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ORIGINAL SCIENTIFIC PAPER

Emphasizing Sport-Specific and Anatomical Factors of Injuries in Amateur Rugby: A Prospective Study

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Abstract

This study aimed to examine injury occurrence, emphasizing the sport-specific and anatomical factors associated with injury occurrence during match and training in amateur rugby players. The participants were 101 players from Croatia (all males, 24.64±4.23 on average, 9.4±4.1 years of experience in rugby). The variables included specific sport factors and injury occurrence factors. Sport data were collected at the beginning of the three-month period, and the occurrence of injuries and factors related to injury occurrence were tracked over the three months throughout the competitive season. Two of the three injuries were traumatic, with no significant difference between backs and forwards in traumatic vs. overuse injuries ($\chi2=2.28$, $p=0.13$). More than one-third of all match-related injuries occurred between the 21st and 40th minutes of the match, with tackling being associated with almost 60% of all match injuries. Thirty percent of training injuries occurred during running, followed by 23% of injuries that occurred during warm-up. Wearing blade studs was a specific injury risk factor (OR=4.11, 95% CI: 2.32-6.87 in comparison to all other types of footwear), with similar odds among backs and forwards (OR=1.78, 95% CI: 0.53-5.78). To prevent injuries in rugby, special attention should be given to players who regularly wear footwear with blade studs and those with improper tackling techniques. Further studies on younger players and females are warranted.

Keywords: *rugby union, anatomy, match, training, warm-up*

Introduction

Rugby union (hereafter "rugby") is a full-contact team sport that originated at the Rugby School in England in the first half of the 19th century. Two teams of 15 players each try to score more points than the other by carrying an oval-shaped ball into the opponent's in-goal area and touching it down or by kicking the ball through the opponent's goalposts. The ball can be moved forward by running with it or kicking it, but it can only be passed backward. Tackling is a key component, with players allowed to bring down the ball carrier. Points are scored through tries (touching the ball down in the in-goal area), conversions (kicking the ball through the goalposts after a try), penalty kicks, and drop goals (kicking the ball through the goalposts during open play). Roughly, two playing positions in rugby are recognized, with forwards being large, physical players, and backs being lighter, faster and more agile (Collins, 2009; Duthie et al., 2003).

Irrespective of the playing position, rugby requires a unique blend of conditioning attributes. Specifically, players cover significant distances during a match (5,000–8,000 meters) and need excellent aerobic endurance to maintain intensity (Swaby et al., 2016). Anaerobic power is also important since high-intensity bursts of speed and power are crucial for tackles, breaks, and sprints. Rugby is generally known for tackling, fending off opponents, and competing in scrums, which places special demands on players' power capacities. Agility and speed are necessary due to quick changes in direction and acceleration, which are vital for attacking and defensive ma-

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neuvers. In general, players tend to be mesomorphic (muscular) with varying body compositions depending on their position (Colomer et al., 2020; Duthie et al., 2003).

Owing to its contact nature and high physiological demands, rugby is associated with high injury rates. In brief, injuries range from 57 to 824.7 injuries per 1000 player-hours, which is a considerably higher rate than in other team sports, including those sports where contact between players is frequent (Williams et al., 2022). The most common injury sites are the head and neck, thigh, and ankle (McIntosh, 2005; Sabesan et al., 2016). Muscular injuries, concussions, and ankle sprains are mostly reported, but even serious injuries are reported (Williams et al., 2022). In a recent study performed with amateur players from Croatia, the authors reported that playing position, level of competition, and training exposure represent major injury risk factors (Bjelanovic et al., 2023). Also, tackles are the primary cause of injuries, with the tackler at greater risk. With respect to playing position and the risk of injury, forwards generally sustain more injuries than backs do (Yeomans et al., 2018).

Injury occurrence in sports is an important and frequently investigated problem (Boroushak et al., 2024; Hatzimanouil et al., 2022). Additionally, a large body of evidence indicates that the risk of injury in rugby is high (Williams et al., 2022). However, most of the studies performed thus far have examined players from professional competition and included a limited number of teams (one-to-two teams). Moreover, studies on players from amateur competition are particularly lacking. To develop specific preventive strategies that are crucial in reducing the number of injuries in sports, it is of utmost importance to identify specific figures for different competitions and variable samples of participants. Therefore, this study aimed to examine injury occurrence in amateur rugby players, define its specifics and evaluate factors associated with injury occurrence in amateur rugby players from Croatia. We hypothesized that certain match-related and training-related factors will be associated with injury occurrence in the studied players.

