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Title:

Patterns of training volume and injury risk in elite rugby union: an analysis of 1.5 million hours of training exposure over eleven seasons.

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DECLARATION OF INTEREST STATEMENT

SPTK and KAS are employed by the Rugby Football Union. MJC is employed by Premier Rugby Limited. CWF provides risk management consultancy services to World Rugby. The remaining authors report no conflict of interest.

DATA AVAILABILITY STATEMENT

Under the terms of the ethics associated with this study and the sensitive nature surrounding private medical player data, data sharing is not possible.

ABSTRACT

Rugby union is a popular team sport that demands high levels of physical fitness and skill. The study aim was to examine trends in training volume and its impact on injury incidence, severity and burden over an 11-season period in English professional rugby. Data were recorded from 2007/08 through 2017/18, capturing 1,455,086 hours of training exposure and 3,703 training injuries. Players completed, on average, 6 hrs 48 minutes of weekly training (95% CI: 6 hrs 30 mins to 7 hrs 6 mins): this value remained stable over the 11 seasons. The mean incidence of training-related injuries was 2.6/1000 player-hours (95% CI: 2.4 to 2.8) with a mean severity rising from 17 days in 2007/08 to 37 days in 2017/18 (Change/ season=1.773, $P<0.01$). Rate of change in severity was dependent on training type, with conditioning (non-gym-based) responsible for the greatest increase (2.4 days/injury/season). As a result of increasing severity, injury burden rose from 51 days absence/1000 player-hours in 2007/08 to 106 days' absence/1000 player-hours in 2017/18. Despite the low incidence of injury in training compared to match-play, training accounted for 34% of all injuries. Future assessments of training intensity may lead to a greater understanding of the rise in injury severity.

Keywords: Training, Rugby, Injury, Epidemiology, Burden

INTRODUCTION

Rugby union is a field-based team game composed of long bouts of low intensity movement or rest interspersed by short bouts of high intensity locomotor or contact activity (Roberts, Trewartha, Higgitt, El-Abd & Stokes, 2008). While all players are exposed to both contact and running demands, backs cover greater distances at higher speeds, while forwards are involved in more than twice the number of contact events and cover greater distances at lower speeds (Quarrie, Hopkins, Anthony & Gill, 2013; Cunniffe, 2009; Dubois et al., 2017). To meet the physical demands and the high skill levels required to play elite rugby union, a number of training modalities are employed to prepare players, including aerobic conditioning, high intensity interval training, strength training and sport specific skills sessions (Tee, Lambert & Coopoo, 2016; Argus, Gill, Keogh, Hopkins & Beaven, 2009; Gannon, Stokes & Trewartha, 2016; McLaren, Smith, Spears & Weston, 2017). The purpose of training is "to prepare players for the physical demands of competition, including the most demanding passages of play" (Gabbett, 2016). Previous studies provide a useful overview of rugby training strategies (Argus et al., 2009; Tee et al., 2016; Gannon et al., 2016; McLaren et al., 2017) but it is difficult to generalise the findings, as they related to single club studies and therefore the results may only reflect the conditioning strategies specific to those clubs. Another limitation to previous studies is the relatively short duration over which they were conducted (usually weeks, months or 1-2 seasons); hence, they do not offer an understanding of how rugby training may have changed over time. In the 11 seasons of data collection included in this study, the use of technology to guide training as well as the management of athletes has received significant attention in both research and practice. While this is the case, there is little information surrounding how these changes have positively or negatively influenced training injury rates or whether training volumes have changed in accordance with these new data driven programs. Further to this, Quarrie et al. (2016) highlighted the importance of managing training load and outlined the need for large scale research projects to provide sufficient evidence to inform decision-making processes regarding player load and welfare.

The incidence of match injury in professional rugby union is relatively high compared with other team sports [81 injuries per 1000 player-hours of exposure (Williams, Trewartha, Kemp & Stokes, 2013)]. A much lower incidence of training injuries [3.0 per 1000 player-hours of training (Williams et al., 2013)], means that the impact of training injuries is often overlooked. Importantly, high training exposure compared to match exposure means the absolute number of injuries associated with training is still relatively high: Brooks and colleagues, (2005b) reported that over a two-season period, 395 injuries were the result of training activities. While match injuries are often the result of unpredictable game events and hence difficult to prevent, training is conducted in a largely controllable environment and, therefore, it may be considered easier to reduce injuries in this environment (Williams et al., 2015). Therefore in an effort to reduce the overall time loss associated with injury in rugby union, the focus of these efforts may be best placed in training, compared with match-play.

Although several studies have examined patterns of training activity in rugby union (Brooks et al., 2005b; Argus et al., 2009; Gannon et al., 2016), there is a sparsity of information regarding changes to the composition and volume of training over time and the impact of these changes on the incidence, severity and type of training injuries. Consequently, the aim of this study was to assess longitudinal changes in volume and type of training, and to explore the effect of these changes on training injury over eleven seasons.

