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Original Research

A retrospective analysis of hamstring injuries in elite rugby athletes: More severe injuries are likely to occur at the distal myofascial junction[★]



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ABSTRACT

Objectives: To describe the most common hamstring injury scenarios and outcomes in elite rugby union.

Design: Retrospective investigation.

Setting: Hamstring injury data from an elite rugby union team was collected over five seasons and retrospectively analysed.

Participants: 74 professional rugby players.

Main outcome measures: Injuries were classified as new or recurrent. Injury severity, activity, player position, and whether the injury occurred during a match or training was determined for each injury. Injury location and grade were determined for more clinically severe injuries where Magnetic Resonance Imaging (MRI) data was available (15 injuries).

Results: Thirty hamstring injuries were sustained over the five seasons. The majority of injuries were new (93%), moderate in severity (60%) and occurred during running (77%). For more clinically severe injuries, the biceps femoris long head (BFlh) was the most commonly injured muscle (73%) and the distal myofascial junction (DMFJ) was the most common injury site (58% of BFlh injuries).

Conclusions: Hamstring injuries most commonly occurred while running and in the BFlh muscle, which is similar to other sports. However, the most common intramuscular injury site was the DMFJ, which contrasts with reports from other cohorts. Future studies should ensure to include the myofascial junction when classifying injury location.

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1. Introduction

Rugby union is a collision sport that requires frequent high-intensity efforts, including running, kicking, rucking, mauling and tackling, as well as exposure to large impacts (Coughlan, Green, Pook, Toolan, & O'connor, 2011; Roberts, Trewartha, Higgitt, El-Abd, & Stokes, 2008). These demands result in some of the highest injury rates reported for any team sport (Nicholl, Coleman, & Williams, 1995; Williams, Trewartha, Kemp, & Stokes, 2013).

Notably, hamstring injuries are the most common lower-limb non-contact injury (Brooks, Fuller, Kemp, & Reddin, 2005; Kara, 2013), and also the greatest cause of player unavailability in some playing positions (e.g. backs) (Brooks et al., 2005). However, despite the obvious burden of hamstring injuries, very few studies have investigated the specific nature of hamstring injuries in elite rugby union.

It is crucial to understand the mechanisms and outcomes of hamstring injury in rugby union in order to design effective injury prevention and rehabilitation strategies. Previous studies have found that the majority of hamstring injuries occur during running and primarily affect the biceps femoris long head (BFLh) muscle (Bourne, Opar, Williams, & Shield, 2015; Brooks, Fuller, Kemp, & Reddin, 2006). However, further details of the location of hamstring injuries in rugby athletes are currently unknown. In track and field athletes, the specific muscle injury site within the BFLh has been suggested to relate to the length convalescence periods and the likelihood of injury recurrence (Pollock et al., 2016). Intramuscular injury sites have not yet been reported for hamstring injuries in rugby union and identifying injury rates by location may influence treatment approaches and the risk of re-injury.

The aim of this study was to comprehensively describe the burden of hamstring injuries in an elite rugby union team, including the description of the most common injury scenarios (player position, activity at time of injury, timing of injury within the season) and outcomes (severity). Additionally, we aim to describe injury grade and location for a sub-set of more clinically severe hamstring injuries.

2. Materials and methods

Retrospective injury data collected over five Super Rugby seasons (2013–2017) were extracted from an athlete management database of one professional rugby union team competing in the Super Rugby competition. Across this five year period, athletes competed in 16 Super rugby games per season. During pre-season, a typical training week was comprised of 12–14 training sessions (approximately 15 h), while in-season, players undertook five to six training sessions per week (approximately 8 h). Training was comprised of upper and lower body weights, dedicated speed technique training sessions, conditioning sessions, and rugby specific sessions. Data from all players in the team squad were eligible for inclusion, and each season there were between 34 and 39 players in the team squad. A total of 74 athletes were included in the study, although not all of these players were present for the full duration of the study period. Informed consent was obtained for all athletes and the rights of all athletes were protected. This study was approved by the human research ethics committees of the University of Canberra, Australian National University and Australian Institute of Sport.

