Descriptive epidemiology of injuries in Japanese male collegiate rugby union players

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Abstract To the best of our knowledge, most previous studies regarding the epidemiology of injuries in rugby union (rugby) players have focused on professional players. Therefore, data on injuries in collegiate rugby players in Japan is limited. The purpose of this study was to conduct a prospective injury survey of Japanese male collegiate rugby players over several years and to analyze the injuries that occurred during matches and training according to field position, type of injury, and mechanism of injury. This prospective study initially registered 128 rugby players from one university club. The occurrence of injuries was recorded by athletic trainers during the rugby seasons between 2017 and 2019. The total injury rate (IR) was 7.26 injuries/1000 player-hours (1000 PHs). The match IR (122.73 injuries/1000 PHs) was almost 31.9 times higher than the training IR (3.84 injuries/1000 PHs). Ankle sprains/ligament injuries (17.7%; 1.28 injuries/1000 PHs) were the most common injuries, in addition to acromioclavicular joint injuries in forwards and hamstring strain injuries in backs. The most common injury mechanism was tackling (16.4%). Injury characteristics differed according to field position; therefore, preventive measures according to field position are necessary. Moreover, the high number of tackle injuries suggests that improved tackle skills would help reduce injuries. The IR among Japanese collegiate rugby players was higher than that reported previously. Injury prevention training for collegiate players is necessary to reduce the number of injuries.

Keywords : prospective study, epidemiology, injury surveillance, injury rate

Introduction

Rugby union (rugby) is a full-contact sport with a high injury rate¹⁾. In previous studies, injury rates reported for the last three Rugby World Cups (2007, 2011, and 2015) ranged from 83.9 to 97.9 injuries/1000 player-hours (PHs)²⁻⁴⁾. These rugby injury rates are higher than those for football (50.8 injuries/1000 PHs during the FIFA World Cup 2014⁵⁾) and ice hockey (49.4 injuries/1000 PHs in six NHL seasons⁶⁾).

In rugby, the incidence of acute injuries is usually higher than that of overuse injuries; these injuries often require surgical treatment and long-term rehabilitation. In particular, concussion⁷⁻⁹⁾, anterior cruciate ligament injury^{10,11)}, and shoulder dislocation¹²⁻¹⁴⁾ are problematic injuries. Sports-related concussion has received consider-

able attention in recent years; it is reportedly associated with cognitive decline as a sequela and increased incidence of Alzheimer's disease^{15,16)}. Furthermore, anterior cruciate ligament injury and shoulder joint dislocation/subluxation result in long-term match and training day loss¹⁰⁻¹⁴⁾. A study of professional rugby players in England reported a knee injury rate of 11.0 injuries/1000 PHs during the match; after anterior cruciate ligament injury, the athlete often requires an average of 255 days before they can play again¹⁰⁾. The rate of shoulder injury was 8.9 injuries/1000 PHs; after shoulder dislocation/subluxation, the athlete often requires an average of 157 days before returning to play¹³⁾. Thus, both injuries have a high occurrence rate and involve a long break from playing. Rugby has a higher injury rate than other sports, causing long-term loss of match and training days; therefore, injury prevention is a top priority.

In the sequence of sports injury prevention, it is neces-

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sary to first conduct epidemiological surveillance of a particular injury to determine its exact nature^{17,18)}. Descriptive epidemiology of injuries on the sports field is useful in determining the extent of the problem regarding the incidence, severity, and mechanism of injuries. In epidemiological studies, it is possible to calculate the injury rate per exposure hour or number of exposures by recording the exposure time in a prospective study. The injury rate can be compared to that in other groups (e.g., sports, player level, or injury type)¹⁹⁻²²⁾, compared between seasons of the same sport, and compared between matches and training, which is a useful means of assessing the relative risk. The National College Athletic Association has long used epidemiological injury data to implement measures to reduce injury risk. In 1998, limits were placed on the number of training days and contacts during the American football spring training season in an attempt to reduce the injury rate, as it was found to be twice as high during the spring training season than during the fall training season¹⁹⁾.

Many epidemiological studies of injuries in rugby have been reported thus far^{2-4,7,8,10-13,23-32)}. However, the majority of these studies involved professional players^{2-4,8,10,12,13,23-26)}. Although research on top competition-level players is important, younger players may take longer to recover from concussion symptoms^{33,34)}, and the recurrence injury risk may increase in those with a history of knee ligament injury or shoulder dislocation^{11,35)}. Considering these factors, it may be necessary to implement counter plans to prevent injury in players who have less competition experience than professional players.

Although collegiate rugby is popular in Japan, there are little epidemiological data on associated injuries. In a previous study, rugby shows that injury characteristics vary according to competition level and age^{27,36)}. Therefore, injury characteristics may differ between professional-level players and Japanese collegiate players. Limited rugby injury data are available in Japan; the existing data analyses in Japan are based on the number and proportion of rugby injuries that were surveyed using a questionnaire^{37,38)}. However, cross-sectional studies are less accurate than prospective studies due to their recall bias. Therefore, it is necessary to conduct a prospective study and calculate the injury rate per exposure hour. In addition, although data obtained regarding university students during one season were reported³⁹⁾, a single season is affected by the rugby training program, the number of matches, and the results of the season; thus, it is better if the survey is conducted over multiple years.

Therefore, the purpose of this study was to conduct a prospective injury survey of Japanese male collegiate rugby players over a number of years and to analyze the injuries that occurred during matches and training according to field position, type of injury, and mechanism of injury.

Materials and Methods

Subjects. This prospective study registered a total of 128 male collegiate rugby players during three years from 2017 to 2019 (2017 season, $n = 90$; 2018 season, $n = 87$; 2019 season, $n = 86$). Fig. 1 shows the schema for player inclusion and exclusion during the survey period. The competition level of the subject team to which the target person belonged matched the competition level required for participation in the All Japan University Rugby Championship.

