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A 2-year prospective study of injury epidemiology in elite Australian rugby sevens: Exploration of incidence rates, severity, injury type, and subsequent injury in men and women

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- 1 **A two-year prospective study of injury epidemiology in elite Australian rugby sevens: exploration of**
- 2 **incidence rates, severity, injury type and subsequent injury in men and women**

1 **ABSTRACT**

2 **Background:** Injuries are common in rugby sevens but studies to date have been limited to short, non-
3 continuous time periods, and reporting of match injuries only.

4 **Purpose:** To report the injury incidence rate (IIR), severity and burden of injuries sustained by men and women
5 in the Australian rugby sevens program; and to provide the first longitudinal investigation of subsequent injury
6 occurrence in rugby sevens, looking beyond tournament-injuries only.

7 **Study design:** Descriptive longitudinal epidemiology study.

8 **Methods:** 90 international rugby sevens players (55 men and 35 women) were prospectively followed over two
9 consecutive seasons (2015-16 and 2016-2017). All medical attention injuries were reported irrespective of time-
10 loss. Individual exposure, in terms of minutes, distance and high speed distance, was captured for each player
11 for matches and on-field training using global positioning system (GPS) devices. The IIR and injury burden (IIR
12 x days lost to injury) were calculated per 1000 player hours, and descriptive analyses performed.

13 **Results:** 73 players (81.1%) sustained 365 injuries at an IIR of 43.2 per 1000 player hours (95%CI 38.8-47.8).
14 Female players experienced a lower but non-significant IIR compared to male players (incidence rate ratio
15 (IRR)=0.91, 95%CI=0.73 to 1.12). Female players sustained a higher proportion of injuries to the trunk region
16 (relative risk (RR)=1.75, 95%CI=1.28 to 2.40) but a lower number to the head/neck region (RR=0.58,
17 95%CI=0.37 to 0.93, p=0.011) compared to male players. The majority (80.7%) of subsequent injuries were of a
18 different site and different nature to previous injuries. A trend towards a reduced number of days, participation
19 time, distance and high speed distance completed prior to the next injury was observed following successive
20 injury occurrence.

21 **Conclusions:** A trend for a lower IIR was observed for female players compared to male players, with variation
22 of injury profiles observed between sexes. Subsequent injuries account for the majority of injuries sustained in
23 rugby sevens, and are typically different to previous types of injuries that have been sustained. Following each
24 successive injury, the risk profile for future injury occurrence appears to be altered, which warrants further
25 investigation to inform injury prevention strategies in rugby sevens.

26

27 **Key terms:** athletic injuries, sports medicine, prospective studies, epidemiology, sports

28

1 **What is known about the subject?**

2 Rugby sevens has become an increasingly popular sport since its introduction into the 2016 Olympic Games.
3 Published injury profiles in rugby sevens are limited by including only tournament-sustained injuries. However,
4 these reports suggest injury risk to be substantially higher than many other sports. There is currently very
5 limited evidence that compares the injury profile from rugby sevens between men and women. No study has
6 examined the characteristics of subsequent injury in rugby sevens previously.

7 **What this study adds to existing knowledge:**

8 This study describes all injury and subsequent injury occurrence for rugby sevens over an extended continuous
9 surveillance period inclusive of both match and training related injuries for both men and women for the first
10 time. The injury profile for male and female players differed, suggesting the need for different priorities for
11 injury prevention strategies based on player sex. Workload and time exposure before injury substantially
12 reduced after the occurrence of each successive injury, suggesting that players might become less tolerant to the
13 physical demands of the sport and increasingly susceptible to subsequent injury following an accumulation of
14 previous injuries. The findings in this paper provide a basis for future exploration into the aetiology and
15 mechanisms of injury, particularly investigating tertiary prevention strategies for mitigating the risk of
16 subsequent injury occurrence in rugby sevens.

1 INTRODUCTION

2 There is a growing interest in the sport of rugby sevens, following its introduction at the 2016 Olympic
3 Games.³⁸ A variant of the traditional 15-a-side rugby union, rugby sevens is comprised of seven players per
4 team competing over two 7-minute halves on a regular size rugby field with similar rules as rugby union.
5 Matches are high-paced³ and, because there are fewer players per side and a shorter duration of play compared
6 to the traditional format, rugby sevens players require different tactics, skills and physical demands.^{33, 34} Recent
7 publications have considered injury, competition, training and match demands of rugby sevens.^{3, 24, 25, 29, 30} Injury
8 comparisons between rugby sevens and union, suggest rugby sevens has a higher rate of injuries that are also
9 typically more severe, causing a longer duration of missed time than injuries in rugby union.^{3, 21} The higher
10 injury rates in rugby sevens have been hypothesised to occur due to faster game play and fewer players, leading
11 to fatigue, coupled with multiple matches played back-to-back over a 2-day tournament-style competition.²³ Not
12 to be discounted is the longer history of injury prevention research and injury prevention measures in rugby
13 union compared to only a small number of descriptive studies in rugby sevens, which are largely limited to elite
14 male cohorts.^{3, 38}

15 The World Series injury reports by World Rugby,¹¹⁻¹⁶ and descriptive injury papers in rugby sevens,^{4, 20, 21, 27}
16 have improved understanding of match injuries, but have not considered injury data reporting across
17 tournaments.^{3, 37} Longer prospective surveillance in rugby sevens cohorts is required to investigate not only the
18 match-focused outcomes, but also to consider injury patterns over successive tournaments as well as training
19 and pre-season periods where a proportion of injuries are likely to occur.^{7, 10, 37} Through monitoring and
20 reporting all of the injuries sustained over time, a greater understanding of the most burdensome injuries that
21 occur in rugby sevens squads can be ascertained. This information is needed to prioritise prevention areas and
22 drive changes to improve player safety.