All injury data were entered in the athlete management database by the team physiotherapist at the time of injury. Clinical notes made by the team doctor and physiotherapist at the time of injury were also available to better confirm injury details if necessary. In this study, an injury was defined as per Fuller et al. (2007) as, “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 and resulted in a player being unable to take a full part in future rugby training or match play.” Therefore, all injuries reported are “time-loss” injuries. The athlete management database coded injuries using the Orchard Sports Injury Classification System (OSICS) at the time of injury (Orchard, 1993). The OSICS codes were used to identify hamstring injuries within the database which contained all injuries. Hamstring injuries were

extracted by screening all injury data for injuries coded using the following OSICS diagnosis codes, TMHX (Hamstring strain), TMHS (Hamstring strain – semimembranosus/tendonosus strain, grade 1–2), TMHB (Hamstring strain – biceps femoris strain, grade 1–2) and TMHR (grade 3 hamstring strain). The OSICS codes were not used for any further analysis.

Hamstring injuries were identified as either new or recurrent. Recurrent injuries were defined as per Fuller et al. (2007) as, “an injury of the same type and at the same site as an index injury and which occurs after a player's return to full participation from the index injury.” In this study, the same type and site of injury was interpreted as a hamstring injury which was within the same muscle, in the same limb. Recurrent injuries were further classified into: ‘early recurrence’ (recurrence within 2 months of return to full participation) or ‘late recurrence’ (recurrence 2–12 months after return to full participation) (Fuller et al., 2007).

Hamstring injury severity was assessed by the number of days that elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection (Fuller et al., 2007). Severity was classified as: slight (0–1 days), minimal (2–3 days), mild (4–7 days), moderate (8–28 days), severe (>28 days) or career ending (Fuller et al., 2007). Other hamstring injury information extracted included the player's position at the time of injury, whether the injury occurred during a match or training and the activity at the time of injury. The season period in which injuries occurred was also determined, and categorised as: ‘pre-season’ (beginning of pre-season to the first round of the season), ‘early season’ (first game to the middle round of the season), ‘late season’ (middle round of the season to the end of the season, including finals where applicable), ‘off-season’ (commencing after the last game of the season until the following pre-season).

A subset of hamstring injuries that were determined to be more clinically severe by the team doctor were assessed via magnetic resonance imaging (MRI). MRI was used to assess approximately half of the injuries in the days following injury occurrence, while other injuries were assessed using ultrasound or clinical assessment by the team doctor and physiotherapist. Generally, injuries were assessed via MRI if, after assessment by the team doctor, it was believed the injury was more severe than a grade 1 injury (based on clinical assessment). For these more clinically severe injuries where MRI data was available, specific injury location and the grade of injury was also identified. If MRI data was not available, the injury was excluded from the classification of location and grade. MRI data were eligible for inclusion if the scan was performed within seven days of the injury. All MRIs were reviewed by a single independent radiologist with 17 years of experience in musculoskeletal radiology (MT). Injury location was classified according to the muscle affected (biceps femoris long head, BFLh; biceps femoris short head, BFsh; semimembranosus, SM; semitendinosus, ST), and the specific region of the muscle affected using the previously described methods of Crema et al. (2016; Fig. 1). Crema et al. (2016) reported perfect (kappa 1.00) intra-rater reliability for classification of injury site using this method. Injury sites were reported as follows: proximal tendon (PT), proximal myotendinous junction (PMTJ), proximal myofascial junction (PMFJ), proximal muscle belly (PMB), distal muscle belly (DMB), distal myofascial junction (DMFJ), distal myotendinous junction (DMTJ) and distal tendon (DT). Where multiple injury sites existed for the same injury, both the primary and secondary injury sites were recorded, where the primary injury site was the injury with the greatest area of signal abnormality on MRI.