MATERIALS AND METHODS

Participants

Over the 11-season period (2007/08 to 2017/18), a mean of 600 (standard deviation (SD): 72, range: 505-725) players per season consented to participate in the study, with a total of 5998 player-seasons captured over the entire period (some players were involved in multiple seasons). Training exposure and injury data were collected as part of the Rugby Football Union injury surveillance project, which included England's 12 Premiership clubs each season. All consenting players deemed eligible for first team selection were included in the study. The study was subject to ethical approval by the host academic institutions [University of Nottingham (2007- 2012) and University of Bath (2011-2018)].

Procedures

In each club, match and training injury data were collected by medical staff and training data by conditioning or sports science staff. Training data were captured using paper-based forms from 2007/08 through 2011/12 and manually entered into a database at the host university. From the 2012/13 season, training data were captured using a bespoke online platform, "Elitehub". Injury data were captured according to the rugby consensus statement (Fuller et al., 2007) using paper-based forms from 2007/08 through 2012/13 and manually entered into a database. From the 2013/14 season, injury data were captured using an online platform, "Rugby Squad" (The Sports Office UK Ltd). For each injury, data pertaining to the count, severity, burden, mechanism and site of injury were documented, while the type of training during which the injury occurred was also recorded.. Training volume data were collected under five categories: full-contact (rugby skills training in which contact occurred without the use of external padding), semi-contact (rugby skills training with the use of pads or bags), non-contact (rugby skills training without contact between players), conditioning (non-gym-based; i.e., conditioning training other than gym-based activities, e.g., running endurance, speed/agility, power etc.) and conditioning (gym-based), with warm up and cool-down not included in total training time (which was calculated as the accumulated time spent in each category). Training volume was reported as the number of players partaking in each session type during the week and the number of minutes spent performing each training type; this was then multiplied to calculate training volume in each category and summed to get total training volume. Only training injuries were included in this analysis and were defined as "any injury that resulted in a player being unable to take a full part in future rugby training or match play for more than 24 hours from midnight at the end of the day the injury was sustained" (Fuller et al., 2007). Injury severity was operationalised as the number of days lost from competition or practice, with the return date from injury being set as the day on which a player became available for full training or was fit for match play, irrespective of whether training or a match was scheduled for that day (Fuller et al., 2007). Injury burden was reported as the number of days absence per 1000 player-hours of exposure and was defined as the product of incidence and severity (Brooks, Fuller, Kemp & Reddin, 2005a; Brooks et al., 2005b).

Data Analysis

Injury incidence was calculated as count of injury per 1000 player-hours (Brooks et al., 2005a; Brooks et al., 2005b). Mean severity was calculated as the total number of days absence divided by the number of injuries while median severity was calculated as the midpoint in the range of severities associated with the injuries. Median severities were calculated to demonstrate the effect that a small number of high severity injuries can impose on mean severity values. Injury burden (days absence/1000 player-hours) was calculated as the product of injury incidence and mean severity (Brooks et al., 2005a). A descriptive analysis outlining the seasonal values for each of these measures was undertaken. Corresponding 95% confidence intervals (CI) were calculated for incidence, severity and burden values. A one-way repeated measures ANOVA, using a Greenhouse-Geisser correction to account for sphericity (Greenhouse & Geisser, 1959), was used to calculate whether the amount of training in each category had changed significantly over the duration of the study period. Effect sizes were calculated as a partial eta squared (η_p^2) and assessed using the guidelines proposed by Cohen (1988) (0.01=*small*, 0.06= *moderate*, 0.14=*large* effect) Linear regression was used to identify significant trends in injury incidence, severity and burden over time. Further to this, linear regression was used to establish the rate of change in injury severity over time for each of the training categories. Statistical significance was set at $P<0.05$; no adjustments were made for the number of statistical tests undertaken. All statistical analyses were completed in SPSS (IBM SPSS Statistics, Version 24, 2018).