Methods

Participants

This study examined injury rates in amateur rugby union players from the Croatian first national division over a three-month period (one half-season). Initially, 122 male players from all teams competing at the highest level of national competition were included, but the final analysis focused on 101 players who consistently participated in weekly surveys. Therefore, the study sample, with an average age of 24.64±4.23 years, represented a significant portion of the total population of amateur rugby players in Croatia. The players were primarily students or employed in other fields, with most engaging in over 40 hours of physically demanding work per week in addition to their rugby commitments. They had an average of 14.76 years of experience in sports and 9.11 years specifically in rugby. The training frequency varied, with most players training three or more times a week. In addition to the Croatian League, some players competed in the Regional Rugby Championship (with teams from Slovenia and Bosnia and Herzegovina) and national team games. The study was conducted with the approval of the national rugby federation, participating clubs, and the Institutional Ethics Committee of the Faculty of Kinesiology, University of Split, adhering to the guidelines of the Declaration of Helsinki. All participants provided informed consent for their anonymized data to be used in the research.

Variables and design

In addition to age, this study collected data on specific sport factors and injury occurrence. Sport data were collected at the beginning of the three-month competitive period, and the occurrence of injuries was tracked over the three months throughout the competitive season (Figure 1).

FIGURE 1. Timeline of the study

The sport factors included experience in rugby and playing position. Injury occurrence was questioned via weekly online questionnaires, following the definition of injury: "Any physical complaint sustained during rugby activities that resulted from exceeding the body's capacity to maintain its integrity" (Fuller et al., 2007). Minor injuries that did not prevent participation the following day were not included. Detailed information was recorded for each injury, including the character of the injury (overuse or traumatic), type of injury (11 types of injury, including dislocation/subluxation, fracture, hematoma/contusion/bruising, strain/ligament injuries, muscle rupture/tear/muscle strain/muscle spasm, scratch, other bone/skeletal injuries, nerve injuries, concussion (with or without loss of consciousness), tendon injuries/rupture/buritis, distortion/sprain (twist), time of the match when injury occurred (warm-up, 0-20 min of the game, 21-40 min of the game, 40-60 min of the game, 60-80+ min of the game), match situation when injury occurred (maul, post-match, tackle-tackler, tackle-ball carrier, ruck, kick off, scrum, line-out, collision), situation in training when injury occurred (during warm up, while running, during strength training, during maul practice, during tackle practice, during ruck practice, during scrum practice), and type of footwear worn when injury occurred (rubber studs–round, rubber blade studs, training shoes/s).

Statistics

After the normality of the distributions for all variables was defined via the Kolmogorov–Smirnov test, descriptive statistics included calculations of means and standard deviations (for age and experience) and frequencies and percentages (for remaining variables). Differences between players according to their playing position (backs vs. forwards) were calculated via the Chi square test ($\chi 2$). The odds ratios (with 95% confidence intervals (CIs)) were calculated to determine the odds of being injured when risk factors were noted.

Statistica ver 13.5 (Tibco Inc. Palo Alto, CA, USA) was used for all calculations, and a p-level of 95% was applied.

Results

The majority of injuries were traumatic, and overuse injuries accounted for <23% of all injuries that players reported over the course of the study. When compared between playing positions, no significant difference was found between backs and forwards in the character/mechanism of the injury ($\chi 2=2.28$, $p=0.13$). According to the type of injury, most of the injuries were strains and ligament injuries (30% in total), followed by hematoma (26% of all injuries) and tendon injuries (13% of all injuries). Owing to null frequencies, the types of injuries were not compared across playing positions (Table 1).

Table 1. The number (F) and percentage (%) of injured players in relation to the character/mechanism and type of injury, with differences between playing positions (Chi square test - χ^2)

	All		Backs		Forwards		χ^2 (p)
	F	%	F	%	F	%	
Character/mechanism of the injury							
Overuse injury	11	22.92	5	16.13	6	35.29	2.28
Traumatic injury	37	77.08	26	83.87	11	64.71	(0.13)
Type of injury							
Dislocation/subluxation	2	4.35	0	0.00	2	6.67	
Fracture	2	4.35	1	6.25	1	3.33	
Hematoma/contusion/bruise	12	26.09	3	18.75	9	30.00	
Strain/ligament injuries	14	30.43	4	25.00	10	33.33	
Muscle rupture/tear/muscle strain/muscle spasm	2	4.35	2	12.50	0	0.00	
Scratch	1	2.17	0	0.00	1	3.33	
Other bone/skeletal injuries	2	4.35	0	0.00	2	6.67	
Nerve injuries	1	2.17	0	0.00	1	3.33	
Concussion (with or without loss of consciousness)	3	6.52	3	18.75	0	0.00	
Tendon injuries/rupture/inflammation/bursitis	6	13.04	2	12.50	4	13.33	
Distortion/sprain (twist)	1	2.17	1	6.25	0	0.00	NC