23 The majority of rugby sevens players will experience multiple injuries over time.³⁷ The probability of an injury
24 (either exactly the same injury or a different injury) is strongly influenced by previous injury occurrences,³⁶ but
25 the inter-relationship between injuries remains poorly understood.^{5, 8, 37} To date, multiple individual injuries in
26 studies of team ball sports have largely been ignored within reporting and analyses or they have been addressed
27 through a restricted definition of 'recurrence' only.¹⁰ Recurrent injuries include only those with the exact same
28 nature and at the exact same site of an earlier sustained injury.¹⁹ Identification that recurrent injuries only
29 account for a small proportion of subsequent injuries,^{1, 5, 6, 31, 37} justifies the objective to look more broadly at

1 relationships between injuries of a different body part and nature to assist in the development of successful
2 injury prevention strategies that account for these relationships.^{5, 6, 36, 37}

3 Gaining a detailed understanding of the injury characteristics in rugby sevens is essential to guide future injury
4 prevention strategies specifically targeted to the needs of rugby sevens players.²⁶ The Australian rugby sevens
5 program includes both a men's and women's squad. Both squads utilise the same injury reporting and workload
6 capture methodologies, providing a unique situation to accurately compare injury patterns from both the men's
7 and women's teams. The aims of this study were firstly to report the frequency, severity, incidence and burden
8 of injuries sustained by men and women in the Australian rugby sevens program and secondly, to provide the
9 first detailed longitudinal investigation of subsequent injury occurrence in rugby sevens, looking beyond match-
10 loss injuries only.

11

12 **METHODS**

13 **Study design and population**

14 All members of the men's and women's Australian international rugby sevens squads were prospectively
15 followed over two consecutive seasons (Season 2015/16: September 1st 2015 to August 31st 2016; Season
16 2016/17: September 1st 2016 to August 31st 2017). All injuries that were sustained during the surveillance
17 period, including during the pre-season, in-season and off-season periods, were recorded with no players
18 excluded from the analysis. Players within the national squads train throughout the year and play intermittently
19 in international competitions (World Rugby Sevens Series). The reporting of this study follows the
20 Strengthening the Reporting of Observational studies in Epidemiology (STROBE) statement.³⁹

21 Ethics approval was obtained from [REDACTED] (C17-006). All
22 participants provided written consent for the Australian Rugby Union (ARU) to share their injury and match
23 data prior to participation. Data were provided to the research team in a format re-identifiable only to the ARU
24 data management team, using a unique player ID code.

25 **Injury definitions**

26 An injury was defined as a medically diagnosed physical complaint that was sustained while undertaking rugby
27 training or rugby competition that resulted in loss or abnormality of bodily structure or functioning, irrespective
28 of time-loss from rugby activities.¹⁹ This is consistent with the medical-attention injury definition described in

1 the rugby union consensus statement on recording and reporting injury.¹⁹ Injuries were sub-categorised as time-
2 loss injuries when the injury caused the player to be unable to participate in rugby training or competition, for
3 greater than 24 hours following the day of injury, irrespective of whether match or training sessions were
4 actually scheduled.¹⁹ Injuries to specific body sites were categorised into body regions according to the rugby
5 union injury reporting consensus guidelines.¹⁹ A subsequent injury was defined as any injury sustained
6 following the initial injury sustained within the surveillance period⁵ and further sub-categorised retrospectively
7 into one of the eight data-driven categories of the revised subsequent injury categorisation model (SIC-2.0)
8 using the automated coding methods that have been published and described in detail elsewhere.³⁷

9 **Injury data collection**

10 All injury data were prospectively collected and recorded in a centralised database (Smartabase, Fusion Sport
11 Pty Ltd, Brisbane Australia) by the teams' qualified medical personnel (sports physiotherapist or sports
12 physician). Each injury was assigned a four-character Orchard Sports Injury Classification System 10 (OSICS-
13 10.1) injury diagnosis code, which details the body part and nature of the injury sustained.³² In addition,
14 information was recorded to identify the body side of the injury (i.e. left, right, bilateral, central), date of injury
15 occurrence, date of return to training, date of full injury resolution, the number of days the player was unable to
16 participate both fully and partially in rugby training and/or competition. Information about the specific injury
17 mechanism and activity were not used in this study due to their inconsistent recording in the database. All data
18 were linked by a unique ID and injuries were time ordered according to the date of injury for each injured
19 player, in accordance with published data guidelines.⁷

20 **Collection and quantification of rugby sevens exposure**

21 Individual player exposure was prospectively captured throughout the surveillance period for all on-field
22 training sessions and matches using a global positioning system (GPS) device (GPSports, SPI HPU, Canberra,
23 Australia). These data were uploaded and stored in a centralised database (Smartabase, Fusion Sport, QLD,
24 Australia). Data were provided to the research team in a de-identifiable format, using the same unique ID used
25 for the injury data, allowing the two data sets to be linked.

26 Multiple external loads were measured using the GPS units. Duration was defined as the total time (minutes)
27 elapsed during rugby training or competition related activity including warm-up and cool-down periods;
28 distance was defined as the total distance covered (m), including walking, running and sprinting; and high speed
29 running was defined as the total distance covered (m) for running speeds captured greater than 5m/s. In the

1 instances where a player completed multiple training sessions or multiple games on the one date, sessional data
2 was collapsed to obtain a daily total of the distance covered and duration completed for these dates.

3 **Analyses**

4 Descriptive analyses were performed separately for men and women to enable comparison to previous literature.
5 Descriptive data are presented both separately and combined for injuries sustained in each year of surveillance,
6 corresponding to the 2015-16 and 2016-17 Sevens World Series seasons. The magnitude of difference between
7 the proportions of specified injury variables in men and women were measured by relative risks (RR), with men
8 as the reference category (RR=1.00), and their associated 95% CIs, with Fisher's exact test used to test for
9 significance set a priori at p-value <0.05.²⁸

10 Injury incidence rates for men and women, for each season, were calculated using the following formula:
11 number of injuries/exposure in hours (individual hours collected from GPS) x1000. Poisson 95% CIs for
12 incidence rates were calculated, and incidence rates were assessed using incidence rate ratios (IRRs) and their
13 associated 95% CIs. Statistically significant differences were determined when the 95% CIs did not include
14 IRR=1.0. Injury burden was calculated using the following formula: mean severity (number of days lost before
15 full return to training/match) x injury incidence. The ten injuries with the largest burden for each sex were
16 plotted graphically in an injury risk (burden) matrix, where the mean injury severity (time-loss days) was plotted
17 against the injury incidence.^{17, 18} All statistical analyses was performed in Stata (Stata/IC 15.1, StataCorp, USA).

18

19 **RESULTS**

20 **Participation and injury occurrence**

21 A total of 90 players (55 men and 35 women) were under surveillance during the 2-year period over which a
22 total of 8457 on-field player participation hours were completed. Of these players, 42 (20 men and 22 women)
23 participated in both the 2015-16 and 2016-17 seasons. A total of 365 injuries were reported over the 2-year
24 surveillance period, sustained by 73 players (81.1%) at an incidence rate of 43.2 (38.8 to 47.8) per 1000 player
25 hours. A 36% increase in the rate of injuries was observed in the 2016-17 season compared to the 2015-16
26 season (IRR=1.36, 95%CI=1.10 to 1.70), which was similarly found in the men's squad (IRR=1.39,
27 95%CI=1.05 to 1.85), however this was not significant in the women's squad (IRR=1.32, 95%CI=1.94 to 1.87).
28 The majority of reported injuries (79.2%) resulted in time-loss from training or competition (Table 1).