RESULTS

Training volume

During the period 2007/08 to 2017/18, a total of 1,501,606 player-hours of training volume (full-contact: 97,855 player-hours; semi-contact: 237,322 player-hours; non-contact: 459,086 player-hours; conditioning, non-gym-based: 220,222 player-hours; conditioning, gym-based: 487,121 player-hours) and 3,782 training injuries were recorded (full-contact: 889; semi-contact: 851; non-contact: 653; conditioning, non-gym-based: 913; conditioning, gym-based: 331; unknown: 145). The mean time spent training over the entire study period was 6 hrs 48 minutes/player/week (95% CI: 6 hrs 30 mins to 7 hrs 6 mins), with monthly differences evident within seasons (Figures 1A and 1B). July, when pre-season training began, showed the highest mean number of training hours at 10 hrs 18 mins. June (3 hrs 24 mins) and May (2 hrs 30 mins), the off-season period, showed the lowest. Over the study period, conditioning (gym-based) and non-contact rugby skills training accounted for the most time on average, with weekly means of 2 hrs 12 mins and 2 hrs 6 mins, respectively. Semi-contact and conditioning (non-gym-based) accounted for a mean of 1 hr per week, while the least amount of time was spent in full-contact rugby skills training (24 mins/player/week). During the season, the focus of training and time spent in different training categories changed. For example, in July, gym-based conditioning and non-gym-based conditioning accounted for 3 hrs 48 mins and 3 hrs 18 mins, respectively, whereas in April these accounted for just 1 hr 48 mins and 30 mins. Despite some within (range: 6–84 mins per week) and between (range: 36-54 mins per week) club variation, no statistically significant changes in training time were seen within clubs over the 11-season period (full-contact: F=1.437, P=0.315, η_p^2=0.324, *large effect*; semi-contact; F=0.407, P=0.769, η_p^2= 0.075, *moderate effect*; non-contact; F=1.154, P=0.350, η_p^2= 0.141, *large effect*; conditioning (non-gym-based): F=1.831, P=0.186, η_p^2= 0.234, *large effect*; conditioning (gym-based): F=2.101, P=0.141, η_p^2=0.231, *large effect*).

*********************** INSERT FIGURE 1 HERE **

Training injury incidence

The mean number of training injuries occurring per season was 344 (29 per club), with the highest number of injuries reported in the 2017/18 season at 438 (mean: 37 per club): Figure 2(A), Table 1. Over the study period, there was no significant change in the incidence of injury overall (Change per season: -0.01/ 1000 player-hours (95% CIs: -0.09-0.05), P=0.69*)*. Individual seasons did however show fluctuation in risk with the 2015/16 season falling below 2 injuries/1000 player-hours. Full contact rugby skills training accounted for the highest injury incidence in all but the 2014/15 season, with a mean of 9.6 per 1000 hours (Figure 2(B)). Conditioning (gym-based) was consistently the activity with the lowest incidence and little between-season variation (mean: 0.7/1000 player-hours, SD: 0.2/1000 player-hours). Across all rugby skill-based components, the incidence of injury was 4.9 per 1000 hours (SD: 1.5), while the combined conditioning components demonstrated a rate of 2.5 per 1000 hours (SD: 0.4).

*********************** INSERT TABLE 1 HERE **

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Training injury severity

Mean severity of training injuries rose in all but two seasons, with the 2017/18 season showing the highest value at 37 days per injury (Figure 3(A)). Over the study period, the mean severity of injury rose by 1.7 days on average each season (B= 1.74; *P*<0.01: Table 2). Median severity of injury rose from 9 days in 2007/08 to 17 days in 2017/18, a rise of 0.8 days per season (Table 1). When injury severity is considered by training type (Figure 3(B)), no single type was consistently associated with the highest severity of injury. In all but two seasons, the training type with the lowest mean injury severity was conditioning (gym-based). Each of the training categories demonstrated an upward trend in injury severity but the rate of increase differed between the training types. Conditioning (non-gym-based) had the highest rate of increase in mean severity, rising an average of 2.4 days per season (B=2.43, *P*<0.01), while conditioning (gym-based) training displayed the lowest rate of change at 0.8 days per season (B= 0.76, *P*=0.13: Table 2).

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Training injury burden

The burden of training injuries rose significantly over the study period (Change per season: 4.4 days absence per 1000 hours (95% CIs: 1.26-6.42), *P*=0.004: Figure 4(A)). This rise was particularly noticeable during the 2016/17 and 2017/18 seasons when the burden was substantially higher than that of the total period as a whole. When analysed by training type, over the same 2-season period a similar rise was seen for full contact training, where burdens of 562 and 533 days absence per 1000 player-hours were recorded, respectively (Figure 4(B)).

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Injury mechanism

There was a change in coding structure of injury mechanism in the 2009/10 season, and therefore the analysis of injury mechanism includes the seasons from 2009/10 to 2017/18 (Figure 5). Running was the most common training injury mechanism (1.1/1000 player-hours), followed by being tackled (0.19/1000 player-hours), accidental collisions (0.16/1000 player-hours) and tackling (0.14/1000 player-hours). The three most severe training injury events were kicking (40 days), scrummaging (39 days) and non-accidental collision (39 days); however, kicking and non-accidental collisions were the rarest events leading to just 35 and 30 injuries respectively (compared to 1300 running injuries) over the study period.

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Injury Location

The most commonly injured body sites were the posterior thigh (incidence: 0.47/1000 player-hours; mean severity: 23 days) and the calf (incidence: 0.33/1000 player-hours; mean severity: 21 days). The knee was the body site with the most severe injuries (incidence: 0.29/1000 player-hours, mean severity: 48 days). The elbow (incidence: 0.03/1000 player-hours; mean severity: 44 days) and shoulder (incidence: 0.19/1000 player-hours; mean severity: 42 days) gave rise to injuries of similar severity, but were less frequent. Injuries to the head/face had an incidence of 0.12 /1000 player-hours and a mean severity of 15 days' absence. The incidence of concussion over the study period was 0.09/1000 player-hours with a mean severity of 14 days. The incidence of concussion rose from 0.01 per 1000 player-hours in the 3-season period 2007/08 to 2009/10 (three cases in three seasons) to 0.21 per 1000 player-hours in the 2017/18 season (32 cases in one season).