Note: NC – Due to null frequencies, the χ^2 test was not performed; Some sums are not equal across variables and tables as a result of non-reporting data

Table 2 summarizes the data on the time of injury occurrence for match-related injuries. Most of the injuries occurred between the 21st and 40th minutes of the match (more than one-third of all match-injuries), whereas an additional one-fourth of the injuries occurred between the 40th and 60th minutes of the match. Differences between playing positions in the time frame when injury occurred were not significant ($\chi 2=2.57$, $p=0.63$), although some dissimilarities were evident (i.e., backs were similarly injured in both previously mentioned periods, whereas forwards suffered more injuries earlier, between the 21st and 40th minutes of the match). With respect to match situations, tackling is related to more than half of the injuries reported, with the tackler being injured in 30% of situations and an additional 27% of injured ball carriers during tackling.

Table 2. The number (F) and percentage (%) of injured players during match, depending on the time and situation when injury occurred, with differences between playing positions (Chi square test - χ^2)

	All		Backs		Forwards		χ^2(p)
	F	%	F	%	F	%	
Time when injury occurred							
During warm-up	2	5.71	1	4.35	1	8.33	
0 to 20 min of the game	6	17.14	3	13.04	3	25.00	
21 to 40 min of the game	12	34.29	7	30.43	5	41.67	
40 to 60 min of the game	9	25.71	7	30.43	2	16.67	
60 to 80+ min of the game	6	17.14	5	21.74	1	8.33	2.57 (0.63)
Match situation when injury occurred							
Maul	2	5.41	0	0.00	2	7.69	
Postmatch	1	2.70	0	0.00	1	3.85	

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Table 2. The number (F) and percentage (%) of injured players during match, depending on the time and situation when injury occurred, with differences between playing positions (Chi square test - χ^2)

	All		Backs		Forwards		χ^2(p)
	F	%	F	%	F	%	
Tackle-tackler	11	29.73	3	27.27	8	30.77	
Tackle-ball carrier	10	27.03	4	36.36	6	23.08	
Ruck	3	8.11	1	9.09	2	7.69	
Kick off	1	2.70	0	0.00	1	3.85	
Scrum	4	10.81	1	9.09	3	11.54	
Line-out	1	2.70	1	9.09	0	0.00	
Collision	4	10.81	1	9.09	3	11.54	NC

Note: NC – Due to null frequencies, the χ^2 test was not performed; Some sums are not equal across variables and tables as a result of non-reporting data

Most of the training-related injuries occurred during running, followed by warm-up (30% and 23% of all training-related injuries, respectively). Interestingly, only the back players were injured while running (66% of all of their injuries occurred during training). Notably, owing to the null frequencies, a χ2 test of differences between playing positions was not performed (Table 3).

Table 3. The number (F) and percentage (%) of injured players in training, depending on the activity when injury occurred

	All		Backs		Forwards	
	F	%	F	%	F	%
During warm up	3	23.08	1	16.67	2	28.57
While running	4	30.77	4	66.67	0	0.00
During strength training	1	7.69	0	0.00	1	14.29
During maul practice	1	7.69	1	16.67	0	0.00
During the tackle practice	1	7.69	0	0.00	1	14.29
During ruck practice	2	15.38	0	0.00	2	28.57
During scrum practice	1	7.69	0	0.00	1	14.29

Note: Some sums are not equal across variables and tables as a result of non-reporting data

When observing the type of footwear worn when injury occurred, most of the injuries occurred when players wore rubber blade studs (43% of all injuries), with no significant difference between playing positions (χ2=6.01, p=0.19) (Table 4). The association between footwear and injury occurrence was additionally analyzed by calculating the odds ratio (OR). Specifically, when the odds ratios were calculated on the basis of regularly used footwear (more than 60% of the observed players did not use blade studs during training), the odds of being injured when wearing blade studs were more than four times greater than those for all other types of footwear (OR=4.11, 95% CI:2.32-6.87). No significant association between playing position and the occurrence of injury while wearing blade studs was detected (OR =1.78, 95% CI:0.53–5.78), indicating that blade studs are similar risk factors for injury at both playing positions.

