/A	<7 days: n = 43 (10.1%)	8–28 days: n = 173 (40.8%)	>28 days: n = 208 (49.1%)	23.8 [23]
Barden and Stokes (Barden & Stokes, 2018)	N/A N/A	N/A N/A	N/A N/A	N/A N/A	20 days 19 days

[a] Inclusive of training injuries.

per 1000 h was reported (Barden & Stokes, 2018). One study included training injuries in injury classification analysis (Junge et al., 2004). Table 3 presents injuries by type as a percentage of overall injury incidence.

Ligament/joint sprains accounted for the most common injury type with an accumulative mean occurrence of 33%, followed by muscle/tendon strains (22.8%), contusions/lacerations (16.4%) and fracture/bony injuries (6%) for 24hr time loss injuries (Archbold et al., 2017; Barden & Stokes, 2018; Palmer-Green et al., 2013). A higher proportion of muscle/tendon injuries (36.2%) and a lower proportion of ligament/joint sprain injuries (17.1%) were documented for an "all-inclusive injury definition irrespective of time loss" for match and training injuries (14–18 years) (Junge et al., 2004). Fracture/bony injury incidence was relatively low throughout the studies and remained under 13.6% (Leung et al., 2017a).

Concussion percentage data were reported in five studies and occurrences ranged from 1.5 to 19% of all injuries (Archbold et al., 2017; Durie & Munroe, 2000; Junge et al., 2004; Leung et al., 2017a, 2017b). Three studies reported concussion by exposure with rates ranging from 4 to 20/1000 h (Archbold et al., 2017; Barden & Stokes, 2018; Leung et al., 2017b).

3.5. Location of injury

Data on injury distribution by body region were reported by all studies (Table 4). Lower limb injuries were the most common, ranging from 23.8% to 52.6% with an overall mean occurrence of 41% for time loss injuries (Archbold et al., 2017; Barden & Stokes, 2018; Palmer-Green et al., 2013). Head/neck injuries ranged from 8.9% (Durie & Munroe, 2000) to 41.3% (Leung et al., 2017a) with an overall mean occurrence of 23% for time loss injuries (Archbold et al., 2017; Barden & Stokes, 2018; Palmer-Green et al., 2013). Interestingly, studies using a more inclusive injury definition reported the two lowest head/neck injury rates of 8.9% (Durie & Munroe, 2000) and 15.9% (Junge et al., 2004) in contrast to the 41.3% reported by Leung et al. (Leung et al., 2017a) using the WR medical attention definition. Barden and Stokes (Barden & Stokes, 2018) reported approximately double the head/neck injury incidence for their AASE group in comparison to their non-AASE group.

3.6. Mechanism of injury

Six of the seven studies classified injury data by phase of play (Palmer-Green et al., 2013; Barden & Stokes, 2018; Durie & Munroe,

Table 3
Injury classification by nature.

Injury Type	Durie and Munroe (Durie & Munroe, 2000)	Junge et al. (Junge et al., 2004)[a]	Palmer-Green et al. (Palmer-Green et al., 2013)[b]	Leung et al. (Leung et al., 2017a)[c]	Leung et al. (Leung et al., 2017b)[c]	Archbold et al. (Archbold et al., 2017)[b]	Barden and Stokes (Barden & Stokes, 2018)[b]
Ligament/Joint Sprain	35.6%	17.1%	39.0%	23.8%	33.8%	31.2%	28.3% (AASE) 33.3% (non-AASE)
Muscle/Tendon	12.6%[e]	36.2%	24.0%	12.0%	10%	17.4%	21.7% (AASE) 28.1% (non-AASE)
Fracture/Bony	7%[d]	4.1%	8.0%	13.6%	10%	8.9%	0% (AASE) 7% (non-AASE)
Central Nervous System/Peripheral Nervous System (CNS/PNS)	n/a	n/a	9.0%[f]	n/a	n/a	n/a	30.4%[g] (AASE) 12.3%[g] (non-AASE)
Contusion/Laceration	28.1%[h]	21.5%	18.0%	20.8%	26.3%	8.7%	19.6% (AASE) 19.3% (non-AASE)
Dislocation	1.1%	4.7%	n/a	n/a	n/a	2.8%	n/a
Concussion	1.5%	2.9%	n/a	18.4%	18.8%	19%	n/a