The mean age of the subjects was 19.3 ± 1.3 years, mean height 175.1 ± 6.4 cm, mean body mass 85.2 ± 11.9 kg, and rugby experience 10.5 ± 4.4 years at the time of participation in the study. Players who failed to participate in rugby training even once because of rehabilitation or those who had been enrolled or retired from the team during the season were excluded from this study.

The group comprised forwards ($n = 66$; 28 front row, 18 second row, and 20 back row) and backs ($n = 62$; 10 halves, 33 inside backs, and 19 outside backs). This study was performed according to the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Health and Sport Science at the University of Tsukuba (approval number: 30-48). All the subjects provided written informed consent before participating in the current study.

Fig. 1 Schema for subject inclusion and exclusion

Definition of injury. This study was designed to consider only time-loss injuries⁴⁰⁾, an injury that prevents a player from fully participating in a subsequent training session (including weight training) or a rugby match. All injured players were clinically diagnosed by team physicians using imaging techniques, including magnetic resonance imaging, computed tomography, and radiography. Injuries were classified according to the Orchard Sports Injury Classification System (OSICS)⁴¹⁾, a sports-specific code system that provides consistent classification and is used worldwide.

Data collection. The occurrences of time-loss injuries were recorded by athletic trainers using an injury record form during three playing seasons (January 2017 to December 2017, January 2018 to December 2018, and January 2019 to December 2019). Injury data included anatomic region, type of injury, time (match or training), the phase of play during which the injury occurred, and days until return to play (number of days that elapsed from the date of injury to the player's return to full participation in team training and availability for match selection). The severity of the injury was assessed using the days until return to play after the injury. The burden of injury⁴²⁾ was calculated by multiplying the injury rate by the mean severity of the injury.

The anatomic regions were classified as follows: head, neck, shoulder, elbow, wrist, chest, thoracic spine, trunk and abdominal, lumbar spine, pelvis/buttock, hip/groin, thigh, knee, lower leg, ankle, and foot⁴¹⁾. The mechanisms of play during which the injury occurred was confirmed through an interview and/or video images recorded by the team athletic trainers and was classified as follows: tackling, tackled, ruck, scrum, lineout/maul, high ball catch, ground collision, other player collision, running, step/cutting, kicking, overuse, other, and unknown. The exposure time data from all matches and training sessions were recorded by the team athletic trainers.

Statistical analyses. The injury rate (IR) was defined as the number of injuries per 1000 player hours (1000 PHs) of exposure time (match and training exposure). In addition, a 95% confidence interval (95% CI)⁴³⁾ was calculated. Significant differences in IR values were assumed if the 95% CIs for the parameters did not overlap. The chi-square test was used to assess differences in the number of injuries. The components for analysis using the chi-square test were match/training, position, injury site, injury type, and injury mechanism. If the observed chi-square test value exceeded the critical value at an α level of 0.05, the finding was significant.

In addition, the IR ratio was calculated by dividing the match IR by the training IR. The IR in the forwards was divided by the IR in the backs, and the IR ratio was calculated for match/training, injury site, injury type, and injury mechanism. The IR ratio was calculated as a 95% CI, and it was determined that there was a significant difference if the CI did not include 1. The statistical procedures were performed using Excel for Office 365 MSO (Build 16.0.11929.20618; Microsoft Corp).

Results

Overall, 84,140.4 hours (match: 2,420.0; training: 81,720.4) of exposure were recorded over three seasons during which 611 injuries (match, 297; training, 314) occurred. The total IR during three seasons was 7.26 injuries/1000 PHs, the mean severity was 33.92 days, and the burden was 246.30 days/1000 PHs (Table 2). The number of match injuries was 297 (48.6%), and the number of training injuries was 314 (51.4%); there was no significant difference in the injury proportion. The match IR was 122.73 injuries/1000 PHs (95% CI, 108.77 to 136.69), and the training IR was 3.84 injuries/1000 PHs (95% CI, 3.42 to 4.27). The IR ratio was 31.94 (95% CI, 27.25 to 37.43), indicating that the match IR was higher than the training IR ($p < 0.05$) (Table 3).

Table 4 shows the match and training IRs according to

Table 1. Match and training exposure during three rugby playing seasons

	Forwards	Backs	Total
No. of players (n)	66	62	128
No. of trainings (n)	763	763	763
No. of matches (n)	121	121	121
Training exposure time (h)	42,669.0	39,051.4	81,720.4
Match exposure time (h)	1,290.7	1,129.3	2,420.0
Total exposure time (h)	43,959.7	40,180.7	84,140.4

Table 2. Total injury rate, severity, and burden

	No.	IR (1000 PHs)	Severity (Days)	Burden (days/1000 PHs)
Total injury	611	7.26	33.92	246.30

IR, Injury rate; PHs, player hours.

Table 3. Injury rate during match and training

	Match		Training		IR ratio (95% CI)	Total	
	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)		No.	IR/1000 PHs (95% CI)
Total injury	297 (48.6)	122.73 (108.77 to 136.69)	314 (51.4)	3.84 (3.42 to 4.27)	31.94 (27.25 to 37.43) *	611	7.26 (6.69 to 7.84)

IR, Injury rate; PHs, player hours; CI, Confidence interval; IR ratio = matches/training; * $p < 0.05$.

Table 4. Injury rate by field positions

	Forwards		Backs		IR ratio (95% CI)
	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)	
Match	133 (43.2)	103.04 (85.53 to 120.56)	164 (54.1)	145.22 (123.00 to 167.45)	1.41 (1.12 to 1.77) *
Training	175 (56.8)	4.10 (3.49 to 4.71)	139 (45.9)	3.56 (2.97 to 4.15)	0.87 (0.69 to 1.08)
Total	308	7.01 (6.22 to 7.79)	303	7.54 (6.69 to 8.39)	1.08 (0.92 to 1.26)

IR, Injury rate; PHs, player hours; CI, Confidence interval; IR ratio = forwards/back; * $p < 0.05$.

field position. There were significant differences in the number of injuries during matches, with 133 injuries in forwards (43.2%) and 164 in backs (51.1%) ($p < 0.05$). The match IR in forwards was 103.04 injuries/1000 PHs (95% CI, 85.53 to 120.56), and the match IR in backs was 145.22 injuries/1000 PHs (95% CI, 123.00 to 167.45). The IR ratio was 1.41 (95% CI, 1.12 to 1.77), indicating that the IR in backs was higher than in forwards ($p < 0.05$).