Table 4. The number (F) and percentage (%) of injured players depending on the type of footwear worn when injury occurred, with differences between playing positions (Chi square test - χ^2)

	All		Backs		Forwards		χ^2 (p)
	F	%	F	%	F	%	
Rubber studs - round	7	14.6	4	23.5	3	9.7	
Rubber blade studs	21	43.8	9	52.9	12	38.7	
Training shoes	4	8.3	2	11.8	2	6.5	
Metal round studs	9	18.8	1	5.9	8	25.8	
Metal blade studs	7	14.6	1	5.9	6	19.4	6.01 (0.19)

Note: Some sums are not equal across variables and tables as a result of non-reporting data

Discussion

There are several important findings of this investigation. First, most of the match-related injuries occurred in tackling situations. Second, during training, the majority of injuries occurred during warm-up and running. Third, most of the injuries occurred when players wore blade studs. Therefore, our initial study hypothesis could be accepted.

Tackling is a fundamental aspect of rugby, but studies have consistently reported that it is also the leading cause of injuries in this sport. In one of the early papers on this problem, Brooks et al. reported that tackling accounted for 15% of all match injuries and 16% of all days missed due to injury in professional rugby unions, with a similar incidence of injury from tackling between forwards and backs (Brooks et al., 2005). With respect to the lack of differences between playing positions, our results are supportive of those findings. However, Yeomans et al. (2021) recently reported that tackling accounts for more than 59% of total rugby injuries (Yeomans et al., 2021). More precisely, tackle injury frequencies ranged from 46–59% at the professional level (Williams et al., 2022) and 50% at lower levels of play (Roberts et al., 2013). Therefore, our results concerning high-risk activity in amateur players are generally consistent with those of previous reports. Interestingly, a similar prevalence was found for attacking and defensive players (e.g., tacklers and ball carriers/approached players). Some specific factors related to injury occurrence for both players are discussed in the following text.

It is widely accepted that poor tackling techniques, such as leading with the head or wrong side shoulder, significantly increase the risk of injury for both the tackler and the ball carrier. In other words, the proper tackling technique involves a low body position, wrapping the arms around the ball carrier, and driving through the tackle. More specifically, a proper technique ensures a controlled force distribution across a larger area. This reduces the risk of concentrated force on a single point, which can lead to injuries such as collarbone fractures or AC joint separations. Additionally, proper techniques emphasize keeping the head up and out of the tackle, reducing the risk of head injuries such as concussions. Additionally, a controlled tackle, where the tackler drives through the ball carrier with its legs, helps to dissipate the force of the impact gradually. This lessens the shock experienced by both players, reducing the risk of injuries such as shoulder dislocations or stingers (Hendricks & Lambert, 2010).

It is important to note that high tackles, particularly those above the line of the shoulder, are more likely to result in injuries for both players, since they include contact with the head or neck, even if the tackle starts lower and rides up. Naturally, the head and neck are particularly vulnerable to injury due to the presence of the brain and spinal cord, and high tackles can cause concussions and neck injuries, sometimes with even catastrophic results (Hendricks & Lambert, 2010). There are additional anatomical and biomechanical factors associated with injury mechanisms during high tackling. First, high tackles often involve greater force, as the tackler may be upright and use their body weight to drive into the ball carrier, and this increased force magnifies the potential for injury. Second, in high tacklers, both the tackler and ball carrier are more likely to lose control and fall awkwardly, increasing the risk of other injuries, such as shoulder dislocations or knee ligament tears.

A player's physical condition plays a significant role in their ability to handle it safely and effectively and thus influences their risk of injury during tackles (Hendricks & Lambert, 2010). Most importantly, stronger muscles, particularly in the neck, shoulders, and core, help to absorb and dissipate the forces experienced during a tackle. Adequate strength allows a player to execute a task with the proper technique, drive through the ball carrier and control the impact. This reduces the previously specified risk of both players losing balance and falling awkwardly, which can lead to injuries. Fatigue can significantly impair a player's decision-making, reaction time, and technique. In other words, a tired player is more likely to mistime a tackle, lose control, or adopt a poor body position, increasing the risk of injury. Therefore, proper endurance capacity allows a player to maintain proper tackling techniques throughout a match, even when fatigued.