Note.
[a] Inclusive of training injuries.
[b] WR 24hr time loss injury definition.
[c] WR medical attention definition.
[d] Excluding overuse apophyseal injuries.
[e] Inclusive of bony bruising.
[f] Not specified if inclusive of concussion injuries.
[g] Inclusive of concussion injuries.
[h] Muscle contusion only, exlc. bony bruising.

Table 4
Injuries by location as a percentage of total injuries.

Injury Location	Durie and Munroe (Durie & Munroe, 2000)	Junge et al. (Junge et al., 2004)[a]	Palmer-Green et al. (Palmer-Green et al., 2013)[b]	Leung et al. (Leung et al., 2017a)[c]	Leung et al. (Leung et al., 2017b)[c]	Archbold et al. (Archbold et al., 2017)[b]	Barden and Stokes (Barden & Stokes, 2018)[b]
Head/Neck[d]	8.9%	15.9%	17.8%	41.3%	32.5%	26.7%	32.6% (AASE) 15.8% (non-AASE)
Upper Limb[e]	25.9%	32.4%	24.4%	26.8%	28.8%	24.2%	32.6% (AASE) 26.3% (non-AASE)
Lower Limb[f]	37.8%	44.7%	47.4%	23.8%	31.4%	40.2%	23.9% (AASE) 52.6% (non-AASE)
Trunk/Torso	9.6%	7%	10.4%	7.8%	7.5%	8.3%[g]	10.9% (AASE) 5.3% (non-AASE)

Note.
[a] Inclusive of training injuries.
[b] WR 24hr time loss injury definition.
[c] WR medical attention definition.
[d] Includes face.
[e] Includes shoulder, arm, wrist, hand.
[f] Includes hip, pelvis, thigh, knee, lower leg, foot.
[g] Includes lower back, abdomen, chest wall, thoracic spine.

2000; Leung et al., 2017a, 2017b; Archbold et al., 2017) (Table 5). The remaining study did not provide positional data but did report overall injury percentages for contact and non-contact injuries (Junge et al., 2004). For the majority of studies, the tackle represented the most dangerous phase of play with overall mean occurrence for “tackling” at 24.7% and “being tackled” at 27.2% (Archbold et al., 2017; Barden & Stokes, 2018; Leung et al., 2017a; Palmer-Green et al., 2013). One study presented the “ruck/maul” as the most dangerous phase of play with an injury occurrence of 31.5% in contrast to 22% for “being tackled” (modified medical attention injury definition) (Durie & Munroe, 2000).

3.7. Methodological design

Six of the seven studies used a prospective cohort or longitudinal design (Archbold et al., 2017; Barden & Stokes, 2018; Durie & Munroe, 2000; Junge et al., 2004; Leung et al., 2017b; Palmer-Green et al., 2013) and one used a retrospective cohort design in which data were collected prospectively but accessed by the author for analysis (Barden & Stokes, 2018). All studies ranged in duration from one to three seasons and investigated multiple teams. Three studies consistently used a medical professional (nurse/medic/physiotherapist) for recording injury data (Barden & Stokes, 2018; Junge et al., 2004; Palmer-Green et al., 2013); one study self-assessed the injuries at a weekly clinic (Durie & Munroe, 2000), three studies used either a designated first aid provider (Leung et al., 2017a), a physiotherapist/athletic trainer (Leung et al., 2017b) or a data champion (Archbold et al., 2017) in which the qualification varied from a ‘health care professional’ to a coach. Three studies solely investigated injury incidence in senior school teams (16–18 years) (Archbold et al., 2017; Barden & Stokes, 2018; Palmer-Green et al., 2013) whilst the remaining four studies investigated school teams across a multitude of ages (9–18 years) (Durie & Munroe, 2000; Junge et al., 2004; Leung et al., 2017a,

Table 5
Percentage of injury occurrence according to phase of play.