Table 5 shows the IR according to anatomic region. Of all the injury sites, the most commonly injured region was the ankle ($n = 107$; 17.5%), followed by the thigh ($n = 92$; 15.1%), and shoulder ($n = 88$; 14.4%) ($p < 0.05$). There was a significant difference between forwards and backs regarding the number of ankle injuries ($p < 0.05$) but no difference in the ankle IR ratio. The number of thigh injuries was significantly different between forwards and backs ($p < 0.05$). The IR of thigh injuries in forwards was 0.48 injuries/1000 PHs (95% CI, 0.27 to 0.68), and the IR of thigh injuries in backs was 1.77 injuries/1000 PHs (95% CI, 1.36 to 2.18). The IR ratio of thigh injuries was 3.70 (95% CI, 2.27 to 6.02), indicating that the IR in backs was higher than in forwards ($p < 0.05$). The number of shoulder injuries was significantly different between forwards and backs ($p < 0.05$).

Table 6 shows the 10 most common types of injuries. The most common types of injuries were ankle sprains/

ligament injuries ($n = 108$; 17.7%) followed by hamstring strain ($n = 62$; 10.1%), knee sprains/ligament injuries ($n = 49$; 8.0%), and concussion ($n = 48$; 7.9%) ($p < 0.05$). Regarding the total injuries, the IR of ankle sprains/ligament injuries (1.28 injuries/1000 PHs; 95% CI, 1.04 to 1.53) was significantly higher than that of all other types of injuries ($p < 0.05$). There was a significant difference between forwards and backs regarding the number of ankle sprains/ligament injuries ($p < 0.05$), but no difference in the ankle IR ratio. Regarding knee sprains/ligament injuries and concussion and the number of injuries, IR ratio was not significantly different between forwards and backs. The number of hamstring strain injuries was significantly different between forwards and backs ($p < 0.05$). The IR of hamstring strain injuries in forwards was 0.34 injuries/1000 PHs (95% CI, 0.17 to 0.51), and the IR of hamstring strain injuries in backs was 1.17 injuries/1000 PHs (95% CI, 0.84 to 1.50). The IR ratio of hamstring strain injuries was 3.43 (95% CI, 1.92 to 6.13), indicating that the IR in backs was higher than in forwards ($p < 0.05$). The number of acromioclavicular joint sprain injuries was significantly different between forwards and backs ($p < 0.05$). The IR of acromioclavicular joint sprain injuries in forwards was 0.39 injuries/1000 PHs (95% CI, 0.20 to 0.57), and the IR of acromioclavicular joint sprain injuries in backs was 0.05 injuries/1000 PHs (95% CI, 0.00

Table 5. Injury rate by anatomic regions

	Forwards		Backs		Total	
	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)
Head	28 (9.1)	0.64 (0.40 to 0.87)	35 (11.6)	0.87 (0.58 to 1.16)	63 (10.3)	0.75 (0.56 to 0.93)
Neck	15 (4.9)	0.34 (0.17 to 0.51)	14 (4.6)	0.35 (0.17 to 0.53)	29 (4.7)	0.34 (0.22 to 0.47)
Shoulder	59 (19.2)	1.34 (1.00 to 1.68)	29 (9.6)	0.72 (0.46 to 0.98)	88 (14.4)	1.05 (0.83 to 1.26)
Elbow	5 (1.6)	0.11 (0.01 to 0.21)	6 (2.0)	0.15 (0.03 to 0.27)	11 (1.8)	0.13 (0.05 to 0.21)
Wrist	9 (2.9)	0.20 (0.07 to 0.34)	10 (3.3)	0.25 (0.09 to 0.40)	19 (3.1)	0.23 (0.12 to 0.33)
Chest	6 (1.9)	0.14 (0.03 to 0.25)	2 (0.7)	0.05 (0.00 to 0.12)	8 (1.3)	0.10 (0.03 to 0.16)
Thoracic spine	2 (0.6)	0.05 (0.00 to 0.11)	2 (0.7)	0.05 (0.00 to 0.12)	4 (0.7)	0.05 (0.00 to 0.09)
Trunk and abdominal	3 (1.0)	0.07 (0.00 to 0.15)	4 (1.3)	0.10 (0.00 to 0.20)	7 (1.1)	0.08 (0.02 to 0.14)
Lumbar spine	30 (9.7)	0.68 (0.44 to 0.93)	17 (5.6)	0.42 (0.22 to 0.62)	47 (7.7)	0.56 (0.40 to 0.72)
Pelvis/buttock	2 (0.6)	0.05 (0.00 to 0.11)	6 (2.0)	0.15 (0.03 to 0.27)	8 (1.3)	0.10 (0.03 to 0.16)
Hip/groin	2 (0.6)	0.05 (0.00 to 0.11)	0 (0.0)	0.00	2 (0.3)	0.02 (0.00 to 0.06)
Thigh	21 (6.8)	0.48 (0.27 to 0.68)	71 (23.4)	1.77 (1.36 to 2.18)	92 (15.1)	1.09 (0.87 to 1.32)
Knee	38 (12.3)	0.86 (0.59 to 1.14)	42 (13.9)	1.05 (0.73 to 1.36)	80 (13.1)	0.95 (0.74 to 1.16)
Lower leg	15 (4.9)	0.34 (0.17 to 0.51)	11 (3.6)	0.27 (0.11 to 0.44)	26 (4.3)	0.31 (0.19 to 0.43)
Ankle	63 (20.5)	1.43 (1.08 to 1.79)	44 (14.5)	1.10 (0.77 to 1.42)	107 (17.5)	1.27 (1.03 to 1.51)
Foot	10 (3.2)	0.23 (0.09 to 0.37)	10 (3.3)	0.25 (0.09 to 0.40)	20 (3.3)	0.24 (0.13 to 0.34)

IR, Injury rate; PHs, player hours; CI, Confidence interval; IR ratio = forwards/back; *p<0.05.