Injury grade was assessed using the British Athletics Muscle Injury Classification system, which classifies injuries into grades zero to four based on the extent of injury, and subcategories a, b and

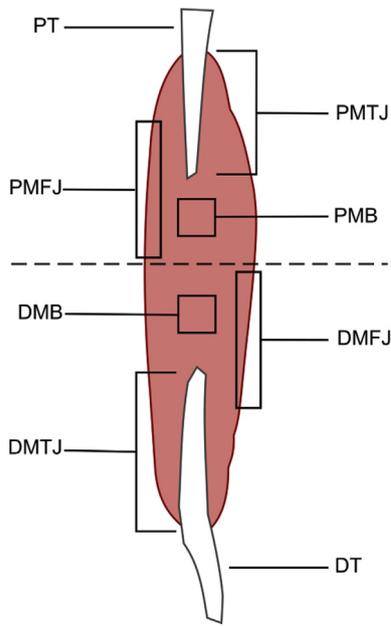


Fig. 1. Representation of hamstring injury location for the subset of more clinically severe injuries. Adapted from Crema et al. (2016). This figure is not intended to be anatomically correct. PT, proximal tendon; PMTJ, proximal myotendinous junction; PMFJ, proximal myofascial junction; PMB, proximal muscle belly; DMB, distal muscle belly; DMFJ, distal myofascial junction; DMTJ, distal myotendinous junction; DT, distal tendon.

c based on the tissues involved (Pollock, James, Lee, & Chakraverty, 2014). Intra-rater reliability assessments for this classification system have varied between ‘substantial’ agreement (kappa 0.71) (Patel et al., 2015) to ‘almost perfect’ agreement (kappa 0.89) (Wangenstein et al., 2017). The criteria for each grade is defined as per Pollock et al. (2014). A detailed description of the criteria for each injury grade can be found in Table 1.

The majority of variables were categorical, and therefore

percentages for each category were reported. Days lost from training and competition was reported as a median and interquartile range (IQR), as inspection of a boxplot revealed non-normally distributed data. For ease of analysis, the classification of injury grade was collapsed into four grade categories (grades 0–4) because the tissues involved were detailed within the location results.

3. Results

A total of 30 hamstring injuries were recorded across the five-season study period, or an average of six injuries per season (range, 1–13). Hamstring injuries accounted for 6% of all injuries reported, and 11% of all lower limb injuries. The majority of injuries were new (93%), compared to recurrent (7%). Time to recurrence for recurrent injuries was 157 and 166, resulting in two late recurrences. There were no early recurrences.

When the timing of hamstring injury within a rugby season was considered, the late season period was the most common time for hamstring injuries, followed by the pre-season (Table 2). A greater number of injuries were recorded during training (63%) compared to during matches (37%). The majority of training injuries occurred during pre-season, while most match injuries occurred in the late season period (Table 2).

Injuries most commonly occurred during running (77%), with a smaller proportion of injuries occurring during a ruck (10%). The activity at the time of injury was unknown in 13% of injury occurrences. A similar number of injuries were sustained by backs (53%) and forwards (47%).

A median of 26 days (IQR 24) was lost from training and competition for each hamstring injury. The majority of injuries were classified as moderate (8–28 days; 60%), followed by severe (>28 days; 37%). A smaller number of injuries were mild (3%), while no slight, minimal or career-ending injuries were reported. Per season, an average of 207 days (range, 57–374) were lost as a result of hamstring injuries.

A total of 18 injuries were determined to be more clinically severe after initial assessment by the team doctor. These injuries were

Table 1
Classification of hamstring injury grade: The British Athletics Muscle Injury Classification System (Pollock et al., 2014).