Position of Play	Durie and Munroe (Durie & Munroe, 2000)	Junge et al. (Junge et al., 2004)	Palmer-Green et al. (Palmer-Green et al., 2013)[a]	Leung et al. (Leung et al., 2017a)[b]	Leung et al. (Leung et al., 2017b)[b,c]	Archbold et al. (Archbold et al., 2017)[a]	Barden and Stokes (Barden & Stokes, 2018)[a]
Tackling	18.5%	n/a	25%	28%	n/a	27.5%	27.7% (AASE) 21.4% (non-AASE)
Being Tackled	22%	n/a	32%	27.4%	n/a	20.4%	25.5% (AASE) 35.7% (non-AASE)
Total Tackle	40.5%	n/a	57%	55.4%	32%	47.9%	53.2% (AASE) 57.1% (non-AASE)
Scrum	13.7%	n/a	7%	0.9%	7%	1.6%	2.1% (AASE) 0% (non- AASE)
Collision	n/a	n/a	4%	21.7%	11%	15.5%	6.4% (AASE) 8.9% (non- AASE)
Ruck/Maul	31.5%	n/a	16%	6.6%	8%	n/a	8.5% (AASE) 10.7% (non-AASE)
Line Out	8.3%	n/a	n/a	1.5%	n/a	1.2%	2.1% (AASE) 1.8% (non- AASE)
Running	n/a	n/a	n/a	4.5%	6%	n/a	2.1% (AASE) 7.1% (non- AASE)
Open Play	6%	n/a	n/a	n/a	n/a	n/a	n/a
Other	n/a	n/a	3%	3.8%	10%	24.6%	21.3% (AASE) 12.5% (non-AASE)
Total Contact	n/a	66.8%	87%	n/a	n/a	n/a	n/a
Total Non-Contact	n/a	33.2%	13%	n/a	n/a	n/a	n/a

Note.
[a] WR 24hr time loss injury definition.
[b] WR medical attention definition.
[c] Data extracted from graph.

2017b). One study investigated injury incidence in school soccer and RU (Junge et al., 2004), whilst the remaining studies focussed solely on RU. Two studies reported training injury incidence per 1000 h (Durie & Munroe, 2000; Junge et al., 2004) with a further two studies reporting training injury data without exposure (Archbold et al., 2017; Palmer-Green et al., 2013). All studies reported data on location, nature and mechanism of injury but only two studies accounted for player position (Barden & Stokes, 2018; Durie & Munroe, 2000). Three studies reported recurrent injuries (Junge et al., 2004; Leung et al., 2017b; Palmer-Green et al., 2013) and none of the studies reported data for school absence.

4. Discussion

The aim of this review was to identify injury incidence and trends in the school RU population. It is evident from the results that despite WR's injury consensus (Fuller et al., 2007) and recent increases in youth Rugby research, injury epidemiology within the school RU cohort specifically remains unclear. This is largely due to wide variations in study methodologies and surveillance practices.

4.1. Injury incidence

A distinctive finding from this review was the degree of variability in reported injury incidence across studies ranging from 23.7 to 129.8/1000 h (Archbold et al., 2017; Barden & Stokes, 2018; Durie & Munroe, 2000; Junge et al., 2004; Leung et al., 2017a, 2017b; Palmer-Green et al., 2013). Overall, this review indicates that time loss injury incidence in the school game is lower in comparison to reported rates in the academy (Palmer-Green et al., 2013), amateur (Yeomans et al., 2018) and the professional game (Williams et al., 2013). It is interesting to note that studies utilising the WR 24hr time loss and medical attention definition reported similar injury incidence rates (23.7–35/1000 h), excluding the AASE data (Archbold et al., 2017; Barden & Stokes, 2018; Leung et al., 2017a, 2017b; Palmer-Green et al., 2013). To date, no review exists for school RU specifically however, Freitag et al. (Freitag et al., 2015) reported a pooled injury incidence of 26.7/1000 h for children and adolescent players (9–21 years). Excluding the AASE data (Barden & Stokes, 2018) and considering only the time-loss match incidence data from Junge et al. (Junge et al., 2004); findings from this review are comparable with the pooled incidence rate (Freitag et al., 2015). However, these comparisons must be interpreted with caution as the pooled incidence rate represents a multitude of Rugby disciplines, sex, injury definitions and levels of competition.