Table 6. Injury rate by injury types

	Forwards		Backs		Total	
	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)
Concussion	23 (7.5)	0.52 (0.31 to 0.74)	25 (8.3)	0.62 (0.38 to 0.87)	48 (7.9)	0.57 (0.41 to 0.73)
Cervical spine facet joint injuries	9 (2.9)	0.20 (0.07 to 0.34)	7 (2.3)	0.17 (0.05 to 0.30)	16 (2.6)	0.19 (0.10 to 0.28)
Acromioclavicular joint sprain	17 (5.5)	0.39 (0.20 to 0.57)	2 (0.7)	0.05 (0.00 to 0.12)	19 (3.1)	0.23 (0.12 to 0.33)
Acute shoulder sprains/subluxation	10 (3.2)	0.23 (0.09 to 0.37)	5 (1.7)	0.12 (0.02 to 0.23)	15 (2.5)	0.18 (0.09 to 0.27)
Rotator cuff muscle injury	8 (2.6)	0.18 (0.06 to 0.31)	10 (3.3)	0.25 (0.09 to 0.40)	18 (2.9)	0.21 (0.12 to 0.31)
Lumbar pain	24 (7.8)	0.55 (0.29 to 0.71)	15 (5.0)	0.37 (0.18 to 0.56)	39 (6.4)	0.46 (0.32 to 0.61)
Hamstring strain	15 (4.9)	0.34 (0.17 to 0.51)	47 (15.5)	1.17 (0.84 to 1.50)	62 (10.1)	0.74 (0.55 to 0.92)
Knee sprains/ligament injuries	22 (7.1)	0.50 (0.29 to 0.71)	27 (8.9)	0.67 (0.42 to 0.93)	49 (8.0)	0.58 (0.42 to 0.75)
Gastrocnemius muscle injury/strain	7 (2.3)	0.16 (0.04 to 0.28)	7 (2.3)	0.17 (0.05 to 0.30)	14 (2.3)	0.17 (0.08 to 0.25)
Ankle sprains/ligament injuries	63 (20.5)	1.43 (1.08 to 1.79)	45 (14.9)	1.12 (0.79 to 1.45)	108 (17.7)	1.28 (1.04 to 1.53) †
Other	110 (35.7)		113 (37.3)		223 (36.5)	

IR, Injury rate; PHs, player hours; CI, Confidence interval; IR ratio = forwards/back; *p<0.05; †significantly higher than that of all other types of injuries (p<0.05).

to 0.12). The IR ratio of acromioclavicular joint sprain injuries was 0.13 (95% CI, 0.03 to 0.56), indicating that the IR in forwards was higher than in backs ($p < 0.05$).

Table 7 shows the IR according to injury mechanisms. Among all injuries, the most common injury mechanism was tackling ($n = 100$; 16.4%) followed by unknown ($n = 90$; 14.7%), tackled ($n = 86$; 14.1%), and overuse ($n = 66$; 10.8%) ($p < 0.05$). Tackled and overuse did not differ significantly between forwards and backs, but the number of tackling injuries was significantly different between forwards and backs ($p < 0.05$). The IR for tackling in forwards was 0.96 injuries/1000 PHs (95% CI, 0.67 to 1.24), and the IR for tackling in backs was 1.55 injuries/1000 PHs (95% CI, 1.07 to 1.81). The IR ratio of tackling was 1.51 (95% CI, 1.02 to 2.25), indicating that the IR in backs was higher than in forwards ($p < 0.05$). The number of running injuries was significantly different between forwards and backs ($p < 0.05$). The IR for running in forwards was 0.36 injuries/1000 PHs (95% CI, 0.19 to 0.54), and the IR for running in backs was 0.70 injuries/1000 PHs (95% CI, 0.44 to 0.95). The IR ratio for running was 1.91 (95% CI, 1.04 to 3.54), indicating that the IR in backs was higher than in forwards ($p < 0.05$).

Discussion

This prospective study described the epidemiology of injuries in Japanese male collegiate rugby players during three playing seasons. The total IR was 7.26 injuries/1000 PHs, and the mean severity of injury was 33.92 days. The burden of injury was indicated by the number of match and training days lost to injury (246.30 days). Addressing injury prevention for rugby players is thought to contribute significantly to reducing lost playing time. Injured players should be provided with effective athletic rehabilitation programs and be required to obtain medical clearance prior to returning to play.

The match IR (122.73 injuries/1000 PHs) was almost 31.9 times higher than the training IR (3.84 injuries/1000 PHs). Rugby is known to have a higher injury risk during matches than during training^{24,25}. The reason for the higher risk is that full-contact play and high-intensity running occur more frequently during matches. Our findings confirmed that the high IR during matches occurred for these same reasons. Thus, there is a need to focus on reducing injuries during rugby matches.

The match IR in this study was higher than that in collegiate rugby players from other countries^{28,31}. Previous research on American collegiate rugby reported that the IR during matches was 26.0 injuries/1000 match exposure (95% CI, 14.4 to 43.3)³¹. A study of male collegiate rugby players in New England reported that the IR during matches was 16.9 injuries/1000 player match hours (95% CI, 15.1 to 18.9)²⁸. Compared to these reports from other countries^{28,31}, the IR during matches in this study was high, indicating that the IR in university students may dif-

fer between countries and regions.