1 **Type of injuries sustained**

2 The majority of injuries sustained were to the lower-limb (58.3%) or upper-limb (21.4%), which resulted in a
3 median time-loss periods of 14 days (interquartile range (IQR)=43) and 15 days (IQR=45), respectively. More
4 specifically, the knee (13.2%), head (12.6%), and thigh (12.6%) were the most common body sites injured, with
5 median time-loss periods of 30 days (IQR=91), 8 days (IQR=16), and 15 days (IQR=30). More than a quarter
6 (25.2%) of all injuries were joint sprains and 16.7% of injuries were of a muscular nature, where median time-
7 loss periods of 23 days (IQR=49) and 11 (IQR=22) occurred, respectively (Table 2).

8 **Comparison of injury in men and women**

9 From the men's squad, forty-six (83.6%) players (age=24.0±3.8) sustained a total of 213 injuries (median=3,
10 IQR=6, range 1-12), while from the women's squad 27 (77.1%) players (age=22.9±3.1) sustained 152 injuries
11 (median=4, IQR=6, range=1-15) over the 2-year surveillance period. Players from the women's squad
12 (IIR=40.8, 95%CI=34.5, 47.8, per 1000 player hours) were found to have a lower but non-significant IIR
13 compared to the men's squad (IIR=45.0, 95%CI=39.2, 51.5, per 1000 player hours) (IRR=0.91, 95%CI=0.73 to
14 1.12). This finding was also observed for the 2015-16 season (IRR=0.93, 95%CI=0.63 to 1.31), the 2016-17
15 season (IRR=0.88, 95%CI=0.67 to 1.16), and for those players who participated in both seasons (IRR=0.99,
16 95%CI= 0.77 to 1.27). Compared with the men's squad, the women's squad had a lower but non-significant
17 rate of both time-loss injuries (IRR=0.90, 95%CI=0.71 to 1.14), and non-time loss injuries (IRR=0.92,
18 95%CI=0.57 to 1.49).

19 When compared to the men's squad, women were more likely to sustain an injury to the trunk region (RR=1.75,
20 95%CI=1.28 to 2.40, p=0.010), but were less likely to sustain an injury to the head/neck region (RR=0.58,
21 95%CI=0.37 to 0.93, p=0.011). More specifically, women had an increased RR of sustaining a hip/groin injury
22 (RR=1.67, 95%CI=1.22 to 2.28, p=0.017), and an increased risk in sustaining a lumbar spine injury (RR=1.91,
23 95%CI=1.38 to 2.64, p=0.018) compared to men. Players in the men's squad were 46% more likely to sustain an
24 injury to the head (RR=0.54, 95%CI=0.32 to 0.92, p=0.010) compared to players in the women's squad. There
25 were no other identifiable differences between the men and women in terms of body site injured and no
26 identifiable differences in terms of the nature of the injuries sustained (Table 2).

1 **Table 1** Summary of injury distribution characteristics, players injured and incidence rate across the 2-seasons (n=90 rugby sevens players)

	Season 2015/16 ^a			Season 2016/17 ^a			Total ^b			Seasons 2015/16 & 2016/17 ^c		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Total players, n	35	27	62	40	30	70	55	35	90	20	22	42
Injured players (%)	27 (77.1)	23 (85.2)	50 (80.6)	31 (77.5)	22 (73.3)	53 (75.7)	46 (83.6)	27 (77.1)	73 (81.1)	19 (95.0)	21 (95.5)	40 (95.2)
Non-injured players (%)	8 (22.9)	4 (14.8)	12 (19.4)	9 (22.5)	8 (26.7)	17 (24.3)	9 (16.4)	8 (22.9)	17 (18.9)	1 (5.0)	1 (4.5)	2 (4.8)
Total injuries sustained	83	58	141	130	94	224	213	152	365	130	140	270
Time loss (%)	73 (88.0)	49 (84.5)	122 (86.5)	96 (73.8)	71 (75.5)	167 (74.6)	169 (79.3)	120 (78.9)	289 (79.2)	109 (83.8)	109 (77.9)	218 (80.7)
Non-time loss (%)	10 (12.0)	9 (15.5)	19 (13.5)	34 (26.2)	23 (24.5)	57 (25.4)	44 (20.7)	32 (21.1)	76 (20.8)	21 (16.2)	31 (22.1)	52 (19.3)
Median number of injury (IQR)	2 (2)	2 (2)	2 (2)	3 (4)	3(5)	3 (4)	3 (6)	4 (6)	3.5 (6)	7 (5)	6 (4)	7 (4)
Injury range	0-8	0-5	0-8	0-10	0-10	0-10	0-12	0-15	0-15	0-12	0-15	0-15
Injury incidence rate ^d	37.3	34.6	36.2	51.9	45.8	49.2	45.0	40.8	43.2	41.9	41.4	41.6
95%CI for incidence rate	29.7-46.3	26.3-44.7	30.4-42.6	43.4-61.6	37.0-56.1	42.9-56.0	39.2-51.5	34.5-47.8	38.8-47.8	35.0-49.7	34.8-48.9	36.8-46.9
Number of players (%) with:												
0 injurie	8 (22.9)	4 (14.8)	12 (19.4)	9 (22.5)	8 (26.7)	17 (24.3)	9 (16.4)	8 (22.9)	17 (18.9)	1 (5.0)	1 (4.5)	2 (4.8)
1 injury	4 (11.4)	6 (22.2)	10 (16.1)	5 (12.5)	4 (13.3)	9 (12.9)	8 (14.5)	3 (8.6)	11 (12.2)	0 (0.0)	0 (0.0)	0 (0.0)
2 injuries	7 (20.0)	7 (25.9)	14 (22.6)	5 (12.5)	1 (3.3)	6 (8.6)	8 (14.5)	2 (5.7)	10 (11.1)	2 (10.0)	1 (4.5)	3 (7.1)
3-4 injuries	11 (31.4)	7 (25.9)	18 (29.0)	8 (20.0)	9 (30.0)	17 (24.3)	8 (14.5)	8 (22.9)	16 (17.8)	3 (15.0)	6 (27.3)	9 (21.4)
5-6 injuries	4 (11.4)	3 (11.1)	7 (11.3)	6 (15.0)	4 (13.3)	10 (14.3)	8 (14.5)	4 (11.4)	12 (13.3)	2 (10.0)	4 (18.2)	6 (14.3)
7-8 injuries	1 (2.9)	0 (0.0)	1 (1.6)	5 (12.5)	2 (6.7)	7 (10.0)	8 (14.5)	7 (20.0)	15 (16.7)	6 (30.0)	7 (31.8)	13 (31.0)
9-10 injuries	0 (0.0)	0 (0.0)	0 (0.0)	2 (5.0)	2 (6.7)	4 (5.7)	4 (7.3)	0 (0.0)	4 (4.4)	4 (20.0)	0 (0.0)	4 (9.5)
11-15 injuries	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (3.6)	3 (8.6)	5 (5.6)	2 (10.0)	3 (13.6)	5 (11.9)

