Playing surface and UK professional rugby union injury risk

[1]Ranson, C., [2]George, J., [3]Rafferty, J., [4]Miles, J., & [5]Moore, I. S.

[1]English Institute of Sport, Manchester, UK. [2]Saracens Rugby Club, St. Albans, UK. [3]Swansea University Medical School, Swansea University, Singleton Park, Swansea, UK. [4]Welsh Rugby Union, Cardiff, UK. [5] Cardiff School of Sport & Health Sciences, Cardiff Metropolitan University, UK

Abstract

Artificial rugby union playing surface installation is increasing. This prospective cohort study aimed to examine the effect of playing surface on match injury types within 157 players of two UK professional rugby union clubs playing 209 matches over three seasons. There was no difference in overall injury risk between the two playing surfaces with injury incidence on artificial 80.2 (CI 69.9 - 91.7) and on grass 81.9 per 1000 match-hours (CI 72.2 - 92.5), with an incidence rate ratio (RR) of 0.98 (CI 0.82 - 1.17). There was a higher rate of concussion (RR 0.52, CI 0.34 – 0.78) and chest injuries on grass (RR 0.26, CI 0.07, 0.95), and a higher rate of thigh haematoma (RR 2.25, CI 1.05 - 4.82) foot injuries (RR 4.12, CI 1.10, 15.40) and injury to players being tackled (RR 1.46, CI 1.00, 2.15) on artificial. Whilst there was no higher injury risk for matches played on artificial versus natural grass surfaces, the higher incidence of concussion and chest injury on grass, and the higher rate of foot injuries on artificial surfaces may be related to tackle and footwear-to-surface interface factors.

Introduction

Rugby union is one of the world's most popular sports, with 102 countries being members of the international governing body 'World Rugby' (World-Rugby, 2014). During matches, there are 15 players on the field from each team and there are competitions for all ages, at all levels, including; school, community, club professional and international.

Rugby union is a collision, invasion game with high match injury rates. Injury incidence within professional rugby union is consistently reported to be between 70 to 100 injuries per 1000 match-hours (Williams, Trewartha, Kemp, Michell, & Stokes, 2015) and as high as 200 injuries per 1000 match-hours within the international game (Moore, Ranson, & Mathema, 2015). A high proportion of professional rugby union players sustain multiple injuries (Moore, Mount, Mathema, & Ranson, 2017) with concussion, and traumatic joint injuries (shoulder and knee) being the most common (Williams, Trewartha, Kemp, & Stokes, 2013). Along with affecting short and potentially long term player health and performance, high injury rates have also been shown to negatively impact team performance within both association football (Eirale, Tol, Targett, Holmich, & Chalabi, 2015; Hagglund et al., 2013) and rugby union (Williams et al., 2016).

Injury risk is thought to be related to interactions between intrinsic athlete characteristics (e.g. age, injury history, muscular strength, mobility, movement control and technique) and extrinsic factors (e.g. workload, equipment and environmental conditions) (Bittencourt et al., 2016). The surface a sport is played on is therefore an extrinsic risk factor (Rennie, Vanrenterghem, Littlewood, & Drust, 2016) and whilst most rugby games are still played on grass, the use of artificial pitches is increasing. Since 2013 four professional UK rugby union clubs have installed, and play their home games on, 4th generation (4G) artificial surfaces. Artificial surfaces are relatively inexpensive and easy to maintain, can be used in all-weather and are their durability means they can be used more frequently than natural grass (Taylor, Fabricant, Khair, Haleem, & Drakos, 2012).

Despite the advantages, there is evidence from association football (Kristenson et al., 2013) and American football (Iacovelli et al., 2013) that artificial surfaces increase contact sport injury risk, particularly traumatic knee and ankle injury. With usage having only recently been adopted in professional rugby union, there are only two studies investigating associations between playing surface type and injury risk. The first compared match injuries sustained on an artificial surface in Hong Kong across a two-month season to training injuries sustained at two English Premiership clubs over a ten-month period (Fuller, Clarke, & Molloy, 2010). The other was a more direct comparison of match injury rates and types played on artificial versus grass surfaces within one English professional rugby union club. However, this was over a relatively short period of one season (Williams et al., 2015). Whilst this second study reported greater incidence of abrasions and more post-match soreness associated with play on the artificial surface, neither of these small-scale studies found a difference in overall injury incidence.