In an injury report of the 2015 Rugby World Cup, the match IR was 90.1 injuries/1000 PHs (95% CI, 77.6 to 104.6)⁴. A meta-analysis of IRs for senior professional rugby players indicated that matches had an IR of 81 injuries/1000 PHs (95% CI, 63 to 105)³⁰. A systematic review analyzing the IRs of senior amateur rugby players reported that the match IR was 46.8/1000 PHs (95% CI, 34.4 to 59.2)³². Compared to the match IR in these reports, the match IR in this study (122.73 injuries/1000 PHs; 95% CI, 108.77 to 136.69) was higher than that for senior rugby players. Injury risk is affected by competition level and age^{23,27,29}. Our results showed that the injury risk was high among collegiate players and professional players³⁰. However, since this study surveyed a single team, it is necessary to follow up with other teams in the future to confirm this finding.

In contrast, the IR during training injuries in this study was 3.42 injuries/1000 PHs; this IR may be lower than in other countries. Previous research on American collegiate rugby reported that the IR during training was 8.3 injuries/1000 exposure (95% CI, 4.5 to 14.1)³¹. A study of male collegiate rugby players in New England reported that the IR during training was 5.5 injuries/1000 athlete-exposure (95% CI, 4.7 to 6.5)²⁸. In these previous studies^{28,31}, the IR was calculated based on the number of exposures; therefore, direct comparisons are not possible. Japanese college rugby may have a lower IR during training, but a higher IR during matches than that in other countries. The differences regarding the match IR may be affected by the number and schedule of matches per playing season. In the United States, one training session time may be limited, but in Japan, there is the possibility that the IR is low because of a relatively longer training time. The differences in IR compared to other countries should be elucidated in future studies.

The IR for backs during matches (145.22 injuries/1000 PHs) was almost 1.4 times higher than that for forwards (103.04 injuries/1000 PHs). Rugby has different play characteristics for forwards and backs. Forward players have to perform many contact plays during breakdown; the common play pattern consists of being tackled over a short distance⁴⁴. Conversely, back players are subjected to high impact during contact play because the common play pattern is open play at high speed⁴⁵. Moreover, backs repeat high-speed running plays. It is thought that the differences in play required for these field positions result in the differences in injury characteristics. In this study, forwards had more shoulder injuries, whereas backs had more thigh injuries. Based on the characteristics of the positions, different injury prevention measures may be necessary for each field position.

The most injured anatomic region was the ankle. This IR did not differ between positions, so is considered that ankle injuries are the highest risk among both forward and back players. The ankle is the site of numerous sports in-

Table 7. Injury rate by injury mechanisms

	Forwards		Backs		Total	
	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)	No. (%)	IR/1000 PHs (95% CI)
Tackling	42 (13.6)	0.96 (0.67 to 1.24)	58 (19.1)	1.44 (1.07 to 1.81)	100 (16.4)	1.19 (0.96 to 1.42)
Tackled	45 (14.6)	1.02 (0.72 to 1.32)	41 (13.5)	1.02 (0.71 to 1.33)	86 (14.1)	1.02 (0.81 to 1.24)
Ruck	29 (9.4)	0.66 (0.42 to 0.90)	23 (7.6)	0.57 (0.34 to 0.81)	52 (8.5)	0.62 (0.45 to 0.79)
Scrum	19 (6.2)	0.43 (0.24 to 0.63)	0 (0.0)	0.00	19 (3.1)	0.23 (0.12 to 0.33)
Lineout/maul	31 (10.1)	0.71 (0.46 to 0.95)	0 (0.0)	0.00	31 (5.1)	0.37 (0.24 to 0.50)
High ball catch	1 (0.3)	0.02 (0.00 to 0.07)	7 (2.3)	0.17 (0.05 to 0.30)	8 (1.3)	0.10 (0.03 to 0.16)
Ground collision	6 (1.9)	0.14 (0.03 to 0.25)	8 (2.6)	0.20 (0.06 to 0.34)	14 (2.3)	0.17 (0.08 to 0.25)
Other player collision	14 (4.5)	0.32 (0.15 to 0.49)	22 (7.3)	0.55 (0.32 to 0.78)	36 (5.9)	0.43 (0.29 to 0.57)
Running	16 (5.2)	0.36 (0.19 to 0.54)	28 (9.2)	0.70 (0.44 to 0.95)	44 (7.2)	0.52 (0.37 to 0.68)
Step/cutting	11 (3.6)	0.25 (0.10 to 0.40)	19 (6.3)	0.47 (0.26 to 0.69)	30 (4.9)	0.36 (0.23 to 0.48)
Kicking	0 (0.0)	0.00	5 (1.7)	0.12 (0.02 to 0.23)	5 (0.8)	0.06 (0.01 to 0.11)
Overuse	32 (10.4)	0.73 (0.48 to 0.98)	34 (11.2)	0.85 (0.56 to 1.13)	66 (10.8)	0.78 (0.60 to 0.97)
Other	15 (4.9)	0.34 (0.17 to 0.51)	15 (5.0)	0.37 (0.18 to 0.56)	30 (4.9)	0.36 (0.23 to 0.48)
Not known	47 (15.3)	1.07 (0.76 to 1.37)	43 (14.2)	1.07 (0.75 to 1.39)	90 (14.7)	1.07 (0.85 to 1.29)

IR, Injury rate; PHs, player hours; CI, Confidence interval; IR ratio = forwards/back; *p<0.05.

juries; however, it is often reported that it is not the most common injury site in rugby^{23,27,28,30-32}. Since this study showed a high rate of injury to the ankle as characteristic of Japanese rugby players, further studies are required to confirm this theory.

The most common type of injury was ankle sprain/ligament injuries. To prevent ankle sprain/ligament injuries, rugby teams should undergo preseason medical screening. A history of ankle sprain, muscle weakness, strength asymmetries, and reduced range of motion has been shown to increase ankle injury risk⁴⁶⁻⁴⁸. At-risk athletes may benefit from trauma-specific preventive interventions. Prevention interventions for this injury should be performed regardless of field position (forwards or backs).