- 1 ^a Injuries are only reported under 2015/16 or 2016/17 if they were sustained during that season; that is if a player sustains 6 injuries in the 2015/16 season they are
2 considered under the “Number of players with 5-6 injuries” row
- 3 ^b The accumulated total of injuries throughout the 2-seasons of surveillance; inclusive of all 90 players who were under surveillance for at least 1-season; if an athlete who
4 was involved for both seasons sustained 12 injuries throughout this period they are considered under the “Number of players with 11-15 injuries” row
- 5 ^c The players who were involved during both the 2015/16 and 2016/17 seasons are included in this section, and these results represent the total of their injuries sustained over
6 the two seasons combined
- 7 ^d Injuries per 1000 player hours
- 8 n= number of players

1 **Table 2** Distribution and days of time-loss for all injuries sustained across the 2015/16-2016/17 seasons by body region, body site, injury nature (total of 73 injured players
 2 (46 men and 27 women) over the 2-year surveillance period)

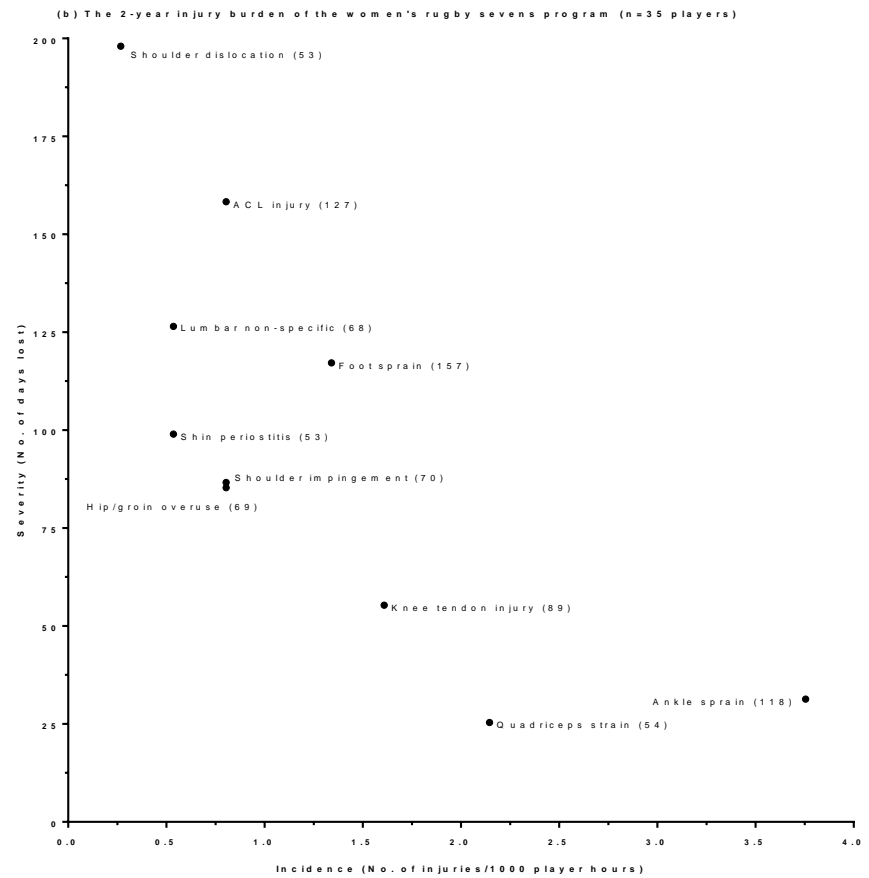
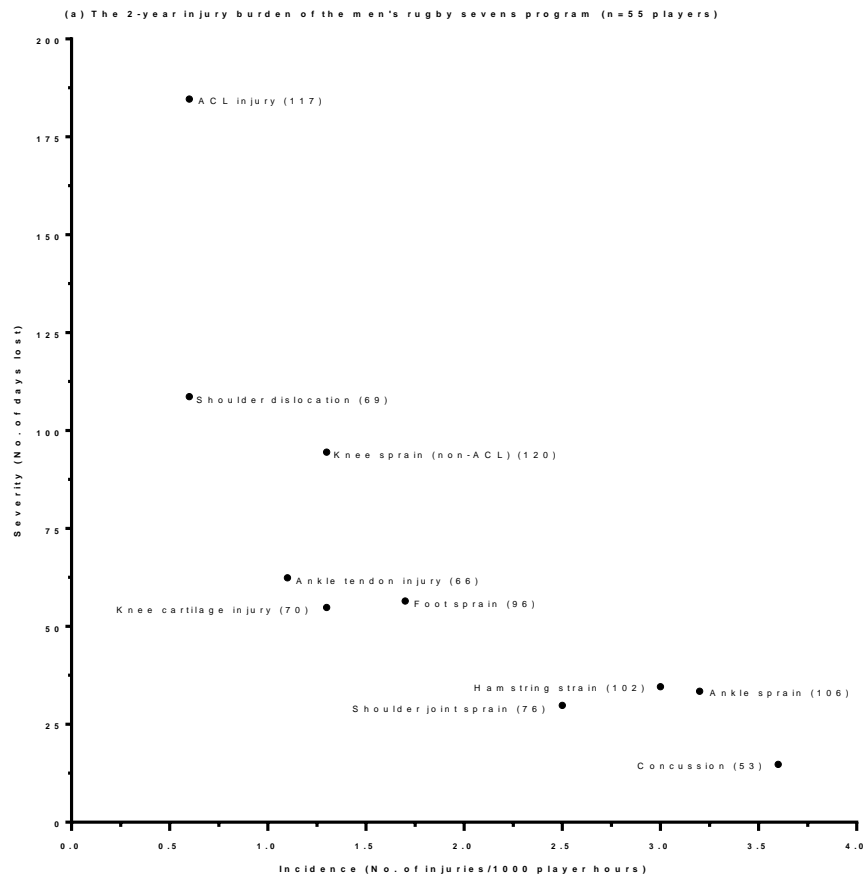
	Male			Female			Total			RR ^b	95%CI	p-value
	n	%	days ^a (IQR)	n	%	days ^a (IQR)	n	%	days ^a (IQR)			
Region injured												
Lower limb	117	54.9	16 (41)	96	63.2	13 (47)	213	58.3	14 (43)	1.22	0.95, 1.58	0.132
Upper limb	50	23.5	14 (37)	28	18.4	29 (50)	78	21.4	15 (45)	0.83	0.60, 1.15	0.300
Head/neck	40	18.8	10 (22)	14	9.2	9 (12)	54	14.8	9 (20)	0.58	0.37, 0.93	0.011*
Trunk	6	2.8	12 (28)	14	9.2	11 (22)	20	5.5	11 (28)	1.75	1.28, 2.40	0.010*
Site injured												
Knee	28	13.2	25 (45)	20	13.2	53 (119)	48	13.2	30 (91)	1.00	0.70, 1.43	1.000
Head	35	16.4	7 (20)	11	7.2	8 (13)	46	12.6	8 (16)	0.54	0.32, 0.92	0.010*
Thigh	29	13.6	16 (30)	17	11.2	11 (34)	46	12.6	15 (30)	0.87	0.59, 1.30	0.526
Shoulder	27	12.7	24 (50)	16	10.5	41 (65)	43	11.8	28 (50)	0.88	0.59, 1.33	0.622
Ankle	22	10.3	20 (65)	19	12.5	11 (31)	41	11.2	13 (50)	1.13	0.79, 1.61	0.614
Wrist/hand	22	10.3	2 (13)	7	4.6	2 (29)	29	8.0	2 (13)	0.56	0.29, 1.08	0.051
Hip/groin	8	3.8	10 (74)	16	10.5	16 (38)	24	6.6	14 (38)	1.67	1.22, 2.28	0.017*
Pelvis/buttock	12	5.6	13 (25)	9	5.9	0 (5)	21	5.8	5 (24)	1.03	0.62, 1.71	1.000
Foot	11	5.2	22 (22)	7	4.6	4 (257)	18	4.9	16 (28)	0.93	0.51, 1.68	1.000
Calf/shin	7	3.3	7 (29)	8	5.3	11 (60)	15	4.1	7 (28)	1.30	0.79, 2.12	0.425
Lumbar	3	1.4	33 (102)	10	6.6	11 (22)	13	3.6	12 (33)	1.91	1.38, 2.64	0.018*
Other	4	1.9	5 (8)	9	5.9	19 (42)	13	3.6	14 (29)	1.70	1.16, 2.50	0.048*
Neck	5	2.4	26 (5)	3	2.0	12 (50)	8	2.2	25 (27)	0.90	0.36, 2.22	1.000
Injury nature												
Joint sprain	55	25.8	23 (49)	37	24.3	28 (49)	92	25.2	23 (49)	0.95	0.72, 1.27	0.807