When making comparisons with other school sports, Faude et al. (Faude, Rößler, & Junge, 2013) reported a lower match injury incidence rate of 15–20/1000 h for school soccer players. Similarly, Junge et al. (Junge et al., 2004) demonstrated for injuries with absence, the school Rugby group sustained statistically more injuries (28.3/1000 h) than the soccer group at 16.2/1000 h ($p < 0.001$). It is difficult to compare data across a range of field-based school sports as there are limited comparable studies reporting injury incidence per 1000 player hours.

Although the selected studies were published across an 18 year period (2000–2018), it was difficult to determine if a trend existed as methodologies varied and incidence rates fluctuated across studies irrespective of time. Studies reporting time loss injuries with similar methodologies demonstrated a slight trend of decreasing injury rate over time from 2013 to 2018 (Archbold et al., 2017; Barden & Stokes, 2018; Palmer-Green et al., 2013), however, fluctuations also existed within this five-year period and analyses excluded the AASE data (Barden & Stokes, 2018).

The variance in injury incidences may also be influenced by age differences within and across studies. Overall injury incidence rates reported in some studies were representative of age disparities of up to nine years. It is known that injury incidence is influenced by age (Hagglund, Walden, & Ekstrand, 2016; Junge et al., 2004; Viviers, Viljoen, & Derman, 2018). Haseler et al. (Haseler et al., 2010) reported a significant increase in the incidence and severity of injuries with age for adolescent males with a linear regression of 5.15/1000 h per year per group (CI 3.57 to 6.74, $R^2 = 0.89$). It could be argued that the older players exhibit greater size, strength and power, possibly leading to harder tackles and collisions, however without individual body mass data this is difficult to deduce conclusively. Future research should consider the influence of body mass, age, and physical strength on injury data within this cohort.

Although inclusion criteria kept study selection strictly to school RU, it was difficult to account for skill variances across teams, yet, its influence on injury risk must be considered when interpreting results. Barden and Stokes (Barden & Stokes, 2018) demonstrated statistically significant increases in injury incidence for the AASE league players in comparison to the non-AASE players. Palmer-Green et al. (Palmer-Green et al., 2013) reported a higher incidence rate of 47/1000 h for academy teams in comparison to school teams at 35/1000 h. In the wider medical and science literature, a higher injury incidence rate is evident in the professional game (Williams et al., 2013) in comparison to the amateur domestic game (Yeomans et al., 2018). This relationship was also demonstrated by Bird et al. (Bird et al., 1998) who reported the schoolboy grade had significantly lower incidence rates compared to the other male grades ($X^2 = 15.92$, $p < 0.001$). This highlights the importance of limiting injury surveillance studies to specific age grades to minimise skill variability. Research investigating the influence of skill on injury risk is limited, however, in Rugby league, Gabbett et al. (Gabbett, Ullah, Jenkins, & Abernethy, 2012) demonstrated that few skill qualities predict contact injuries. This is an area that warrants further exploration within the school RU cohort as there are potential injury prevention consequences.