Whilst investment in artificial surfaces at both rugby union playing and training venues is increasing across the UK, little is known about the likely associated injury and player welfare

consequences. Therefore, the aim of this study was to examine the effect that playing surface had on injury rates and types sustained over three seasons, at two professional rugby union clubs who played their home matches on artificial surfaces.

Methods

Participants

All 157 players (age = 25.6 ± 10.1 years; mass = 105.3 ± 35.2 kg; height = 183.3 ± 17.7 cm) of the first team squads at two UK professional rugby union clubs participated in this prospective cohort study. One based in England and the other in Wales. All players provided informed injury surveillance consent. Study approval was provided by the Cardiff School of Sport's ethics committee.

Data Collection

Based on international consensus methods (Fuller et al., 2007), all club first-team regular season match injuries that occurred throughout the 2013-2014, 2014-2015 and 2015-2016 seasons were recorded. The primary injury definition used in the study was;

Any physical complaint sustained by a player during a match, that prevented the player from taking a full part in all training activities or match play for more than 1 day following the day of injury, irrespective of whether match or training sessions were actually scheduled.

A dedicated Physiotherapist at each club recorded the following details relating to each injury; dates of injury occurrence and return to sport, body area, diagnosis (OSICS10)(Rae & Orchard, 2007), number of days-lost, player position at time of injury, mode of onset (sudden, gradual, impact, insidious)(Orchard et al., 2016), activity at the time of injury (e.g. running, tackling, scrum, line-out, ruck), match time of injury (warm-up, first, second, third or fourth quarter, and unknown) and playing surface (natural grass, fully artificial).

Injuries that occurred when players were representing other teams, for example on international duty or at loan clubs, were excluded from the study. Additionally, training or non-rugby related injuries, injuries sustained during warm-up, medical illness, pre-season match injuries and injuries that occurred on playing surfaces consisting partially of artificial material and partially of natural grass were excluded.

Exposure

Player match-hours of exposure for each club were calculated according to the following formula:

Player match-hours = (number of players (15) x match duration (1.33 hours)) x number of matches

Both teams played their home matches on 4G artificial surfaces that conformed to World Rugby's standard relating to the use of artificial rugby turf (World-Rugby, 2016). The make and model for one was SIS Rugger (SIS, Cumbria, UK) and the other FieldTurf Optimum RGF 65 (FieldTurf, France). Only matches that were played on either artificial surface or natural

grass were included in the analysis, with matches played on hybrid grass/artificial surfaces excluded.

Statistical Analysis

Injury incidence was calculated per 1000 match-hours; [number of injuries / (match-hours x 1000)]. Rate ratios were used to compare incidences, with uncertainties in rate ratios calculated by assuming the natural logarithm of the ratio of two Poisson distributed random variables is normally distributed (Gu, Ng, Tang, & Schucany, 2008).

Bootstrapping was used to calculate confidence intervals for mean severity (days-lost) for each injury (Efron & Tibshirani, 1994). A non-parametric test, the Kolmogrov-Smirnov two sample test (Massey), was used to compare injury severity on each surface. For all the above tests, 90% confidence, or a p-value of less than 0.1, was taken to be the value at which the null hypothesis was rejected. An incidence rate ratio of 1.43 (moderate effect) (Hopkins, 2010) was chosen as the smallest worthwhile effect. Consequently, an incidence rate ratio of 1.43, with 80% power and a 90% confidence interval the minimum sample size required was 28 matches (1107 match-hours) on each surface.

Results

Over the three seasons, there were 113 matches played on grass and 96 on artificial surfaces, equating to 2260 and 1920 player match-hours respectively. There were 339 injuries resulting in 7729 days-lost with a mean severity of 22.8 days lost (CI 20.1 – 25.8).

On grass, there were 185 injuries resulting in 4200 days-lost, whilst on artificial surfaces there were 154 injuries resulting in 3511 days-lost. The mean injury severity on grass was 22.7 days lost, (CI 19.1 – 26.7), while the mean injury severity on artificial surfaces was 22.8 days lost (CI 18.8 - 27.4). The median injury severity was identical for both surfaces (11.0, CI 10.0 – 13.0).

Overall injury incidence was 81.1 per 1000 match-hours (CI 74.0 - 88.7). On artificial the injury incidence was 80.2 per 1000 match-hours (CI 69.9 – 91.7) and on grass the injury incidence was 81.9 per 1000 match-hours (CI 72.2 – 92.5). The incidence rate ratio (RR) was 0.98 (CI 0.82 - 1.17) meaning the probability of there being a difference in rates is less than 90%.