Muscle injury	30	14.1	15 (30)	31	20.4	9 (16)	61	16.7	11 (22)	1.28	0.96, 1.69	0.119
Haematoma/laceration	33	15.5	8 (7)	16	10.5	17 (20)	49	13.4	9 (11)	0.75	0.50, 1.16	0.213
Tendon injury	25	11.7	20 (26)	19	12.5	4 (58)	44	12.1	10 (57)	1.04	0.72, 1.50	0.871
Cartilage injury/impingement	21	9.9	23 (33)	13	8.6	12 (46)	34	9.3	19 (30)	0.91	0.58, 1.42	0.718
Neural/CNS injury	17	8.0	12 (15)	6	4.0	8 (10)	23	6.3	11 (9)	0.61	0.30, 1.23	0.132
Other	9	4.2	28 (38)	13	8.6	44 (93)	22	6.0	28 (84)	1.46	1.01, 2.11	0.117
Joint dislocation/instability	12	5.6	16 (78)	8	5.3	64 (125)	20	5.5	32 (119)	0.96	0.55, 1.66	1.000
Bone injury	11	5.2	25 (35)	9	5.9	19 (46)	20	5.5	23 (42)	1.09	0.66, 1.79	0.817
Total	213	100.0	14 (29)	152	100.0	13 (46)	365	100.0	13 (34)			

1 ^aThe median number of days of time-loss

2 ^bRR=relative risk calculated using Fisher's exact test comparing the injuries between men and women with men as the reference category

3 IQR=interquartile range; n=number of injuries; CI=confidence interval; * indicates a statistically significant difference



1

2 **Fig 1** Relationship between the injury burden (number of injuries/1000 player hours x total days lost to injury (i.e. severity)) for the ten injury types with the largest burden
 3 for the men's and women's rugby sevens squads

1 The injuries with the highest burden for the men's squad were non-ACL knee injuries (120 days absence/1000
2 player-hours), ACL knee injuries (117 days absence/1000 player-hours, and ankle sprains (106 days
3 absence/1000 player-hours). In the women's squad, the highest burdens were attributable to foot sprains (157
4 days absence/1000 player-hours), ACL injuries (124 days absence/1000 player-hours) and ankle sprains (118
5 days absence/1000 player-hours). Other notable differences in injury burden between the two squads included
6 the men having a higher burden compared to the women for hamstring strains (103 compared with 31 days
7 absence/1000 player-hours) and concussion (53 compared with 9 days absence/1000 player-hours) (Fig 1).