4.2. Injury definition

A second aim of this study was to critically appraise the injury surveillance procedures and methods used in school RU injury research. The findings from this review indicate study methods remain widely inconsistent which may contribute to the large variance in injury incidences reported as injury capture rates are dependent upon definition used. For example, due to the physical nature of RU, contusions and lacerations are common which would be captured using an “all-inclusive” or “medical-attention” injury definition but may not necessarily require >24hr time loss from training or games (Fuller et al., 2007). Although these broader injury definitions may increase the volume of injury data, they are not without limitations and may not accurately provide clinical relevance for medical practitioners and physiotherapists (Brooks & Fuller, 2006; Fuller et al., 2007). Junge et al. (Junge et al., 2004) reported the highest incidence rate of 128.9/1000 h for an “all-inclusive” definition yet, 79.1% of injuries which sought medical attention did not require absence from play. When analysing injuries with >1 day's absence, injury incidence dropped to 28.3/1000 h. Careful consideration should be given to injury definition when designing injury surveillance studies as it will dictate the presentation of injury incidence in that cohort and potentially lead to an under or over-representation of injury risk (Cross et al., 2018; Fuller, Taylor, Kemp, & Raftery, 2017).

4.3. Data collection methods

Variability in the qualification of injury recorders was also observed across the studies. Due to the nature of the school game, access to medical staff can vary considerably dependent on several external factors such as funding, level of play, type of school (public or fee-paying). It is therefore logistically difficult to adopt the same standardised injury surveillance approach as in the professional game (Williams et al., 2013). Inconsistency in the quality of injury recording practices was also evident in a recent review by Yeomans et al. (Yeomans et al., 2018) examining the community amateur game with some studies using player self-reported measures. It could be argued that data recorded by a medical professional maybe more accurate and reliable than data recorded by an unqualified injury recorder without medical expertise (Fuller et al., 2017). Archbold et al. (Archbold et al., 2017) attempted to verify the source of injury diagnosis and reported that 61% of all injury diagnosis were made by a qualified health professional. The logistic difficulty in attempting to standardise surveillance practices in non-professional cohorts has been illustrated by a number of reviews (Bleakley et al., 2011; Freitag et al., 2015; Yeomans et al., 2018). Future studies should attempt to verify the source of diagnosis in school populations where access to medical staff is limited to improve the reliability of injury data (Cross et al., 2018).

4.4. Injury severity

According to van Mechelen et al. (van Mechelen et al., 1992), injury incidence and severity are identified as the two key parameters in epidemiological research, with both being equally important in understanding the extent of injury risk. Archbold et al. (Archbold et al., 2017) reported the highest proportion of severe injuries at 49.1% of all injuries representing at least 20 times the severe injury rate reported by Durie and Munroe (Durie & Munroe, 2000) and Junge et al. (Junge et al., 2004). This figure is also higher than the recently reported 26% in the professional game for severe injuries (Williams et al., 2013). The most common cause of severe injuries reported by Archbold et al. (Archbold et al., 2017) was concussion at 15.9%. Under the Irish Rugby Football Union (IRFU) Graduated Return to Play (GRTP) Concussion protocol (Irish Rugby Football Union (IRFU), 2019), players under 20 years must not return to play for at least 23 days after sustaining a suspected concussion. When analysing injury severity for this cohort, results must be interpreted with caution due to the influence of the GRTP. When comparing with other school sports, Faude et al. (Faude et al., 2013) reported severe injury rates (>28 days) ranging from 10% to 15% for children and adolescent soccer teams. The absence of medical professionals in the school game and the inconsistent follow-ups across the studies may attribute to the lack of available injury severity data (Hagglund et al., 2016).

It is difficult to attempt to quantify injury burden in school RU with such limited severity data and future research should address this gap in the literature as it has important implications for the welfare of school players. It is also worth noting that none of the included studies reported time loss from school resulting from injury which may also help to quantify injury burden. Lee and Garaway (Lee & Garraway, 1996) reported that 16% of schoolboy RU match injuries resulted in time loss from school in comparison to 27% of RU club match injuries resulting in missed education/employment.