Grade	Sub-category	Description of muscle strain injury
Grade 0	A.	A focal neuromuscular injury with normal MRI.
	B.	MRI characteristic of delayed onset muscle soreness - generalised patchy high signal change affecting several muscles.
Grade 1	A.	Extends from the fascia and demonstrates high signal change on fat suppressed/STIR images within the periphery of the muscle. No greater than 10% into the muscle and with longitudinal length of less than 5 cm within the muscle. Frank muscle fibre disruption is not usually seen, but evidence of fibre disruption of less than 1 cm with limited high signal change may still be classified in this grade. Intermuscular fluid/haematoma on MRI may be evident within the fascial planes over a greater distance.
	B.	Sited within the muscle or, more commonly, at the myotendinous junction (MTJ). High signal change extends over a limited area of less than 5 cm and less than 10% of the muscle cross-sectional area at its maximal site. Frank muscle fibre disruption is not usually seen but evidence of fibre disruption of less than 1 cm with limited high signal change may still be classified in this grade.
Grade 2	A.	Extend from the peripheral fascia into the muscle - high signal change will be evident from the periphery of the muscle. The high signal change will either measure between 10% and 50% of the cross-sectional area or extend between 5 cm and 15 cm within the muscle. Architectural fibre disruption will be less than 5 cm.
	B.	Occur within the muscle or, more commonly, at the MTJ. The high signal change will either measure between 10% and 50% of the muscle cross-sectional area or have a longitudinal length between 5 cm and 15 cm. There is likely to be evidence of muscle fibre disruption of less than 5 cm.
	C.	Extend into the tendon. Injury within the tendon is evident over a longitudinal length of less than 5 cm and less than 50% of the maximal tendon diameter on axial images. If the injury is near the free tendon there may be some loss of tension in the free tendon. It may still be classified as 2c, rather than 3c, if the injury size is compatible with the measurement above.
Grade 3	A.	Extend from the peripheral fascia into the muscle. High signal change patterns of greater than 50% of the muscle cross-sectional area or greater than 15 cm in length. There will be evidence of architectural fibre disruption which is likely to be greater than 5 cm.
	B.	Occur within the muscle or, more commonly, at the MTJ. High signal change patterns of greater than 50% of the muscle cross-sectional area or greater than 15 cm in length. There will be evidence of architectural fibre disruption which is likely to be greater than 5 cm.
	C.	Intratendinous injury. Evidence of injury in the tendon over a longitudinal length of greater than 5 cm or greater than 50% of the tendons maximal cross-sectional area. No evidence of a complete defect but there may be loss of the usual straight margins and tendon tension.
Grade 4		Complete tear to the muscle.
	C.	Complete tear to the tendon.

Table 2
Hamstring injuries by season period.

	Pre-season	Early season	Late season	Off-season	Total season
Training injuries	9 (47%)	3 (16%)	6 (31%)	1 (5%)	19
Match injuries	0 (0%)	4 (36%)	6 (55%)	1 (9%)	11
Total	9 (30%)	7 (23%)	12 (40%)	2 (7%)	30

evaluated using MRI and 15 of these were eligible for inclusion. All included MRIs were performed within three days of injury occurrence (mean, 1.5 ± 0.9 days). The majority of the subset of more clinically severe injuries affected the BFlh, and the most common injury site was the DMFJ (Table 3). Notably, in this subset of data for which injury location was assessed, the BFlh muscle was affected (either as the primary or secondary injury site) in 90% of injuries that occurred during running ($n = 10$).

Most of the clinically more severe injuries occurred at a single injury site. However, in four cases (27%), a secondary injury site was evident (Table 4). The majority of injuries assessed using MRI were grade 2 injuries (80%), with fewer grade 3 injuries (20%). There were no grade 0, 1 or 4 injuries.

4. Discussion

Hamstring injuries in rugby union are highly prevalent; however, few studies have investigated the specific scenarios and outcomes of these injuries in elite rugby athletes. To our knowledge, this is the first study to report the specific location of hamstring injury in rugby athletes. We found that in more clinically severe injuries, the BFlh was the most commonly affected muscle, which aligns with previous research in both rugby union and other running-based sports (Askling, Tengvar, Saartok, & Thorstenson, 2007; Bourne et al., 2015; Connell et al., 2004; Crema et al., 2016). However, the most common intramuscular location was the distal myofascial junction (DMFJ). This has not been previously reported in rugby athletes, and differs from the site reported for other sports including soccer, Australian Rules football (ARF), and track sprinting (Askling et al., 2007; Connell et al., 2004; Crema et al., 2016). In these cohorts, the MTJ has been widely reported as the most common injury site (Askling et al., 2007; Connell et al., 2004; Crema et al., 2016; Slavotinek, Verrall, & Fon, 2002). While it is important to note that the analysis of injury location only reflects injuries that were determined to be more clinically severe, and it is unknown whether this trend would be evident for less severe injuries, these data suggest that rugby athletes may differ from other running athletes in that they are more susceptible to sustaining hamstring injuries at a different location of the BFlh.