8 **Subsequent injuries**

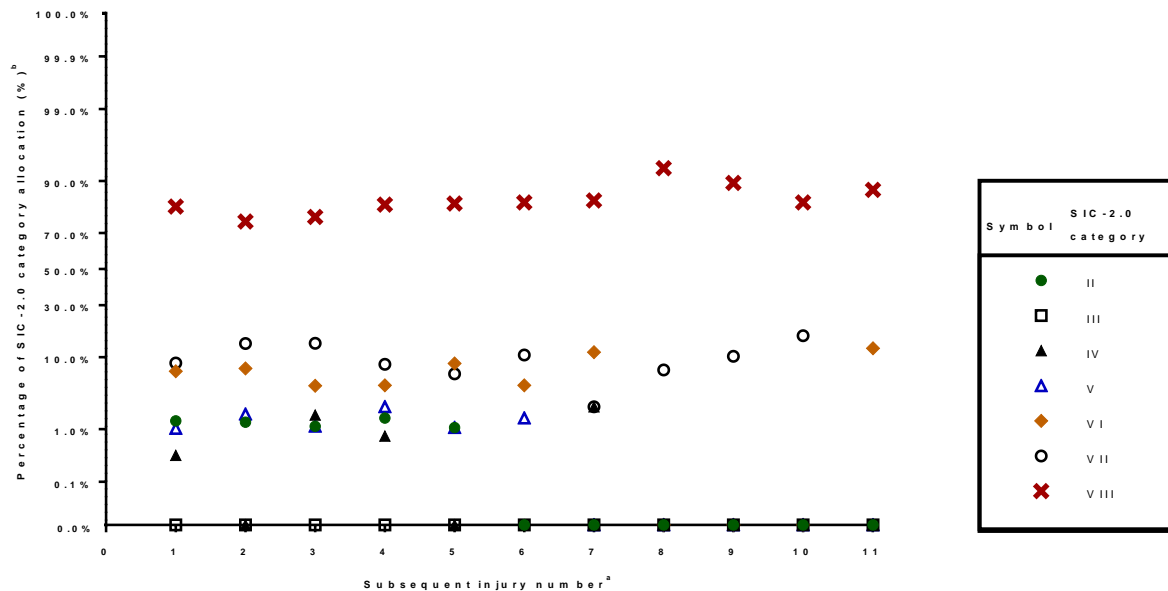
9 Over the 2-year period, 38 (69.1%) men and 24 (68.6%) women sustained at least two injuries. Overall, the
10 median number of injuries increased from 2 (range=0-8) in the 2015-16 season to 3 (range=0-10) in the 2016-17
11 season. Of the 42 players who participated in both seasons, 40 (95.2%) sustained at least one subsequent injury,
12 with 5 (11.9%) sustaining between 11 and 15 injuries over the 2-year period.

13 The majority (80.7%) of subsequent injuries sustained were to a different site and of a different nature (SIC-2.0
14 category VIII), with 10.3% of all subsequent injuries to a different site but of the same nature (SIC-2.0 category
15 VII (injury) and 6.1% to the same site but of a different nature (SIC-2.0 category VI (injury) (Fig 2.) The SIC-
16 2.0 category allocation for each injury number sustained demonstrates that for each successive injury sustained,
17 the general category allocation of subsequent injury types remains quite constant. The SIC-2.0 category VIII
18 was clearly the most common category type over each injury number (75.6% to 92.3%), with small deviations
19 noted for categories VI and VIIs over successive injury occurrences. The subsequent injury SIC-2.0 categories II
20 (re-injury after recovery, to the same site, same nature, same side, and same structure), III (exacerbation before
21 recovery, to the same site, same nature, same side, and same structure), IV (injury to the same site, same nature,
22 same side, but of a different structure) and V (injury to the same site, same nature, but different side of the body)
23 accounted for less than 2.9% of all subsequent injury relationship to previous injuries.

24 Following an initial injury, the severity of time loss days for each successive injury declined. Injuries sustained
25 following the fourth injury were typically of a reduced severity than the injuries that preceded them (Fig 3). A
26 general decline in the volume of workload completed preceding each successive injury was observed with each
27 successive injury sustained (Fig 4). The number of days remaining injury free before injury occurrence reduces
28 gradually as each successive injury was sustained, indicating that the days of survival, remaining injury free, in
29 rugby sevens participation is reduced with each successive injury. A similar trend was also observed for the

1 number of on-field minutes participated in before the occurrence of each injury. Accumulated workloads
 2 measured in total distance covered and running high speed metres before injury occurrence, were also observed
 3 to generally decline as a larger number of successive injuries are sustained.

4



5

6 **Fig 2** The distribution of subsequent injury categories (SIC-2.0) for each individual injury number sustained

7 ^a Successive subsequent injury counts greater than 11 were not included as only one player sustained more than
 8 12 injuries

9 ^b Probability percentage scale, SIC-2.0 category allocation percentage

10 *Legend for the key titled SIC-2.0 category:*

11 SIC-2.0 II - Re-injury after recovery, to the same site, same nature, same side, and same structure

12 SIC-2.0 III - Acute or continual/sporadic exacerbation before recovery, to the same site, same nature, same side,
 13 and same structure

14 SIC-2.0 IV - Injury to the same site, same nature, same side, but of a different structure

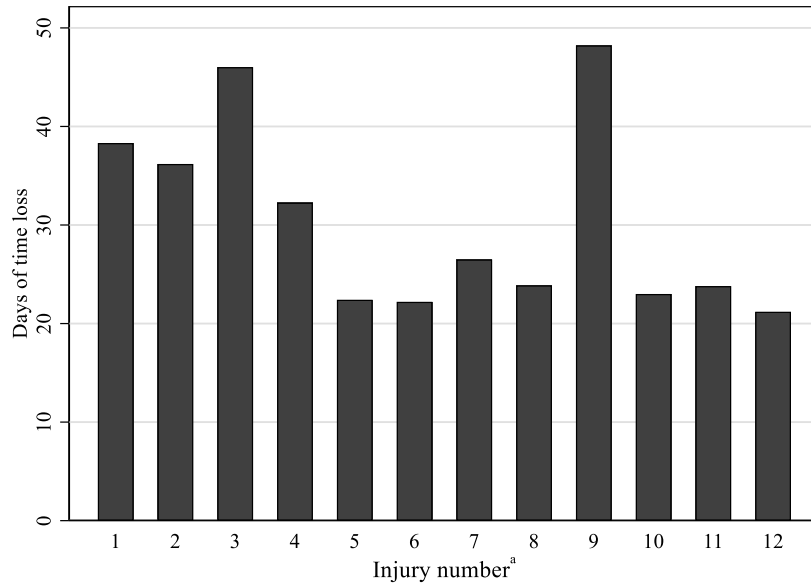
15 SIC-2.0 V - Injury to the same site, same nature, but different side of the body