4.5. Mechanism of injury

This review demonstrated that for school RU, the majority of studies attributed the highest rates of injury incidence to the tackle. The tackle has been identified as the most dangerous phase of play across all ages and levels of Rugby union (Viviers et al., 2018). Data previously reported by Freitag et al. (Freitag et al., 2015) demonstrated that 39.6%–64% of injuries were attributed to the tackle which is comparable to the overall mean occurrence of 51.9% reported in this review. It should be noted that the large variance demonstrated by Freitag et al. (Freitag et al., 2015) includes a mix of age grades, level of play and Rugby disciplines. Evaluating epidemiological studies to understand injury mechanism and most dangerous phase of play has important implications for future injury prevention strategies (World Rugby, 2016–2020; Viviers et al., 2018).

4.6. Classification of injury

When considering injury type, ligament/joint sprains and muscle/tendon injuries were the two most prevalent injury groups which is similar to the amateur (Yeomans et al., 2018) and professional games (Williams et al., 2013). Concussion incidence (1.5–19%) was consistent with data (2.2–24.6%) previously reported by Freitag et al. (Freitag et al., 2015). Concussion incidence increased fivefold and head/neck injury increased twofold for players in the AASE competition in comparison to the non-AASE competition (Barden & Stokes, 2018). This increase could be due to a number of possible factors such as increased physicality and strength, higher level of professionalism and competitiveness possibly resulting in harder tackles (Williams et al., 2013). While it is possible there has been an improvement in detection and recording of concussion with the recent changes to GRTP protocol and the "*If In Doubt Sit Them Out*" campaign (Rugby, 2010), it may also be contributing to an overrepresentation of concussion incidence as not all suspected concussions or head injuries may equate to true diagnosed concussions. Future research should attempt to quantify and differentiate between suspected and diagnosed concussions which will increase the accuracy of concussion incidence data whilst also evaluating the GRTP protocol.

5. Limitations

One limitation of this study was the low number of studies included for systematic review. The wide variability in injury surveillance practices and methods in addition to a lack of school specific RU research resulted in only seven studies being suitable for descriptive review and analysis. A meta-analysis was also not possible due to the large inconsistency in surveillance practices, injury definitions and the method of incidence reporting. Therefore, a pooled incidence value would not be truly representative of the school cohort and could lead to inaccurate conclusions.

6. Conclusion

This paper serves to improve the current understanding of injury epidemiology and surveillance practices in school RU and provides the first known systematic review on the subject. Inconsistencies in injury definitions and injury recording practices make conclusions challenging. Overall, injury incidence rates in school RU are lower than previously reported in the academy, amateur and professional game for time loss injuries. Similar to the amateur and professional game, the tackle was also associated with the highest injury risk for school players. Injury risk appeared to increase with age and skill level, however the influence of body mass was not explored. Injury burden was difficult to ascertain due to a lack of injury severity data.

Future studies should consider the influence of age, skill and body mass on injury incidence and attempt to limit such parameters in future studies to improve accuracy and validity of data. The nature of the school game presents itself with logistic difficulties in carrying out injury surveillance as highlighted in this review. An updated international consensus on injury surveillance practices for the school game should be established to improve the standardisation and quality of injury surveillance research. With consistent and standardised injury surveillance data, injury risk factors may be identified, and appropriate injury prevention measures can be put in place, thus enhancing the welfare and safety of the school player.

Conflicts of interest

Therese M. Leahy, Ian C. Kenny, Mark J. Campbell, Giles D. Warrington, Roisin Cahalan, Andrew J. Harrison, Mark Lyons, Liam G. Glynn, and Thomas M. Comyns declare that they have no potential conflicts of interest that are directly relevant to the content of this review.

Ethical approval

Not applicable for Systematic Review, None declared.

Funding

Funding was provided by the Irish Rugby Football Union (IRFU) and the University of Limerick, Ireland.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2019.05.005.

References

Accident compensation corporation. Available from: www.acc.co.nz/. (Accessed October 2018).

Archbold, H. A. P., Rankin, A. T., Webb, M., Nicholas, R., Eames, N. W. A., Wislon, R. K., et al. (2017). RISUS study: Rugby injury surveillance in ulster schools. *British Journal of Sports Medicine, 51*(7), 600.

