Appendix 1: Case study: Tackle injuries to ball carriers in rugby

The data set

A study was conducted in which video records of every tackle that occurred in 434 professional rugby matches was coded on a range of dimensions, including the location on the body at which the tackler(s) contacted the ball carrier ('tackle height').[1] The information in the table has been restricted to that from 43 366 tackles in which a single tackler tackled a ball carrier (i.e. the 100 tackle events per match that met this criteria). For the purposes of the example below, an injury is defined as 'any injury sustained by a ball carrier during a rugby tackle that required them to be removed from the field of play for the remainder of the match'.

Different denominators: different perspectives on risk

Rates of injury have been presented in Table 1 as 'per 10 000 tackles' and 'per 10 000 player-hours'. If data were reported using only the time-based denominator, as has been the case in most studies of sports injury epidemiology, the conclusion drawn would be that 'high' and 'middle' tackles are those that carry the greatest risk to ball carriers. When the relative frequency of the tackles is considered, and the rates are presented on a 'per 10 000 tackles' basis, head/neck tackles place ball carriers at the greatest risk of injury *when they occur*.

Table 1 Injury rates to ball carriers in rugby tackles, expressed via event-based and time-based denominators.

		Injuries requiring the player to be removed from the match		
Tackle height	**Tackles per match**	**Per 10 000 tackles**	**Per 10 000 player-hours**	**Percent of injuries per 10 000 player hours**
Head/neck	4 ± 2	43 (23 to 79)	4 (2 to 8)	13 (7 to 23)
High	37 ± 10	12 (8 to 17)	11 (8 to 16)	36 (26 to 47)
Middle	44 ± 9	9 (6 to 13)	10 (7 to 15)	32 (23 to 43)
Low	15 ± 5	16 (9 to 26)	6 (3 to 10)	19 (12 to 29)

The different perspectives provided by 'per-event' and 'per-time' denominators can be helpful in identifying injury prevention priorities. If the overall risk of injuries was considered 'unacceptably high' by those responsible for managing the risks in the sport, then reducing the numbers of the most

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common tackles in the game would have the greatest effect; together 'high' and 'middle' tackles account for over two-thirds of all tackle injuries requiring ball carriers to be removed from the pitch. Reducing the numbers of such tackles, or the characteristics of them, would probably require major changes to the sport of rugby. If, however, the overall degree of risk was considered 'acceptable', then focussing on decreasing the number of 'head and neck' tackles would have a modest effect on overall injury rates, but reduce the occurrence of a particularly risky element of the sport (note: head/neck tackles are not permitted within the laws of rugby, but sometimes occur).

The type of exposure measures that can form the basis of risk statistics is presented in Table 2, along with a range of the risk measures that have been reported in studies of team sports injury epidemiology. The examples are taken from the same study discussed above.

Bahr R, *et al. Br J Sports Med* 2020; 54:372–389. doi: 10.1136/bjsports-2019-101969

Table 2 A range of exposure and risk statistics derived from injury surveillance data - examples from a study of rugby tackle injuries.[1]

Statistic	Value	Calculation	Explanation	Comment
Injury statistics				
Number of injuries (carrier injury replacements in 434 matches)	53	Nil	Count of the number of tackler injuries requiring the injured player to be replaced observed in 434 matches.	The 'numerator' used for calculating the rate of tackler replacement injuries per unit of time or per tackle. Absolute numbers and costs of injuries *are* of interest to risk managers, especially when provided in parallel with rates
Number of injured players (some were injured more than once)	48	Nil		The numerator for calculating 'injury risk'
Exposure measures				
Player hours in 434 matches	17 360	30*579	Thirty players (15 from each team) multiplied by 579 (hours of play in 434 matches of 80 minutes duration)	This number provides a 'time-window' denominator. Usually it is assumed that time lost for yellow and red cards, or time gained for 'extra time' is negligible and is ignored.
Number of single tackler tackle events in 434 matches	43 366	Nil	All tackles in 434 matches were coded, regardless of whether they resulted in injury	This number forms an 'event-based' denominator.