16 SIC-2.0 VI - Injury to the same site but of a different nature

17 SIC-2.0 VII - Injury to a different site, but of the same nature

18 SIC-2.0 VIII - Injury to a different site and of a different nature

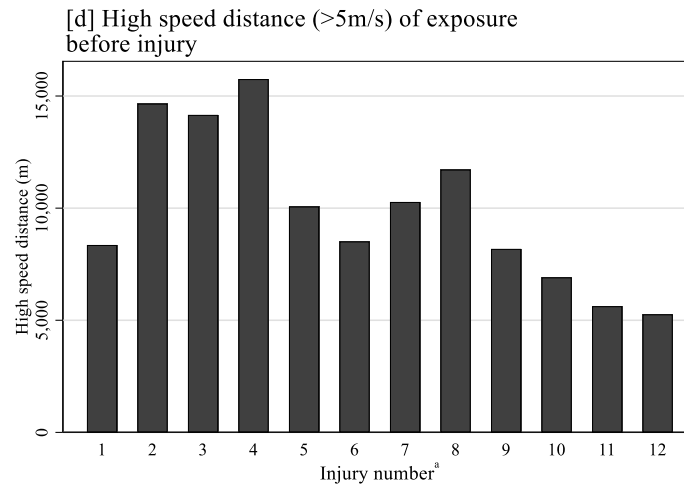
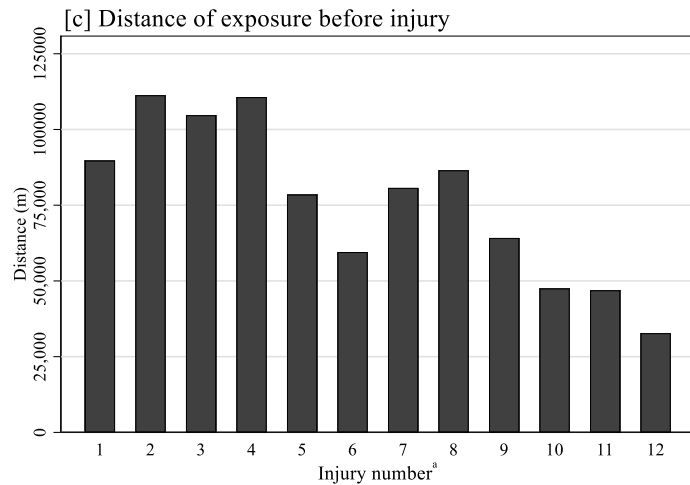
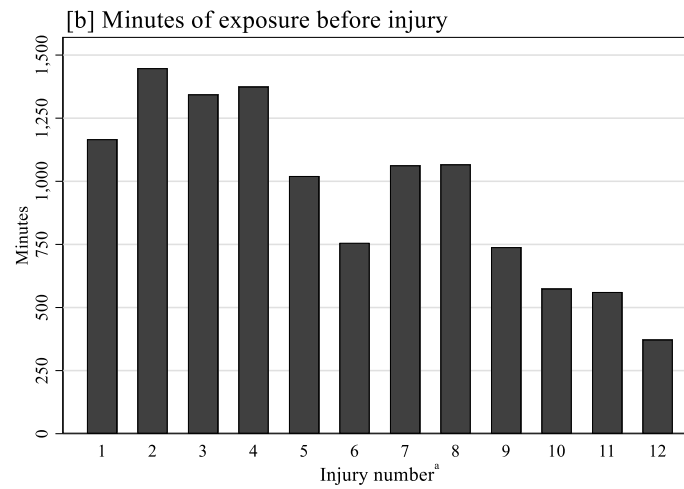
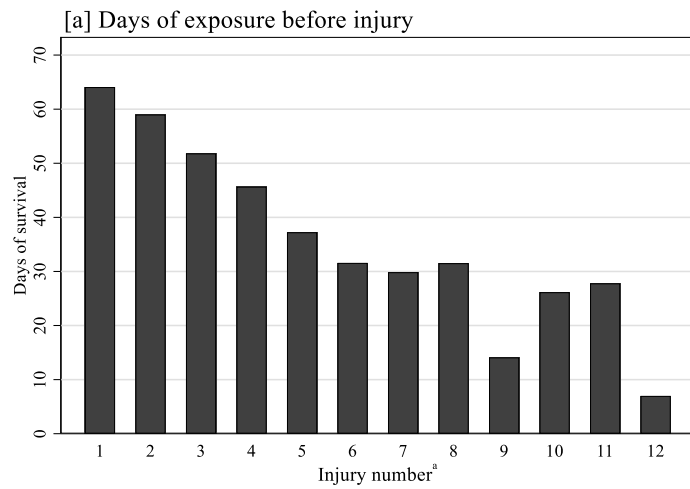
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1

2 **Fig 3** Time loss days (mean) for each successive injury sustained (n=362 injuries in 72 rugby sevens players)

3 ^a Successive injury counts greater than 12 were not included as only one player sustained more than 12 injuries



1
 2 **Fig 4** The mean exposure before the occurrence of each successive injury sustained (n=362 injuries in 72 rugby sevens players)
 3 ^a Successive injury counts greater than 12 were not included as only one player sustained more than 12 injuries

1 **DISCUSSION**

2 This study is the first to describe injury and subsequent injury occurrence for rugby sevens over an extended
3 continuous surveillance period inclusive of both match and training related injuries for both men and women.
4 The men were found to have an increased risk of sustaining an injury compared to the women, with differences
5 in injury profiles observed between men and women. More than two-thirds of the players sustained at least one
6 subsequent injury, with the majority of subsequent injuries occurring at a different site and of a different nature
7 to previous injuries. Workload and time exposure before injury was observed to substantially reduce after the
8 occurrence of each successive injury, suggesting that a player commonly becomes less tolerant to the required
9 workloads and increasing susceptible to subsequent injury following an accumulation of previous injuries.
10 These findings provide a basis for future exploration into the aetiology and mechanisms of subsequent injury,
11 particularly investigating tertiary prevention strategies for mitigating the risk of subsequent injury occurrence in
12 rugby sevens.