Barden, C., & Stokes, K. (2018). Epidemiology of injury in elite English schoolboy rugby union: A 3-year study comparing different competitions. *Journal of Athletic Training, 53*(5), 514–520.

Bird, Y. N., Waller, A. E., Marshall, S. W., Alsop, J. C., Chalmers, D. J., & Gerrard, D. F. (1998). The New Zealand rugby injury and performance project: V. Epidemiology of a season of rugby injury. *British Journal of Sports Medicine, 32*(4), 319–325.

Bleakley, C., Tully M Fau - O'Connor, S., & O'Connor, S. (2011). Epidemiology of adolescent rugby injuries: A systematic review. *Journal of Athletic Training, 46*, 555–565.

Brooks, J. H., & Fuller, C. W. (2006). The influence of methodological issues on the results and conclusions from epidemiological studies of sports injuries: Illustrative examples. *Sports Medicine, 36*(6), 459–472.

Carter, M. (2015). The unknown risks of youth rugby. *BMJ, 350*. https://www.bmj.com/content/350/bmj.h26.abstract.

Cross, M., Williams, S., Kemp, P. T. S., Fuller, C., Taylor, A., Brooks, J., et al. (2018). Does the reliability of reporting in injury surveillance studies depend on injury definition? *Orthop J Sports Med, 6*(3).

Durie, R. M., & Munroe, A. D. (2000). A prospective survey of injuries in a New Zealand schoolboy rugby population. *Sports Med NZ, 28*, 84–90.

Faude, O., Rößler, R., & Junge, A. (2013). Football injuries in children and adolescent players: Are there clues for prevention? *Sports Medicine, 43*(9), 819–837.

Finch, C. (2006). A new framework for research leading to sports injury prevention. *Journal of Science and Medicine in Sport, 9*, 3–9.

Freitag, A., Kirkwood, G., Scharer, S., Ofori-Asenso, R., & Pollock, A. M. (2015). Systematic review of rugby injuries in children and adolescents under 21 years. *British Journal of Sports Medicine, 49*(11), 511–519.

Fuller, C. W., Molloy, M. G., Bagate, C., Bahr, R., Brooks, J. H., Donson, H., et al. (2007). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *British Journal of Sports Medicine, 41*(5), 328–331. https://doi.org/10.1136/bjsm.2006.033282.

Fuller, C. W., Taylor, A., Kemp, S. P., & Raftery, M. (2017). Rugby world cup 2015: World rugby injury surveillance study. *British Journal of Sports Medicine, 15*, 51–57.

Gabbett, T. J., Ullah, S., Jenkins, D., & Abernethy, B. (2012). Skill qualities as risk factors for contact injury in professional rugby league players. *Journal of Sports Science, 30*(13), 1421–1427.

Hagglund, M., Walden, M., & Ekstrand, J. (2016). Injury recurrence is lower at the highest professional football level than at national and amateur levels: Does sports medicine and sports physiotherapy deliver? *British Journal of Sports Medicine, 50*(12), 751–758.

Halstead, M. E., & Walter, K. D. (2010). Clinical report—sport-related concussion in children and adolescents. *Pediatrics, 126*(3). https://doi.org/10.1542/peds.2010-2005 [Published Online First: 1 September 2010].

Haseler, C. M., Carmont, M. R., & England, M. (2010). The epidemiology of injuries in English youth community rugby union. *British Journal of Sports Medicine, 44*(15), 1093.

Hill, N. E., Rilstone, S., Stacey, M. J., Amiras, D., Chew, S., Flatman, D., et al. (2018). Changes in northern hemisphere male international rugby union players' body mass and height between 1955 and 2015. *BMJ Open Sport Exerc Med, 4*(1).

Irish Rugby Football Union. (2012). *Annual report 2011-2012: A growing game*. Dublin: IRFU.