The overwhelming majority of hamstring injuries across many sports occur during running (Bourne et al., 2015; Brooks et al., 2006; Dalton, Kerr, & Dompier, 2015; Gabbe, Bennell, Finch, Wajswelner, & Orchard, 2006; Woods et al., 2004). Therefore, factors related to the execution of running mechanics, and sport-specific demands during running may assist in explaining the reported difference in injury location in rugby athletes. It has been suggested that differing task demands may elicit differing running mechanics between cohorts (Sayers, 1999). Additionally, sport-specific demands of other tasks (eg. kicking) may fatigue the hamstrings differently throughout game play (Duhig, Williams, Minett, Opar, & Shield, 2017). However, both the magnitude of differences in running mechanics between different sporting cohorts, and the influence of running mechanics on hamstring injury susceptibility, require further research before we can understand if, and how, this may relate to hamstring injury location.

Further, several studies have suggested that the anatomy of the hamstrings may influence injury occurrence (Battermann, Appell, Dargel, & Koebke, 2011; Beltran, Ghazikhanian, Padron, & Beltran, 2012; Evangelidis, Massey, Pain, & Folland, 2015; Fiorentino, Epstein, & Blemker, 2012; Opar, Williams, & Shield, 2012; Rehorn & Blemker, 2010; Sutton, 1984; Timmins et al., 2015). However, given the high incidence of hamstring injuries located at the PMTJ in other cohorts, to date, investigations have focussed mainly on the anatomy of the proximal aponeurosis of BFlh (Battermann et al., 2011; Beltran et al., 2012; Evangelidis et al., 2015; Fiorentino et al., 2012). While Entwisle, Ling, Splatt, Brukner and Connell (2017) noted that the complex, highly variable anatomy and dual innervation of the distal hamstrings may have influenced the high rate of recurrence of DMTJ injuries observed in their study of ARF athletes, no direct link between hamstring anatomy and injury was described (Beltran et al., 2012; Entwisle et al., 2017; Sutton, 1984). Further, this study focussed on the MTJ. Based on the findings of the current study, future research should examine the influence that muscle fascia may have on hamstring injury occurrence. In fact, a recent consensus statement highlighted the need for more detailed investigations into the relationship between fascial tissues and sports injuries (Zügel et al., 2018). There is some evidence to suggest that fascial tissues may provide a pathway for force

Table 3
Primary injury location for more clinically severe injuries: Injured hamstring muscle and intramuscular injury site ($N = 15$).

	BFlh	BFsh	ST	SM	All hamstring muscles
PT	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
PMTJ	2 (17%)	0 (0%)	0 (0%)	1 (50%)	3 (19%)
PMFJ	2 (17%)	1 (100%)	0 (0%)	0 (0%)	3 (19%)
PMB	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1 (6%)
DMB	1 (8%)	0 (0%)	0 (0%)	0 (0%)	1 (6%)
DMFJ	7 (58%)	0 (0%)	0 (0%)	1 (50%)	8 (50%)
DMTJ	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
DT	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total proximal	4 (34%)	1 (100%)	1 (100%)	1 (50%)	7 (40%)
Total Distal	8 (66%)	0 (0%)	0 (0%)	1 (50%)	9 (60%)
Total	11* (73%)	1 (7%)	1 (7%)	2 (13%)	

BFlh, biceps femoris long head; BFsh, biceps femoris short head; ST, semitendinosus; SM, semimembranosus; PT, proximal tendon; PMTJ, proximal myotendinous junction; PMFJ, proximal myofascial junction; PMB, proximal muscle belly; DMB, distal muscle belly; DMFJ, distal myofascial junction; DMTJ, distal myotendinous junction; DT, distal tendon. *Note. There were 11 injuries to the BFlh in total; however, one injury spanned two locations (PMFJ and DMFJ) and therefore 12 intramuscular locations are reported for BFlh.