*********************** INSERT FIGURE 6 HERE **

DISCUSSION

This study presents an in-depth summary of training patterns and training injuries over the seasons 2007/08 to 2017/18 in the top tier of English professional rugby. Over this period, neither the volume of training as a whole, nor the breakdown of the defined individual training categories, changed significantly. In contrast, within individual seasons, the volume and proportion of each training category changed substantially between pre-season and in-season periods. Pre-season training focussed on conditioning, whereas in-season focussed on non-contact rugby skills and gym-based conditioning. The overall incidence of training injury remained relatively stable, with full contact training injuries consistently the most frequent. There was a steady upwards trend over the 11 seasons for injury severity across all training categories. Injury burden followed a similar pattern to injury severity, as a function of the stable incidence and rising severity. Given the high number of injuries associated with running, the most common sites for injury were the posterior thigh, calf and ankle, while the most severe injuries occurred to the knee.

Over the course of the 11 seasons, the overall pattern of training remained stable (Figure 1A). Although the mean time spent training per player did not change, there was a rise in the total reported training volume between the 2007/08 (106,000 hours) and 2017/18 seasons (152,533). This rise in total volume, but no change in mean training time per player, reflects increasing squad sizes across Premiership clubs (mean squad size 2007: 45, mean squad size 2018: 60). To account for this change in squad size over time, the data presented in Figure 1 reflects mean time per player per week and therefore controls for squad size. It is important to recognise, however, that these are mean figures and each club will employ its own unique training methodology. Furthermore, the distribution of training volumes varies across the different stages of the season (Figure 1B). Unsurprisingly, June and May were the months with the lowest mean training volumes, as these months include the mandatory 5-week off-season for players and the majority of volume reported in May was provided by the small number of teams that make the playoff stages of domestic and European competitions. July and August comprise the main portion of the preseason period and these months had a mean training volume of 9 hrs per player per week (compared to the in-season period September to April of 6 hrs 6 mins per player per week).

Several previous papers have reported the structure of training in professional rugby union (Argus et al., 2009; Gannon et al., 2016; McLaren et al., 2017). The preseason training volumes reported in this study are comparable with those reported by Gannon et al. (2016) (7 hrs 24 mins) and McLaren et al. (2017) (8 hrs 48 mins to 9 hrs 24 mins). In a similar Premiership rugby sample (seasons 2002/03 and 2003/04), Brooks et al. (2008) reported a figure of 9 hrs 12 mins, supporting the conclusion that mean training duration for Premiership teams during preseason has, in fact, not changed over an even longer period of time.

During early pre-season (July), training was focused on athlete conditioning (gym-based conditioning, 3 hrs 48 mins; 3 hrs 18 mins, other conditioning). As the playing period of the season drew closer (August), the emphasis for training moved towards rugby skills but with a continued large proportion of time spent on gym-based conditioning. This corresponds with data from other studies that show a reduction in the volume of conditioning from pre-season to in-season (Argus et al., 2009; Gannon et al., 2016; Tee et al., 2016). The reduction in general conditioning sessions after pre-season is likely due to the adoption of individual prescription (Gannon et al., 2016). Interestingly, despite anecdotal evidence suggesting a greater emphasis on strength, power and size of players in recent years, there was no statistically significant changes seen in time spent performing gym-based conditioning over the 11-season period. This finding may indicate changes to the content and efficiency of training, with greater stimulus achieved through the same volume of training. In the present study, during the in-season period there was a weekly training volume of 6 hrs 6 mins per player per week, which is comparable with the 6 hrs 42 mins (first 20 weeks in-season) or 6 hrs 30 mins (final 11 weeks in-season) reported by Gannon et al. (2016) and the 6 hrs 18 mins reported by Brooks et al. (2008). The highest number of training injuries occurred during periods with the highest training volume (July and August); however, the incidence of injury did not change significantly during these periods.