Other conditioning capacities could also contribute to injury risk during tackling. For example, good mobility allows for a greater range of motion during a tackle, reducing the risk of muscle strains or joint sprains. Proper flexibility aids in recovery from tackles and reduces the risk of lingering stiffness or soreness, which could contribute to future injuries. Good balance and coordination are essential for maintaining control during a tackle, which helps prevent awkward falls or collisions that can lead to injuries while good agility allows a player to adjust to the movements of the ball carrier, improving their chances of executing a safe and effective tackle.

The concept of a warm-up is fundamental in injury prevention, particularly in sports and physical activities of high intensity, such as rugby (McGowan et al., 2015). The warm-up phase is generally designed to prepare the body both physically and mentally for exercise or strenuous activity. It should involve a series of low-intensity exercises that gradually increase in intensity and are aimed at improving performance while reducing the risk of injury (Silva et al., 2018). However, our results highlighted the high occurrence of injury, specifically during the warm-up phase. Therefore, our results contradict the main concept of the war-up routine in general. While the authors of the study are deeply involved in rugby training and medical issues, some contextual factors that could contribute to the high occurrence of injury, specifically during warm-up, are discussed in the following text.

First, warm-up generally prepares the body for subsequent efforts through several mechanisms, including increased blood flow and oxygen delivery, increased muscle temperature, improved joint mobility, activation of the nervous system, and mental focus and preparation (McGowan et al., 2015; Silva et al., 2018). However, if the warm-up is too short or rushed, the muscles, joints, and cardiovascular system may not be fully prepared for the demands of physical activity. This is particularly problematic if the intensity of the warm-up is too high (e.g., sprinting or performing maximal effort too early), since it can lead to muscle fatigue or overstretching, increasing the risk of muscle pulls or joint injuries.

Importantly, a recent study revealed a high prevalence of repeated injury in amateur rugby players (Bjelanovic et al., 2023). With respect to the high occurrence of injury during warm-up during training, it is possible that, here, players who had minor, undiagnosed injuries or lingering issues from past injuries were at higher risk of injury during a warm-up because the warm-up might exacerbate that condition, turning minor discomfort into a full-blown injury. This is particularly the case if they approach warm-up with less attention or seriousness. A lack of focus could lead to improper execution of exercise, awkward movements, or even collisions with other athletes, resulting in injury. We must note that our players were amateurs and, in most cases, were students and/or employed persons (please see Methods for more details). Therefore, a lack of focus and/or fatigued status were very possible. Specifically, they often train in the late afternoon and evening after their work or study, and their coordination could be impaired, which clearly increases the risk of awkward movements or falls even during warm-up activities.

The problem of appropriate warm-up is recognized by rugby authorities. As a result, the World Rugby the "Activate" program; an injury prevention exercise program. It's designed to reduce the risk of injuries, including concussions, in youth and adult community-level rugby players. In brief, "Activate" a warm-up exercise program designed to be used three times per week prior to rugby training and matches. There are three age-specific program (under-15/16/18) incorporating balance, resistance and plyometric exercises, each containing four phases to be progressed throughout the season (every 4–8 weeks). Activate was disseminated by the Rugby Football Union (RFU) in 2017 following the publication of the efficacy study. Coaches could access resources freely through the RFU website and attend regional workshops delivered by RFU community rugby coaches, who received specific Activate training. In 2018, all resources became available open access and workshops were replaced by a 'workshop on demand' system (Barden et al., 2022).

Our analyses highlighted a relatively high occurrence of injuries while running during training, but only among back players (>60% of all training-related injuries). There are several factors that could explain these results. First, backs often have training regimens that emphasize speed and agility drills (Campbell et al., 2018). This means more sprints, more changes in direction, and potentially more mileage at higher intensities than forwards. The increased volume can put more stress on their bodies, leading to overuse injuries. Second, even seemingly simple running drills, when performed repeatedly at high intensity, can lead to overuse injuries in backs (Aicale et al., 2018; Krivickas, 1997). Finally, historically, some training programs for backs may have focused more on speed and skills than on strength and conditioning. This can increase their vulnerability to injuries, as adequate strength and conditioning are crucial for injury prevention.

Unlike traditional round or conical studs, blade studs are flatter and have sharper edges (Figure 2). They are designed to provide increased grip and traction on firm ground, which can be beneficial for important performance in rugby, such as acceleration and rapid direction changes.