13 **Injury occurrence**

14 The 2-year injury incidence rate of 40.8 and 45.0 per 1000 player hours respective for the women's and men's
15 programs, were lower than previously reported in men's rugby sevens, where incidence rates have been as high
16 as 119.8 per 1000 hours.³ Previous research has been limited to recording player exposure and injuries during
17 tournaments only,^{3, 22, 29} whereas this study also considered training sessions completed outside of tournaments.
18 Training represents a significant proportion of the workload completed over the season, therein serving to dilute
19 the injuries with greater exposure hours, which could explain why the IIRs reported in this study are lower than
20 those previously published in men's rugby sevens.²⁴ There have been few data reported in elite female rugby
21 sevens players to date, but the findings here are similar to those reported in a cohort of elite American players
22 where an IIR of 46.4 per 1000 player hours was found over a 4-year surveillance period using a time-loss match
23 only injury definition.²⁹ The increase in the rate of injuries for both the men's and women's squads over the
24 2015-16 and 2016-17 seasons was a finding of interest. It is possible that this increase could be explained
25 through improved injury reporting practices by the squad's medical staff in the second season of the study,
26 however this hypothesis warrants further investigation.

27 **Different injury profiles in men's and women's rugby sevens**

28 In many contact sports, differences in injury profiles are apparent in men and women, with key examples of
29 higher ACL in the knee, concussion and wrist/hand fractures in women.⁹ Challenges in comparing injury types

1 between sexes exist as often data is collected in different ways across studies. In this study, the data collection,
2 injury definitions and local training facilities were homogeneous for men and women supporting the direct
3 comparison of injury types. The differences observed, between sexes, may be accounted for by specific styles of
4 play or training modalities, though further investigation to clarify the injury disparity between sexes is needed.
5 Identification that injuries profiles are different for men and women, informs future injury prevention research
6 that prevention strategies made need to be tailored according to gender.

7 **Subsequent injury characteristics in rugby sevens**

8 Subsequent injury occurrence accounted for the majority of injuries sustained, which has been previously
9 established in other contact and team ball sports.^{10, 36} The finding that the majority of subsequent injuries were to
10 a different site and different nature (SIC-2.0 category VIII), is comparable to the findings previously identified
11 in Australian rugby sevens players where 78.7% of all subsequent injuries were found to be SIC-2.0 category
12 VIII subsequent injuries.³⁷ The small variation in the distribution of SIC-2.0 category allocation when analysed
13 over a number of successive injuries suggests that the relationship between injury and previous injury does not
14 substantially change over time as more injuries are sustained.

15 Contrary to previous research in rugby union, the severity of injury was not found to increase with a greater
16 number of injuries being sustained.⁴¹ In fact, an overall trend in injury severity reduction was observed
17 following the fourth occurrence of injury. Recent research in subsequent injury occurrence in rugby union, has
18 also demonstrated that subsequent injury occurrence was not associated with an increased severity of injury
19 compared to previous injuries.⁴⁰ Future research should focus on the effect of accumulated days lost through
20 multiple injury occurrences rather than the severity of each injury being the prime focus in injury analysis.

21 The reduction in time and workload exposure preceding injury occurrence observed with successive injury
22 occurrence, suggests that player robustness to injury was reduced as a greater number of injuries were sustained.
23 This indicates that a player is completing smaller on-field workload volumes before the onset of successive
24 subsequent injuries, meaning that they survival for shorter volumes of training before they sustain the next
25 subsequent injury. Time to injury has been demonstrated to be progressively shorter following the occurrence of
26 an increasing number of injuries in Australian football within a singular season.⁶ It has been proposed that
27 substantial workload completion following an injury should be a key consideration in the return to play (RTP)
28 decision process to reduce the risk for future injury occurrence.² In elite Australian football, an accelerated
29 rehabilitation process following injury to expedite the RTP process was associated with a higher risk of

1 subsequent injury.³⁵ Protective effects against future subsequent injury were seen when RTP was delayed,
2 possibly due to the greater accumulated running and high speed running workloads.³⁵ The reduced durations and
3 distances completed by the players in this present study with increases in subsequent injury occurrence, suggests
4 a possible causal link between workload and risk of subsequent injury.

5 Our injury results have new implications for clinical practice in the areas of injury rehabilitation and return to
6 play. While subsequent injuries may not be of increased severity, the time a player remains injury free following
7 injury appears to reduce, resulting in an increased accumulated injury burden overall. Investigation into
8 associated injury aetiology and mechanisms of subsequent injury occurrence to guide the development of
9 tertiary injury prevention strategies is warranted to mitigate the risk of subsequent injury occurrence in rugby
10 sevens.

11 **Strengths and limitations**

12 This study provides a comprehensive overview of match and training injury in rugby sevens, including male and
13 female elite players over two seasons .The use of individual player GPS data allowed for accurate exposure
14 measures to be used, removing the assumptions that are commonly made in exposure calculations when
15 estimates of player minutes are derived from team averages, which is a limitation of previous research in rugby
16 sevens.³

17 Similar to previous research in rugby sevens, exposure measures only accounted for time on-field, excluding the
18 effect of other training modalities such as gym and weights sessions. These training sessions are likely to
19 influence injury risk, so future capture and quantification of these sessions should be considered. A number of
20 the players within the squads did not complete both seasons, nor did all players complete the entirety of a
21 season. Therefore, the injury results may be biased by those players who were under surveillance for a longer
22 duration and who would also have been more likely to sustain an injury because of longer periods of exposure.
23 Relationships to any injuries that were sustained prior to the surveillance period could not be analysed. This
24 remains a limitation to all subsequent injury research and application of existing subsequent injury
25 frameworks.^{5, 37} There was incomplete capture of injury mechanism and activity data and these variables
26 were not included in the analysis, which was a limitation of this study.

27

28 **Recommendations for future research**

1 As demonstrated in this study, it is important that injury studies in rugby sevens moves towards longitudinal
2 analysis, extending beyond single tournaments or match-only injuries.^{7, 10} The links identified between
3 subsequent injuries in rugby sevens should be explored as there are important implications on future injury risks
4 following an accumulation of previous injuries. This will help to inform the development of future targeted
5 injury prevention programs in rugby sevens.

6

7 **CONCLUSION**

8 A trend for a higher IIR in male players was observed compared to the female players, with distinct differences
9 in injury profiles identified between both groups. The most commonly injured sites were the head, thigh and
10 knee for men and the knee, ankle and thigh for women. The injury types with the largest burden were non-ACL
11 knee and ACL injuries for men, and foot sprains and ACL injuries for women. Rugby sevens players commonly
12 sustained multiple subsequent injuries which were typically different to their previous injuries. With successive
13 subsequent injury occurrence, player susceptibility to future injury appears to increase. Thus, following injury
14 the risk profile for future injury occurrence is altered. This research serves as an important start point for further
15 investigation of injury aetiology and mechanisms in rugby sevens to inform injury prevention strategies.

16

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