Over the period 2007/08 to 2017/18 the incidence of training injuries remained stable with a mean of 2.6 per 1000 player-hours. In the Premiership over the period 2002-2004, Brooks et al. (2005b) reported an incidence of 2.0 per 1000 player-hours, while a study of Australian Super Rugby reported a value of 2.3 per 1000 player-hours during the 2014 season (Whitehouse, Orr, Fitzgerald, Harries & McLellan, 2016). In a 2013 meta-analysis, Williams et al. (Williams et al., 2013) reported a comparable value of 3 injuries per 1000 player-hours of training for professional rugby. While the incidence of training injury is often not sub-divided by training category, Brooks et al. (2005b) reported a significantly higher incidence of injury in rugby skills training (2.1/1000 hours) compared to conditioning (1.6/1000 hours). The present study has demonstrated an incidence of injury during combined rugby skills training greater than that of conditioning (4.9 vs 2.5/1000 hours), with these figures notably higher than that reported by Brooks et al. (2005b). Although it is possible to control certain aspects of full contact training, when exposed to full contact training in a dynamic fast moving rugby environment, injuries can be considered more unpredictable than that of other training types. It is therefore unsurprising that the incidence rate in this training type is highest across all categories. While a reduction in the amount of training may seem a logical step to help reduce the number of training injuries, it is important to consider that a certain amount of contact training is likely necessary to not only prepare an athlete for the physical demands of the sport (Gabbett, 2016) but also to be able to successfully complete the technical components of rugby skills such as tackling, rucking and mauling. Considering this, it could be argued that the length of time spent undertaking full contact training may in fact need to increase, with a greater exposure to technical contact based training such as that suggested by Hendricks and colleagues (2016; 2018) In the context of this dataset, it is not possible to establish how much, if any, of full contact training focused on tackle technique; however, given the evidence suggesting poor tackle technique is linked with higher match injury risk (Hendricks et al., 2015; Burger et al., 2016; Tucker et al., 2017; Cross et al., 2017), it is recommended that a portion of the focus should be on the technical aspects of the tackle.

Although injury incidence remained stable over the 11 seasons, injury severity rose almost every season. Given the potential for the mean value to be skewed by one or two long-term injuries, the median is also reported and this showed a similar upward trend over the 11-season period (Table 1). A similar trend has been reported for match injury severity (Kemp et al., 2019) and although the mechanisms for such a rise may stem from bigger contact events from stronger and faster players during games, in the training setting the trend for increased severity cannot be attributed solely to this high velocity contact as the increase in severity is evident across numerous session types. Therefore, the rise in injury severity may highlight a number of issues, including adoption of more conservative return to play protocols alongside the concurrent increase in squad sizes, or a genuine increase in the complexity of rugby union injuries. Though injury rates per training category have remained stable, the severity of these injuries has risen. Full contact training and gym-based conditioning displayed the greatest rise in mean severity (26 and 23 day rise on average between 2007/08 and 2017/18). Although gym-based conditioning exhibited the second largest rise over the time period, in 2017/18 conditioning (non-gym) exhibited the highest mean severity of injuries at 42 days, followed by full contact training at 40 days. Given the stability of training volume over time, the increase in injury severity may be a result of a change in other aspects of training, such as frequency, duration or intensity (Smith, 2003). As both the frequency and duration (overall volume) have not shown statistically significant changes, it is possible that changes in training intensity may have contributed to this rise in severity. This hypothesis cannot be examined with the data presented here, as training intensity was not captured, but it would be important to investigate this in future studies. Injury burden is considered a measure of overall injury risk as it accounts for both the incidence and severity of injury (Fuller, 2018). The present study demonstrates that the burden of injuries rose significantly from 2007/08 to 2015/16. During the 2016/17 and 2017/18 seasons this increase in burden was particularly evident, with this rise attributable to increases in both the incidence and severity of full contact training injuries. More detailed analysis of the composition and implementation of this category of training may also provide a greater understanding of the specific issues involved.

One further aspect to consider when evaluating the burden of injuries is the relative contribution of incidence and severity within the burden figure. Two teams exhibiting the same injury burden may not experience the same impact on player availability (Fuller, 2018). A team experiencing an injury burden resulting from high incidence but low severity injuries will be influenced by larger number of players unavailable for shorter periods of time, whereas a team experiencing an injury burden comprised of low incidence but high severity injuries will be affected by fewer players unavailable over longer periods. This difference would be more pronounced on a team if the players lost to injury in the low incidence high severity scenario are players that would have a significant effect on team performance. In the present study, the increase in burden is largely caused by rising severity; therefore, in practice, strategically planning for periods with reduced player availability in key positions is essential, with adjustments to squad sizes and strength and depth in those key roles recommended.

This study has demonstrated that the overall volume and composition of training, as well as the incidence of training injuries, in English professional players did not change over the last 11 seasons. However, the severity of injuries associated with training rose in all but two seasons between 2007 and 2018. One limitation of this study was that training intensity was not captured and therefore its potential impact on injury severity was not examined. Tools such as Global Positioning Systems (GPS) and session Rating of Perceived Exertion (Halson, 2014) may provide valuable, additional information in this context. A further limitation of this study is the lack of individual training volumes per player. These data were collected on a team basis, so individual contributions of injury status, player experience, player age, or other factors were not examined. This further supports the work of Cross et al. (2016), which outlined the need for more long-term studies that assess individualised relationships between training load and injury risk in professional rugby. The practical implications of this study are evident for both practice and policy. In practice, this data can be used by clubs to identify differences between themselves and that of elite rugby union clubs in England, in both the volume of training completed as well as the injury patterns they see. Future work is needed to establish the exact nature, methodologies, intensity and composition of full contact training in particular, given its high incidence of injury. Furthermore, developing a greater understanding of the mechanisms driving the increase in injury severity is warranted to reduce the overall burden of injury from training. Capturing just over 1.5 million hours of training volume and 3,703 training injuries, this study provides the largest and most comprehensive view of training volume and training injury in professional rugby union. Although between season variation is apparent, the volume of training did not change between 2007/08 and 2017/18. Training injury incidence remained relatively stable, but the number of injuries associated with training is worthy of attention given that they are sustained in potentially more "controllable" conditions than those in match play. Improving understanding of evolving injury patterns in training and developing injury reduction strategies have the potential to positively impact upon on welfare of rugby participants as well as improving career longevity of those players involved at the professional level of the game.