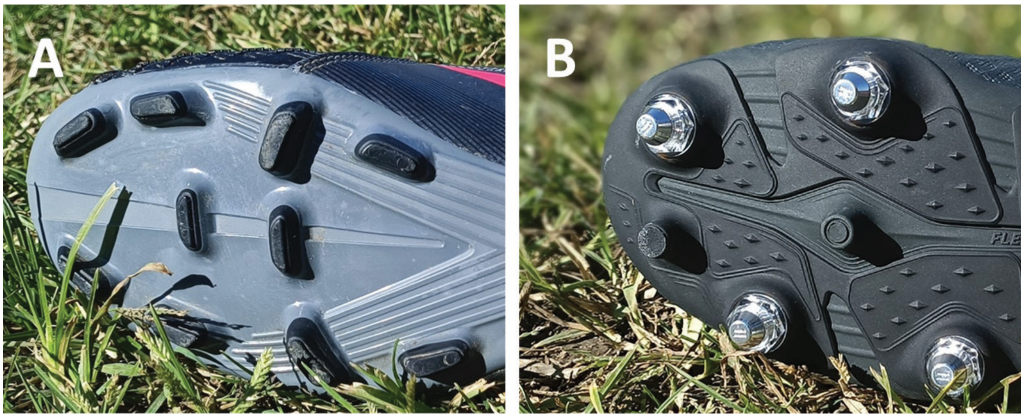

FIGURE 2. Blade studs (2A), and round studs (2B)

However, blade studs in sports (including rugby) have been a topic of debate because of their potential link with increased injury risk (Hall & Riou, 2004). Therefore, our results concerning the high risk of injury occurrence in players who wore blade studs are not surprising. There are several mechanisms that could explain our results. Before discussing this topic, we must note that in the following text, only the mechanisms of injury to players who wore footwear with blade studs will be discussed.

As previously mentioned, blade studs have increased grip. Compared with a conical stud, which is a single point, a blade stud has a wider, flatter surface that contacts the ground (Hall & Riou, 2004). This larger contact area distributes the player's weight over a greater area, leading to increased traction. Additionally, the sharp edges of blade studs are designed to "bite" into the firm ground. This digging-in action further enhances grip, especially during rapid acceleration, sharp turns, and sudden stops. This combination of increased surface area and the cutting action of blade studs minimizes slippage on firm ground, providing more secure footing for the player. This enhanced stability can be particularly beneficial when players need to change direction quickly and maintain balance during tackles and rucks. However, while it provides performance benefits, it also contributes to the potential for injury.

The first mechanism is related to traumatic injuries. Because the foot is more firmly planted in the ground, it may be less likely to release naturally during a tackle or collision. This can put extra stress on the joints, potentially leading to knee or ankle injuries. Second, the increased grip of blade studs can alter the biomechanics of running and movement. Some studies suggest that they may lead to greater muscle activation in certain leg muscles, potentially creating imbalances over time (Brock et al., 2014). These imbalances can increase the risk of overuse injuries to specific anatomical locations, such as hamstring tears and calf strains. Additionally, the way in which blade studs interact with the ground can involve placing different mechanical loads on the foot. This could lead to some specific overuse injuries over time. Specifically, because blade studs tend to distribute force more unevenly than round studs do, this can result in issues such as plantar fasciitis, shin splints, or Achilles tendinitis due to the repetitive stress on certain parts of the foot and leg.

This study is not without limitations. First, we observed amateur players from one country, and therefore generalization is possible only to similar samples. Also, study design did not allow us precise identification of the injuries and related factors (participants were interviewed by phone). Therefore, we can not be absolutely certain on accuracy of responses. However, prospective study design, and relatively large sample of participants which included players from the whole country are important strengths of the investigation.

Conclusions

Tackling was found to be a strong risk factor for injury occurrence during rugby matches. Properly tackling techniques, appropriate conditioning, awareness of safety protocols, and rule enforcement are therefore crucial. By understanding the risks associated with tackling and implementing appropriate prevention strategies, injury risk can be decreased.

The relatively high prevalence of warm-up related injuries is probably the result of inadequate preparation, improper execution of a specific movement, or existing physical conditions. To minimize risk, warm-ups are carefully planned, gradual in intensity, and player-centered. Players should also pay attention to any signs of discomfort or tightness and adjust their routine accordingly. Proper hydration, rest, and mental focus are additional critical factors to ensure that warm-ups are effective and safe. Also, coaches should be encouraged to use "Activate" program, which is specifically designed for warm-up in rugby sport.

While blade studs can improve important performance indicators in rugby players, by providing enhanced traction and grip, they also increase the risk of twisting injuries, lacerations, and overuse injuries. As a result, the choice of studs should be made carefully, considering field conditions, player position, and personal injury history.

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Conflicts of interest
The authors declare that there are no conflict of interest.

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