Bahr R, *et al. Br J Sports Med* 2020; 54:372–389. doi: 10.1136/bjsports-2019-101969

Statistic	Value	Calculation	Explanation	Comment
Number of players who appeared in the 434 matches	1403	Nil		This is a count of the size of the cohort across the entire study period; it is used as the denominator for calculating 'injury risk'.
Number of full player matches	13 020	30*434	Thirty players (15 from each team) multiplied by 434 matches	This number provides a 'per-match' denominator.
Number of athlete-exposures (athlete-participations)	17 685	Nil	Count of the number of players who took the field over 434 matches (players can be substituted for tactical purposes or replaced due to injury)	The similarity to the number of player hours is coincidental; there are 40 hours of player-time per match, and the average number of athlete exposures per match over this series of matches was 40.8.
Risk measures				
Period prevalence (percentage of cohort injured)	3%	(48/1403)*100	Percentage of people who appeared in matches who were replaced	Often reported as 'risk per season' or 'risk per year'. Can't be easily used to compare between activities if the duration of surveillance varies from activity to activity. The longer the surveillance period, the higher the risk will appear to be for closed cohorts
Injuries per 1 000 player-hours	3.1	(53/17 360)*1 000	The number of injuries is divided by the number of hours of player exposure, and multiplied by a scaling factor (e.g. 1 000, 10 000) to provide a rate that is convenient to work with (e.g. numbers in the range of 1	The most commonly reported metric of injury rates in studies of rugby injury epidemiology has been rate of injuries per 1 000 player-hours. This convention is endorsed in the consensus document by Fuller et al.[2]

Statistic	Value	Calculation	Explanation	Comment
			to 1 000 rather than numbers less than zero or greater than 1 000	It is relatively simple to estimate based on the number of matches played. Comparisons of incidence rates between activities or within activities over time based on this denominator require the assumption that the number and characteristics of energy transfers to which participants are exposed remains relatively constant per unit of exposure time.
Injuries per 1 000 matches	122	(53/434)*1 000	Rate of tackler replacements per rugby union match multiplied by 1 000. The rate per match is multiplied by a factor that provides a convenient interpretation; 0.12 carrier replacement injuries per match; 12.2 per 100 matches, 122 per 1 000 matches etc.	Ignores number of players and match duration, and provides an estimate of the number of injuries an observer would expect to see if they watched 1 000 matches. Not useful for comparing incidence rates between activities of differing durations or numbers of participants.
Injuries per 1 000 hours of play (ignoring number of players)	92	(53/579)*1 000	The rate per hour is multiplied by a factor that provides a convenient interpretation; 0.9 carrier replacement injuries per hour; 9.2 per 100 hours, 92 per 1 000 hours etc.	Ignores number of players, and provides an estimate of the number of injuries an observer would expect to see if they watched 1 000 hours of play. Not useful for comparing between activities with differing numbers of participants (because the sizes of the populations at risk differ)
Injuries per 1 000 athlete-exposures	3.0	(53/17685)*1 000	Carrier injury replacements per 1 000 athlete exposures	Injuries per 1 000 athlete exposures are commonly reported in injury surveillance in the United States. Problematic for comparing between activities that

Statistic	Value	Calculation	Explanation	Comment
(athlete-participations)				have different numbers of typical athlete exposures per match, or when the average exposure time per player changes over time.
Injuries per 1 000 full player matches	4.1	(53/13020)*1 000		Not commonly used. It ignores the duration of the match, and as such has similar drawbacks to reporting injuries per athlete exposure, because the time-window of exposure varies between activities of different durations.
Injuries per 1 000 'ball in play' player-hours	6.8	(53/7740)*1 000		Not commonly used, but technically a more accurate measure of exposure than injuries per 1 000 player-hours, because players are only exposed to tackles when the ball is ‘in play’.
Injuries per 1 000 'ball in play and ball-carrier’s team in possession' player-hours	13.5	(53/3819)*1 000		Again, not commonly used, but an even closer approximation of actual time exposed to the risk of ball carrier injuries. Players are only tackled when the ball is in play and their team is in possession.
Injuries per 1 000 tackle events	1.2	(53/43366)*1 000	Ball-carrier injury replacements per 1 000 times tackled	Provides an accurate assessment of per-event injury rates, but in isolation ignores frequency of occurrence of the event of interest. Injury rates per event have been sometimes been termed ‘injury propensity’.[3]

Statistic	Value	Calculation	Explanation	Comment
Injuries per 1 000 players per year	24	(23+17+13)*1 000/ (983+589+627)		Sometimes provided as a gross estimate of injury risk when participant numbers and injury numbers are available, but no measure of exposure for players is available (e.g. data derived from insurance claims combined with registers of participants). Of limited use when exposure varies by subgroup or across sports.

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