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TABLES

Table 1: Summary of training injury data (2007-2018) including injury count, injuries as proportion of all recorded injuries, exposure, incidence, median severity, mean severity, burden.

Season	Injury count	Proportion of all injuries (%)	Exposure, (hours)	Incidence (number per 1000 player-hrs)	Median severity (days absence)	Mean severity (days absence)	Burden (days absence per 1000 player-hrs)
2007/08	318	33 (29-36)	106000	3.0 (2.7-3.3)	9 (8-10)	17 (15-19)	51 (46-57)
2008/09	258	25 (22-28)	103200	2.5 (2.2-2.8)	11 (9-12)	22 (19-25)	55 (49-62)
2009/10	298	32 (28-36)	119200	2.5 (2.2-2.8)	9 (8-10)	20 (18-22)	50 (45-56)
2010/11	340	31 (28-35)	117241	2.9 (2.6-3.2)	11 (10-12)	21 (19-23)	61 (55-68)
2011/12	323	33 (30-37)	129200	2.5(2.2-2.8)	10 (9-11)	22 (20-25)	55 (49-61)
2012/13	335	36 (33-40)	128846	2.6 (2.3-2.9)	13 (12-14)	29 (26-32)	75 (68-84)
2013/14	414	36 (33- 40)	142759	2.9 (2.6-3.2)	12 (11-13)	25(23-28)	73 (66-80)
2014/15	325	34 (30-37)	141304	2.3 (2.1-2.6)	10 (9-11)	28 (25-31)	64 (58-72)
2015/16	304	40 (36-45)	159398	1.9 (1.7-2.1)	17 (15-19)	30 (27-34)	57 (51-64)
2016/17	429	36 (32-39)	147983	2.9 (2.6-3.2)	12 (11-13)	33 (30-36)	96 (87-105)
2017/18	438	38 (35-42)	152533	2.9 (2.6-3.2)	17 (15-18)	37 (34-41)	106 (97-117)

Table 2: Regression analysis: season-on-season change in mean injury severity 2007/08 to 2017/18

Training Type	Change per season	*P*-value	5-year change
Rugby skills: full contact	1.77 (0.96-2.59)	<0.01	9 day rise in severity
Rugby skills: semi-contact	0.90 (-0.72-2.52)	0.24	5 day rise in severity
Rugby skills: non-contact	1.31 (0.11-2.51)	0.04	7 day rise in severity
Conditioning: non-gym based	2.43 (1.55-3.31)	<0.01	12 day rise in severity
Conditioning: gym-based	0.76 (-0.26-1.79)	0.13	4 day rise in severity
All training types	1.74 (1.27-2.20)	<0.01	9 day rise in severity

FIGURES

Figure Captions:

- Figure 1: Average number of hours training per week per player by (A) season and (B) month. Values shown represent mean number of hours per player per week. Values less than 0.4 (24 mins per week) are not labelled for clarity.
- Figure 2: Training injury incidence for the seasons 2007-2018. (A) all training exposure types combined (B) training exposure by categories. Data points in Figure 2(A) represent the seasonal mean and the error bars 95% CI values; the solid grey line represents the period mean and the broken grey lines the 95% CIs for the mean.
- Figure 3: Training injury severity, 2007/08-2017/18. (A): all session types combined (B): by session type. Data points in Figure 23A) represent the seasonal mean and the error bars 95% CI values; the solid grey line represents the period mean and the broken grey lines the 95% CIs for the mean.
- Figure 4: Training injury burden for the seasons 2007-2018. (A)= all session types combined (B)= broken down by session type. Grey lines in Figure 4(A) represent the period mean and 95% CI's around the mean.
- Figure 5: Training injury event for the seasons 2009/2010 to 2017/18. Injuries reported with the event "N/A" (<1%), "Other" (16%), "Unknown" (10%) are not included in the graph.
- Figure 6: Injury burden as a function of body site for the seasons 2007/08 to 2017/18. The X-axis represents incidence (number per 1000 player-hours) while the Y-axis represents mean severity (days absence).