Table 4
Primary and secondary injury sites for more clinically severe injuries with multiple injury sites.

Injuries with multiple injury sites	Primary Injury site		Secondary Injury site	
	Muscle	Intramuscular injury site	Muscle	Intramuscular injury site
Case 1	BFlh	DMB	BFlh	PMB
Case 2	BFsh	PMFJ	BFlh	DMFJ
Case 3	BFlh	PMFJ	ST	DMFJ
Case 4	ST	PMB	BFlh	DMTJ

BFlh, biceps femoris long head; BFsh, biceps femoris short head; ST, semitendinosus; SM, semimembranosus; PT, proximal tendon; PMTJ, proximal myotendinous junction; PMFJ, proximal myofascial junction; PMB, proximal muscle belly; DMB, distal muscle belly; DMFJ, distal myofascial junction; DMTJ, distal myotendinous junction; DT, distal tendon.

transmission, which may influence muscle mechanics (Yucesoy & Huijing, 2007; Zügel et al., 2018). Notably, the morphology of rugby players is unique and adapted to withstand large loads and collisions during scrums, rucks and mauls (Quarrie, Hopkins, Anthony, & Gill, 2013). Therefore, given the distinct morphology of rugby athletes, it is reasonable to suggest that the morphology of the hamstring muscle-tendon complex in rugby athletes may contribute to their increased propensity for injury at the DMFJ (Higham, 2014).

The methods used to classify injury location, as previously reported by Crema et al. (2016) are a strength of the current study. These methods provide a detailed breakdown of injury location by muscle, including the specific tissues involved and longitudinal location. In contrast, previous studies attempting to classify injury site have only considered the longitudinal location of the injury without consideration of the tissues involved (Verrall, Slavotinek, Barnes, & Fon, 2003; Esterman; Verrall, Slavotinek, Barnes, Fon, & Esterman, 2006), or have not reported injury locations for each hamstring muscle separately (Connell et al., 2004; Slavotinek et al., 2002). In fact, many studies have not considered the myofascial junction (MFJ) at all within their methods for classifying injury location (Askling et al., 2007; Cohen et al., 2011). Additionally, definitions describing the fascial location in some classification systems is unclear, and may lead to compromised reliability for reporting of this injury location (Wangensteen et al., 2017). Crema et al. (2016) reported the DMFJ as the third most common injury location for the BFlh in soccer players, with a similar proportion of injuries as the DMTJ. It is likely that many other studies have overlooked or potentially misclassified injuries to the MFJ. Future studies should include the MFJ in their injury site classification, as both the current study and Crema et al. (2016) have demonstrated that these injuries may comprise a large proportion of hamstring injuries when correctly identified.

The injury recurrence rate in this study is lower than previously reported. The rate of recurrent injury in this sample of rugby athletes was 7%, which is much lower than previously reported rates of 23% and 45% in rugby union (Bourne et al., 2015; Brooks et al., 2006). This may be influenced by loss to follow up across the five year study period, as some players left the club within the five year study period. However, in the current study, all recurrent injuries were confirmed by MRI, and were established as a true recurrence of the same muscle injury. While in previous studies, a recurrence was either not clearly defined or based on the judgement of the clinician examining the injury (Bourne et al., 2015; Brooks et al., 2006). Therefore, it is likely that the recurrence definition used in this study provides a more accurate representation of true recurrence of injury to the same muscle.