Forwards have more shoulder injuries, and acromioclavicular joint injury is also more common in forwards. These injuries are caused by forced bruising of the joints or horizontal adduction of the shoulder. To prevent these injuries in rugby players, tackling and grounding skills need to be improved.

In contrast, the risk of hamstring strain injuries was higher in backs than in forwards. The above-mentioned differences in playing styles of field positions may affect the incidence of major injuries between forwards and backs. Moreover, in this study, backs experienced more injuries during running than forwards.

A history of muscle strain increases the risk of relapse⁴⁹. Preventive training interventions for those with a history of muscle strain may be effective. A report of professional rugby players in England⁵⁰ showed that hamstring eccentric training (Nordic hamstrings) resulted in a lower incidence of hamstring muscle injuries during training and competition. Such eccentric training is expected to have the same effect on university students. To prevent muscle strain at an earlier age, it is necessary to implement preventative hamstring training interventions in young rugby players before they reach the professional level.

In this study, the most common injury mechanism was tackling (16.4%). Rugby tackles account for the majority of injuries. In addition, tackle skills are related to injuries. How contact takes place (tackle posture, head position) affects the occurrence of concussion^{51,52}. In this study, concussion was the fourth most common injury at 7.9%, and both forwards and backs required attention for these injuries. Therefore, it is necessary to improve the tackle skills of young and inexperienced players to prevent concussions.

Ankle sprains/ligament injuries were the most common injuries in male college rugby players in addition to acromioclavicular joint injuries in forwards and hamstring strain injuries in backs. In previous research, a movement control exercise program⁵³⁻⁵⁵ has been reported to contribute to a reduction in the incidence of joint sprains and muscle strain. Implementing such movement control exercise programs before warming up and during pre-train-

ing may lead to injury prevention. In addition, improved tackle skills will help to reduce injuries and prevent concussion.

This study has several limitations. First, it investigated a single rugby team, and injury characteristics may differ according to competition level. Second, the subjects were male rugby players only. In addition, the injury mechanisms were not clear from the interview process we undertook in this study. In the future, it is necessary to conduct surveys on multiple teams as well as female rugby players and to clarify the injury mechanism using video analysis.

In conclusion, this prospective study described the epidemiology of injuries in Japanese male collegiate rugby players during three playing seasons. The IR among Japanese collegiate rugby players was higher than that reported previously. The match IR in this study was higher than that in collegiate rugby players from other countries. Ankle sprains/ligament injuries were the most common injuries in addition to acromioclavicular joint injuries in forwards and hamstring strain injuries in backs. Moreover, improved tackle skills will help to reduce the number of tackle injuries. In the practice model of injury prevention, the actual status of trauma should first be clarified based on an epidemiological survey^{17,18}. The next step will require validation of injury prevention interventions. To reduce injury in collegiate rugby players, it is necessary to improve their contact skills through intervention movement control exercise programs.

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Conflict of Interests

YK is an employee of Japan Sports Science Inc., but has not received any payment for this study from Japan Sports Science Inc. Therefore, the authors have declared that no competing interests exist.

Author Contributions

RO and MT conceptualized study design and protocol, and determined the study institutions. RO, GO, SN, YK, YK, and AO collected and assembled the data. RO carried out the analysis and interpretation of data and drafted the manuscript. All authors have critically reviewed, revised and approved the manuscript.

References

- 1) Nicholl JP, Coleman P and Williams BT. 1995. The epidemiology of sports and exercise related injury in the United Kingdom. *Br J Sports Med* 29: 232-238. doi: 10.1136/bjsm.29.4.232.