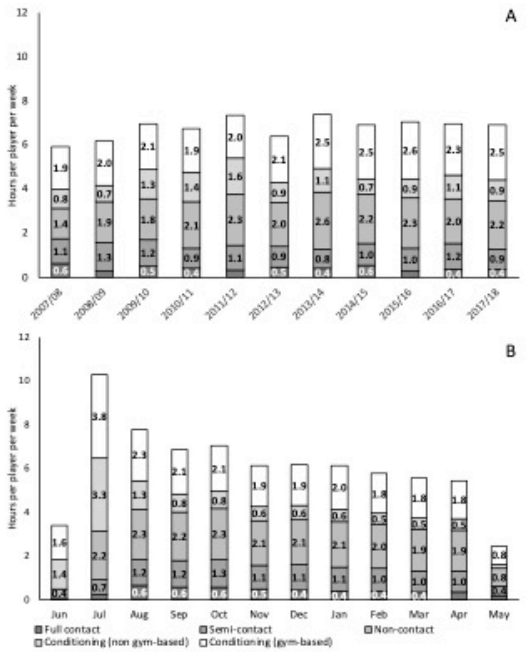

A
B
Hours per player per week
2007/08
2008/09
2009/10
2010/11
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17
2017/18
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Full contact
Semi-contact
Non-contact
Conditioning (non gym-based)
Conditioning (gym-based)

Fig 1.

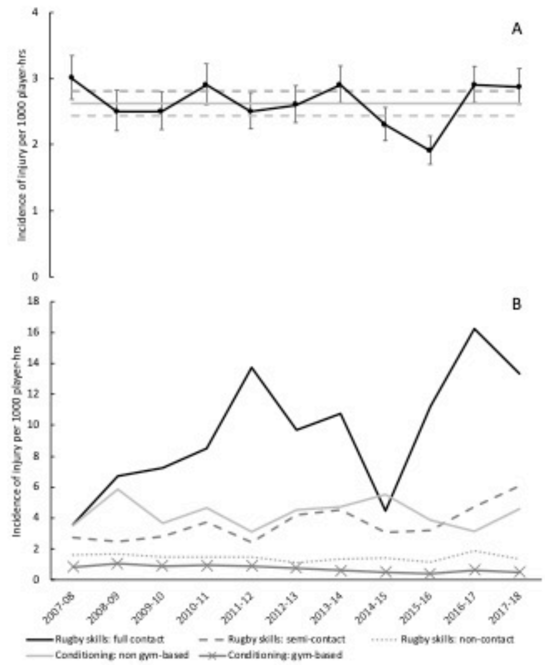

A
B
Incidence of injury per 1000 player-hrs
Incidence of injury per 1000 player-hrs
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Rugby skills: full contact
Rugby skills: semi-contact
Rugby skills: non-contact
Conditioning: non gym-based
Conditioning: gym-based

Fig 2.

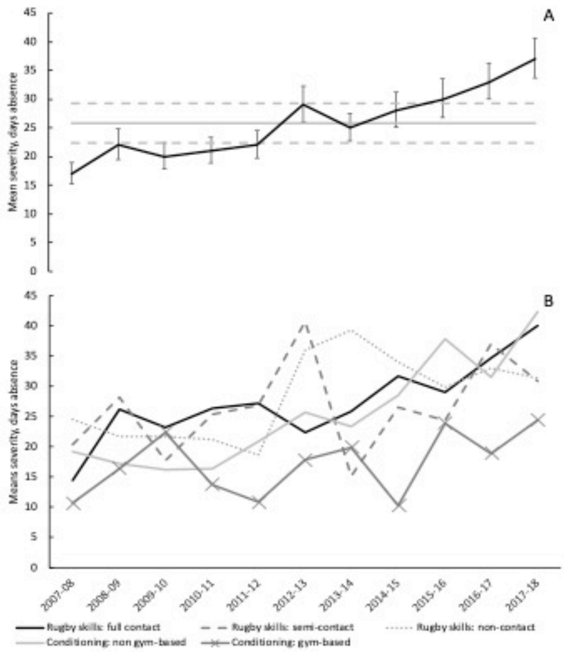

A
Mean severity, days absence
45
40
35
30
25
20
15
10
5
0
B
Means severity, days absence
45
40
35
30
25
20
15
10
5
0
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Rugby skills: full contact
Rugby skills: semi-contact
Rugby skills: non-contact
Conditioning: non gym-based
Conditioning: gym-based

Fig 3.