Irish Rugby Football Union (IRFU). (2019). *Concussion protocols*. Available from: https://www.irishrugby.ie/playing-the-game/medical/irfu-concussion-protocols/. (Accessed February 2019).

Junge, A., Cheung, K., Edwards, T., & Dvorak, J. (2004). Injuries in youth amateur soccer and rugby players—comparison of incidence and characteristics. *British Journal of Sports Medicine, 38*(2), 168.

Lee, A. J., & Garraway, W. M. (1996). Epidemiological comparison of injuries in school and senior club rugby. *British Journal of Sports Medicine, 30*(3), 213.

Leung, F. T., Franettovich, S., Melinda, M., Brown, M., Rahmann, A., Mendis, M. D., et al. (2017). Epidemiology of injuries in Australian school level rugby union. *Journal of Science and Medicine in Sport, 20*(8), 740–744.

Leung, F. T., Franettovich, S., Melinda, M., & Hides, J. A. (2017). Injuries in Australian school-level rugby union. *Journal of Sports Science, 35*(21), 2088–2092.

McCoy, G. F., Piggot, J., Macafee, A. L., & Adair, I. V. (1984). Injuries of the cervical spine in schoolboy rugby football. *Bone Joint Res. British volume, 66-B*(4), 500–503.

McIntosh, A. S. (2005). Rugby injuries. *Medicine and Sport Science, 49*, 120–139.

van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Medicine, 14*(2), 82–99.

Moher D, L. A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine, 6*(7).

SportCIC. (2016). *Open Letter: Preventing injuries in children playing school rugby*, 2016.

Palmer-Green, D. S., Stokes, K. A., Fuller, C. W., England, M., Kemp, S. P. T., & Trewartha, G. (2013). Match injuries in English youth academy and schools rugby union: An epidemiological study. *The American Journal of Sports Medicine, 41*(4), 749–755.

Patel, D. R., Yamasaki, A., & Brown, K. (2017). Epidemiology of sports-related musculoskeletal injuries in young athletes in United States. *Translational Pediatrics, 6*(3), 160–166.

Pollock, A. M., & K.G. (2017). Tackle and scrum should be banned in school rugby. *British Journal of Sports Medicine*. https://blogs.bmj.com/bmj/2017/09/25/allyson-pollock-and-graham-kirkwood-tackle-and-scrum-should-be-banned-in-school-rugby/.

Pollock, A. M., White, A. J., & Kirkwood, G. (2017). Evidence in support of the call to ban the tackle and harmful contact in school rugby: A response to world rugby. *British Journal of Sports Medicine*, 51. https://bjsm.bmj.com/content/51/15/1113.

Rugby, W.. World rugby concussion management. 2010-2019. Available from: https://playerwelfare.worldrugby.org/concussion. (Accessed February 2019).

Tucker, R., Raftery, M., & Verhagen, E. (2016 Aug). Injury risk and a tackle ban in youth rugby union: Reviewing the evidence and searching for targeted, effective interventions. A critical review. *British Journal of Sports Medicine, 50*(15), 921–925. https://doi.org/10.1136/bjsports-2016-096322.

Viviers, P. L., Viljoen, J. T., & Derman, W. (2018). A review of a decade of rugby union injury epidemiology: 2007-2017. *Sport Health, 10*(3), 223–227.

Williams, S., Trewartha, G., Simon, K., et al. (2013). A meta-analysis of injuries in senior men's professional rugby union. *Sports Medicine, 43*(10), 1043–1055.

World Rugby. (2016-2020). *World rugby strategic plan. 2016:*. . (Accessed October 2018).

World Rugby. (2019). *A year in review 2017* [online] Available at: http://publications.worldrugby.org/yearinreview2017. (Accessed 26 October 2018).

Yeomans, C., Kenny, Ian C., Cahalan, R., Warrington, G. D., Harrison, A. J., Hayes, K., et al. (2018). The incidence of injury in amateur male rugby union: A systematic review and meta-analysis. *Sports Medicine, 48*(4), 837–848.