- 2) Fuller CW, Laborde F, Leather RJ and Molloy MG. 2008. International Rugby Board Rugby World Cup 2007 injury surveillance study. *Br J Sports Med* 42: 452-459. doi: 10.1136/bjsm.2008.047035.
- 3) Fuller CW, Sheerin K and Targett S. 2013. Rugby World Cup 2011: International Rugby Board injury surveillance study. *Br J Sports Med* 47: 1184-1191. doi: 10.1136/bjsports-2012-091155.
- 4) Fuller CW, Taylor A, Kemp SP and Raftery M. 2017. Rugby World Cup 2015: World Rugby injury surveillance study. *Br J Sports Med* 51: 51-57. doi: 10.1136/bjsports-2016-096275.
- 5) Junge A and Dvořák J. 2015. Football injuries during the 2014 FIFA World Cup. *Br J Sports Med* 49: 599-602. doi: 10.1136/bjsports-2014-094469.
- 6) McKay CD, Tufts RJ, Shaffer B and Meeuwisse WH. 2014. The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. *Br J Sports Med* 48: 57-62. doi: 10.1136/bjsports-2013-092860.
- 7) Bleakley C, Tully M and O'Connor S. 2011. Epidemiology of adolescent rugby injuries: a systematic review. *J Athl Train* 46: 555-565. doi: 10.4085/1062-6050-46.5.555.
- 8) Kemp SP, Hudson Z, Brooks JH and Fuller CW. 2008. The epidemiology of head injuries in English professional rugby union. *Clin J Sport Med* 18: 227-234. doi: 10.1097/JSM.0b013e31816a1c9a.
- 9) Suzuki K, Takemura M, Nagai S, Ogaki R, Kumazaki A, Hirose N and Miyakawa S. 2018. Analysis of the playing situation leading to concussion during six playing seasons of a collegiate rugby union team. *Jpn J Clin Sports Med* 26: 355-362 (in Japanese).
- 10) Dallalana RJ, Brooks JH, Kemp SP and Williams AM. 2007. The epidemiology of knee injuries in English professional rugby union. *Am J Sports Med* 35: 818-830. doi: 10.1177/0363546506296738.
- 11) Ogaki R, Takemura M, Takaki S, Shimasaki T and Furukawa T. 2017. Epidemiology of knee injuries in collegiate rugby union players. *J Phys Fitness Sports Med* 6: 343-348. doi: 10.7600/jpfsm.6.343.
- 12) Bohu Y, Klouche S, Lefevre N, Peyrin JC, Dusfour B, Hager JP, Ribaut A and Herman S. 2015. The epidemiology of 1345 shoulder dislocations and subluxations in French Rugby Union players: a five-season prospective study from 2008 to 2013. *Br J Sports Med* 49: 1535-1540. doi: 10.1136/bjsports-2014-093718.
- 13) Headey J, Brooks JH and Kemp SP. 2007. The epidemiology of shoulder injuries in English professional rugby union. *Am J Sports Med* 35: 1537-1543. doi: 10.1177/0363546507300691.
- 14) Ogaki R, Takemura M, Nagai S, Imoo Y, Takaki S and Miyakawa S. 2015. The epidemiology of shoulder injuries in collegiate rugby union players. *Jpn J Clin Sports Med* 23: 543-551 (in Japanese).
- 15) Solomon GS, Ott SD and Lovell MR. 2011. Long-term neurocognitive dysfunction in sports: what is the evidence? *Clin Sports Med* 30: 165-177. doi: 10.1016/j.csm.2010.09.002.
- 16) Guskiewicz KM, Marshall SW, Bailes J, McCrea M, Harding HP Jr, Matthews A, Mihalik JR and Cantu RC. 2007. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc* 39: 903-909.
- 17) Finch C. 2006. A new framework for research leading to sports injury prevention. *J Sci Med Sport* 9: 3-9. doi: 10.1016/j.jsams.2006.02.009.
- 18) van Mechelen W, Hlobil H and Kemper HC. 1992. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med* 14: 82-99. doi: 10.2165/00007256-199214020-00002.
- 19) Albright JP, Powell JW, Martindale A, Black R, Crowley E, Schmidt P, Monroe J, Locy D, Aggler T, Davis WR, Salvatore G, Miller D, Helwig D, Soboroff S, Nivens J, Carpenter J, Kovan J, Arndt E, Sweeney H and Lombardo J. et al. 2004. Injury patterns in big ten conference football. *Am J Sports Med* 32: 1394-1404. doi: 10.1177/0363546504264159.
- 20) Hootman JM, Dick R and Agel J. 2007. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train* 42: 311-319.
- 21) Kuzuhara K, Shibata M and Uchida R. 2017. Injuries in Japanese junior soccer players during games and practices. *J Athl Train* 52: 1147-1152. doi: 10.4085/1062-6050-52.12.23.
- 22) Iguchi J, Yamada Y, Kimura M, Fujisawa Y, Hojo T, Kuzuhara K and Ichihashi N. 2013. Injuries in a Japanese Division I collegiate American football team: a 3-season prospective study. *J Athl Train* 48: 818-825. doi: 10.4085/1062-6050-48.4.15.
- 23) Bathgate A, Best JP, Craig G and Jamieson M. 2002. A prospective study of injuries to elite Australian rugby union players. *Br J Sports Med* 36: 265-269. doi: 10.1136/bjsm.36.4.265.
- 24) Brooks JH, Fuller CW, Kemp SP and Reddin DB. 2005. Epidemiology of injuries in English professional rugby union: Part 1 match injuries. *Br J Sports Med* 39: 757-766. doi: 10.1136/bjsm.2005.018135.
- 25) Brooks JH, Fuller CW, Kemp SP and Reddin DB. 2005. Epidemiology of injuries in English professional rugby union: part 2 training injuries. *Br J Sports Med* 39: 767-775. doi: 10.1136/bjsm.2005.018408.
- 26) Brooks JH, Fuller CW, Kemp SP and Reddin DB. 2005. A prospective study of injuries and training amongst the England 2003 Rugby World Cup squad. *Br J Sports Med* 39: 288-293. doi: 10.1136/bjsm.2004.013391.
- 27) Haseler CM, Carmont MR and England M. 2010. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med* 44: 1093-1099. doi: 10.1136/bjsm.2010.074021.
- 28) Kerr HA, Curtis C, Micheli LJ, Kocher MS, Zurakowski D, Kemp SP and Brooks JH. 2008. Collegiate rugby union injury patterns in New England: a prospective cohort study. *Br J Sports Med* 42: 595-603. doi: 10.1136/bjsm.2007.035881.
- 29) Lee AJ and Garraway WM. 1996. Epidemiological comparison of injuries in school and senior club rugby. *Br J Sports Med* 30: 213-217. doi: 10.1136/bjsm.30.3.213.
- 30) Williams S, Trewartha G, Kemp S and Stokes K. 2013. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med* 43: 1043-1055. doi: 10.1007/s40279-013-0078-1.
- 31) Willigenburg NW, Geissler KE, Roewer BD, Caldwell T, Salazar LD, Borchers JR, Higgins T and Hewett TE. 2014. Injuries in American collegiate club rugby: a prospective study. *Ann Sports Med Res* 1: 1005.
- 32) Yeomans C, Kenny IC, Cahalan R, Warrington GD, Harrison AJ, Hayes K, Lyons M, Campbell MJ and Comyns TM. 2018. The incidence of injury in amateur male rugby union: a systematic review and meta-analysis. *Sports Med* 48: 837-848. doi: 10.1007/s40279-017-0838-4.