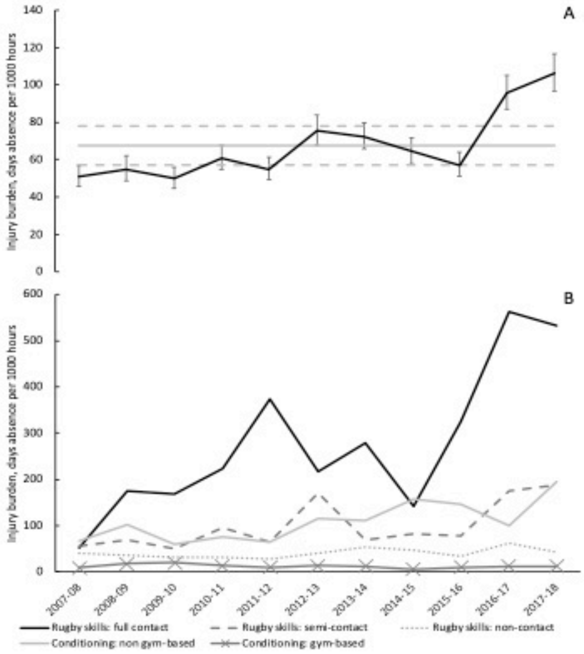
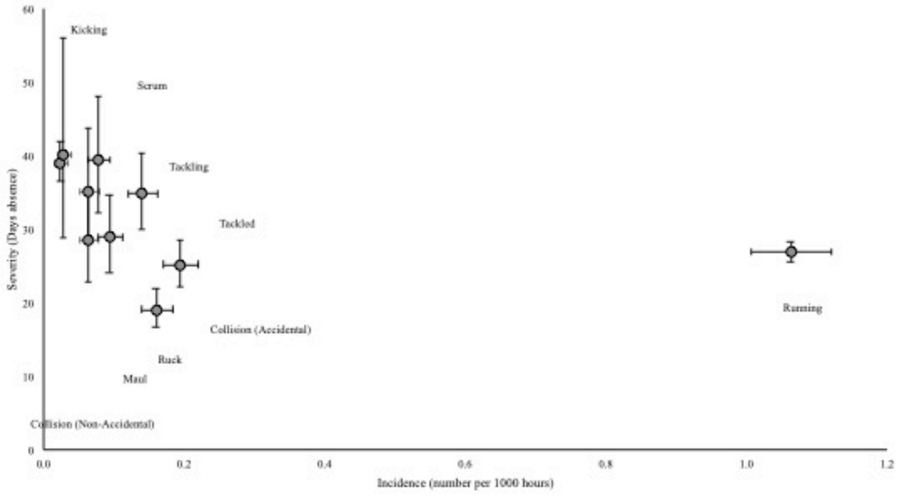

A
B
Injury burden, days absence per 1000 hours
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Rugby skills: full contact
Rugby skills: semi-contact
Rugby skills: non-contact
Conditioning: non gym-based
Conditioning: gym-based

Fig 4.



Kicking
Scrum
Tackling
Tackled
Running
Collision (Accidental)
Ruck
Maul
Collision (Non-Accidental)
Severity (Days absence)
Incidence (number per 1000 hours)
0
10
20
30
40
50
60
0.0
0.2
0.4
0.6
0.8
1.0
1.2

Fig 5.

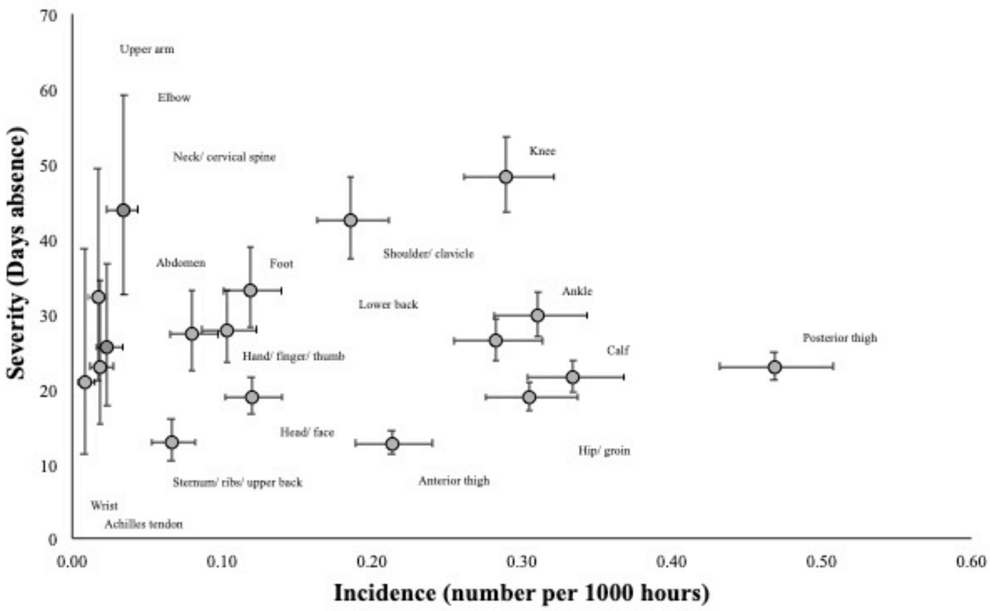

Severity (Days absence)
70
60
50
40
30
20
10
0
Upper arm
Elbow
Neck/ cervical spine
Knee
Shoulder/ clavicle
Abdomen
Foot
Ankle
Lower back
Posterior thigh
Calf
Hand/ finger/ thumb
Head/ face
Hip/ groin
Sternum/ ribs/ upper back
Anterior thigh
Wrist
Achilles tendon
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Incidence (number per 1000 hours)

Fig 6.