The average severity of hamstring injuries (days lost from training and competition) reported in this study (median 26 days) is slightly higher than the 17 and 21 days reported in previous studies (Bourne et al., 2015; Brooks et al., 2006). However, it may also be valuable to consider the proportion of injuries in each

severity category, for which the majority (60%) of injuries were moderate (8–28 days lost). This is similar to data previously reported in rugby, and also in soccer where 51% of injuries were classified as moderate using the same severity categories (Ekstrand, Hagglund, & Walden, 2011).

This study is the first to report the timing of hamstring injury across a season in elite rugby union. Overall, the late season was the most common timing of hamstring injury (40% of all injuries). Notably, the number of injuries in the late season was almost double that of early season injuries (12 and 7 injuries, respectively). This may be related to fatigue accumulated across the competition season, and is an important consideration for periodization of training and injury prevention across a season.

This study has several limitations that should be acknowledged. First, it was retrospective in nature, and therefore MRI data was only available for injuries which the team doctor deemed necessary to image at the time of injury. This resulted in a clear selection bias for those injuries to be assessed for injury grade and location via MRI. Hence, the classification of injury location and grade may not be representative of all injuries since minor injuries may only have been assessed with clinical examination or ultrasound. Therefore, the results related to injury location should not be assumed to generalise to minor hamstring injuries. Similarly the grade of injury may have been influenced by the need for an MRI. All injuries in this study were either grade 2 or 3 but this may reflect a tendency for grade 0 and 1 injuries to be clinically assessed without MRI. Therefore, it is possible that grade 0 and 1 injuries are under-reported in this study due to its retrospective design. Further, this limitation resulted in only a small sample of injuries being classified for location and grade. However, the population of rugby athletes at the elite level is relatively small and few studies have described this population. Therefore, the sample obtained in this study is novel and of reasonable size for the population examined. The retrospective nature of this study also prohibited accurate collation of exposure time to training and matches throughout the study period. Therefore, injury incidence was not normalised by exposure. Particular consideration should be given to this when interpreting the proportion of match and training injuries. While the majority of injuries in this study occurred during training (63%) as opposed to matches (37%), it is likely that athletes had far greater exposure times to training compared to matches. Previously, Brooks et al. (2006) reported a greater incidence of injury during matches compared to training in rugby athletes. Therefore, considering the large number of training hours per week relative to game time, it is likely that the rate of injury may be greater in matches when corrected for duration of exposure. Finally, this study utilised a sample of elite rugby players from a single club, and therefore the training and hamstring injury prevention strategies undertaken by the players in this study may not be representative of all rugby players. Caution should therefore be exhibited when generalising these findings to other cohorts such as sub-elite rugby athletes.

The findings of this study are important for informing injury prevention and rehabilitation programs suitable for hamstring injuries in rugby athletes. Injury prevention programs should be designed with consideration to the most common site of injury. Our finding that rugby athletes predominantly incur more severe injuries to the DMFJ in the BFLh suggests that injury prevention programs should include exercises that target the distal region of the BFLh. For example, both the stiff-leg deadlift and Nordic hamstring exercise have shown greater activation in the distal, rather than proximal, region of BFLh and would therefore be suitable to include in a hamstring injury prevention program for rugby athletes (Hegyi, Peter, Finni, & Cronin, 2018; Mendez-Villanueva et al., 2016).

5. Conclusion

This is the first study to classify intramuscular injury location for hamstring injuries in elite rugby union. In contrast to other running-based sports, the most common injury site for clinically more severe injuries was the DMFJ. While the reason for this is unclear and warrants further investigation, this finding is directly applicable to injury prevention program design for rugby athletes. Further, this study highlights the need for future studies to include the MFJ when classifying intramuscular injury location in hamstring injuries.

Ethical approval

This study was approved by the human research ethics committees of the Australian National University (approval no: 2018371), University of Canberra (approval no: 20180268). Reciprocal approval was also granted by the Australian Institute of Sport ethics committee.

Conflicts of interest

We affirm that we have no financial affiliation (including research funding) or involvement in any commercial organization that has direct financial interest in any matter included in this manuscript, except as disclosed in an attachment and cited in the manuscript.

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