- 33) Harmon KG, Drezner JA, Gammons M, Guskiewicz KM, Halstead M, Herring SA, Kutcher JS, Pana A, Putukian M and Roberts WO. 2013. American Medical Society for Sports Medicine position statement: concussion in sport. *Br J Sports Med* 47: 15-26. doi: 10.1136/bjsports-2012-091941.
- 34) Zuckerman SL, Lee YM, Odom MJ, Solomon GS, Forbes JA and Sills AK. 2012. Recovery from sports-related concussion: days to return to neurocognitive baseline in adolescents versus young adults. *Surg Neurol Int* 3: 130. doi: 10.4103/2152-7806.102945.
- 35) Ogaki R, Takemura M, Iwai K and Miyakawa S. 2014. Risk factors for shoulder injury in collegiate rugby union players. *Int J Sport Health Sci* 12: 31-37. doi: 10.5432/ijshs.201327.
- 36) Quarrie KL and Chalmers DJ. 2001. Impact of professionalism on injuries in rugby union. *Br J Sports Med* 35: 450. doi: 10.1136/bjism.35.6.450.
- 37) Fukuda J, Takao Y, Saitou K and Furuya M. 2005. Survey of injuries in the national Japanese rugby football team. *Jpn J Orthop Sports Med* 25: 242-245 (in Japanese).
- 38) Ryu J, Eto M, Oikawa H, Ono H, Kikukawa K, Kotani A, Sakuraba K, Takazawa Y, Matsumoto M, Moriya H and Takazawa H. 2000. Injuries and its prophylaxis in rugby football players of medical students. *Jpn J Orthop Sports Med* 20: 390-398 (in Japanese).
- 39) Takemura M, Nagai S, Iwai K, Nakagawa A, Furukawa T, Miyakawa S and Kono I. 2009. Injury characteristics in Japanese collegiate rugby union through one season. *Football Science* 6: 39-46.
- 40) Fuller CW, Molloy MG, Bagate C, Bahr R, Brooks JH, Donson H, Kemp SP, McCrory P, McIntosh AS, Meeuwisse WH, Quarrie KL, Raftery M and Wiley P. 2007. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sport Med* 41: 328-331. doi: 10.1136/bjism.2006.033282.
- 41) Orchard J, Rae K, Brooks J, Häggglund M, Til L, Wales D and Wood T. 2010. Revision, uptake and coding issues related to the open access Orchard Sports Injury Classification System (OSICS) versions 8, 9 and 10.1. *Open Access J Sports Med* 1: 207-214. doi: 10.2147/OAJSM.S7715.
- 42) Quarrie KL and Hopkins WG. 2008. Tackle injuries in professional Rugby Union. *Am J Sports Med* 36: 1705-1716. doi: 10.1177/0363546508316768.
- 43) Knowles SB, Marshall SW and Guskiewicz KM. 2006. Issues in estimating risks and rates in sports injury research. *J Athl Train* 41: 207-215.
- 44) Shimasaki T, Chiba G and Nakagawa A. 2013. Attack aspects from ruck in rugby game of world top-level in recent years. *The Japan Journal of Coaching Studies* 26: 133-143 (in Japanese). doi: 10.24776/jcoaching.26.2_133.
- 45) Duthie G, Pyne D and Hooper S. 2003. Applied physiology and game analysis of rugby union. *Sports Med* 33: 973-991. doi: 10.2165/00007256-200333130-00003.
- 46) Ogaki R, Takemura M, Iwai K, Miyamoto Y, Imoo Y, Nagai S, Furukawa T, Shimasaki T, Washiya K and Miyakawa S. 2013. Intrinsic risk factors for ankle sprain in collegiate rugby union players. *Football Science* 10: 51-56 (in Japanese).
- 47) Fousekis K, Tsepis E and Vagenas G. 2012. Intrinsic risk factors of noncontact ankle sprains in soccer: a prospective study on 100 professional players. *Am J Sports Med* 40: 1842-1850. doi: 10.1177/0363546512449602.
- 48) Willems TM, Witvrouw E, Delbaere K, Mahieu N, De Bourdeaudhuij I and De Clercq D. 2005. Intrinsic risk factors for inversion ankle sprains in male subjects: a prospective study. *Am J Sports Med* 33: 415-423. doi: 10.1177/0363546504268137.
- 49) Ogaki R, Otake G, Nakane S, Kosasa Y, Kanno Y, Murakami T, Tanigawa S and Takemura M. 2020. The epidemiology of muscle strain in male collegiate rugby players. *Jpn J Athl Train* 5: 123-132 (in Japanese).
- 50) Brooks JH, Fuller CW, Kemp SP and Reddin DB. 2006. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med* 34: 1297-1306. doi: 10.1177/0363546505286022.
- 51) Sobue S, Kawasaki T, Hasegawa Y, Shiota Y, Ota C, Yoneda T, Tahara S, Maki N, Matsuura T, Sekiguchi M, Itoigawa Y, Tateishi T and Kaneko K. 2017. Tackler's head position relative to the ball carrier is highly correlated with head and neck injuries in rugby. *Br J Sports Med* 52: 353-358. doi: 10.1136/bjsports-2017-098135.
- 52) Suzuki K, Nagai S, Ogaki R, Iwai K, Furukawa T, Miyakawa S and Takemura M. 2019. Video analysis of tackling situations leading to concussion in collegiate rugby union. *J Phys Fitness Sports Med* 8: 79-88. doi: 10.7600/jpfs.8.79.
- 53) Attwood MJ, Roberts SP, Trewartha G, England ME and Stokes KA. 2018. Efficacy of a movement control injury prevention programme in adult men's community rugby union: a cluster randomised controlled trial. *Br J Sports Med* 52: 368-374. doi: 10.1136/bjsports-2017-098005.
- 54) Hislop MD, Stokes KA, Williams S, McKay CD, England ME, Kemp SPT and Trewartha G. 2017. Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *Br J Sports Med* 51: 1140-1146. doi: 10.1136/bjsports-2016-097434.
- 55) Hislop MD, Stokes KA, Williams S, McKay CD, England M, Kemp SP and Trewartha G. 2016. The efficacy of a movement control exercise programme to reduce injuries in youth rugby: a cluster randomised controlled trial. *BMJ Open Sport Exerc Med* 2: e000043. doi: 10.1136/bmjsem-2015-000043.