Injury rates for each body location are shown in Table 1. Head, thigh, ankle, knee and shoulder injuries had high incidence on both surfaces. The only surface to surface differences by body location were; higher head (RR 0.57, CI 0.38 – 0.84) and chest (RR 0.26, CI 0.07 - 0.95) injury incidence on grass, and higher thigh (RR 1.62, CI 1.04 - 2.52) and foot (RR 4.12, CI 1.10 - 15.40) incidence on artificial, although the number of foot injuries was low (7 on artificial and 2 on grass).

Seventy-three of the 80 head injuries (91%, 17.9 per 1000 match-hours, CI 14.6 - 21.7) were concussions, with a higher concussion incidence on grass (23.2, CI 18.0 - 29.3 vs 12.0, CI 8.2 – 17.0 per 1000 match-hours, RR 0.52, CI 0.34 – 0.78). Nine of the 11 chest injuries were sustained on grass. Eight of the nine were impact injuries causing either rib fracture/contusion, chondral or sternoclavicular joint sprain.

The thigh injuries were predominantly muscle strains (8.3 per 1000 match hours, CI 6.1 - 11.1) and haematomas (5.2 per 1000 match hours, CI 3.5 - 7.4). Of these, there was a higher haematoma incidence on artificial (RR 2.25 CI 1.05 - 4.82) but no thigh muscle strain surface to surface difference. The majority (62%) of thigh haematomas occurred when being tackled, with 29% due to tackling and 9% due to accidental collisions.

The ankle injuries primarily consisted of ligament strains (lateral ligament, syndesmosis and deltoid; Table 2) with no surface to surface differences in incidence. Six of the eight foot injuries occurred on an artificial surface and these consisted of two Lisfranc joint and one first metatarsophalangeal dislocation, a cuboid fracture, a calcaneal haematoma and a plantar fascia rupture.

Sixty-five percent of the knee injuries (5.6 per 1000 match-hours, CI 3.9 - 8.0) were to the major ligaments with no surface to surface incidence differences. There was only one anterior cruciate ligament rupture, which was sustained on an artificial surface.

There were no surface to surface differences within the shoulder injuries. There were also no between surface differences in 'time of injury' injury rates, with the greatest proportion of injuries occurring in the fourth quarter of matches played on both surfaces (24% and 26% on artificial and grass respectively).

There were also no between surface differences in the rates of injury for each mode of onset, with a high proportion being sudden onset and impact injuries (Table 3). Sixty-seven percent of all injuries were associated with contact events, with the tackle (tackling and being tackled) making up the majority (Table 4). There was a higher incidence of injury to players being tackled on artificial surfaces [RR 1.46 (CI 1.00 - 2.15)]. Sixty-two (84%) of the 74 non-contact related injuries had 'running' as the activity associated with injury, in addition to eight (11%) being due to 'landing'. There were no surface related differences for 'running' [RR 1.00 (CI 0.66 – 1.52)] or 'landing' [RR 2.94 (CI 0.74 – 11.65)].

Forwards had a greater injury incidence on grass (92.0 per 1000 match-hours, CI 77.8 - 108.1) compared to artificial surfaces [66.4 per 1000 match-hours, CI 53.7 - 81.3, RR 0.73 (CI 0.56 - 0.94)]. There was no between surface difference in injury incidence for backs. There were no between surface differences in the severity of injuries, with the set of days-lost being the same within the chosen significance cut-off.

Discussion

The aim of this study was to compare longitudinal rugby union injury types and rates sustained on natural grass and artificial playing surfaces. There was no difference in the overall injury incidence, but specific body regions differences were evident. A higher incidence of concussion and chest injury was reported on grass, whilst a higher incidence of thigh haematoma and foot injury was reported on artificial surfaces. There was also a higher incidence of injuries to forwards on natural grass surfaces.

The comparable overall injury incidence rate supports previous findings in rugby union (Williams et al., 2015) and association football (Rennie et al., 2016), which showed little difference in injury risk between the two surfaces. This provides reassurance to governing

bodies who are considering installing artificial surfaces and to players who play for a team who regularly plays on artificial surfaces.

The overall injury incidence of 81.1 per 1000 match-hours is comparable with the 81 per 1000 match-hours reported in a 2013 professional rugby union injury surveillance meta-analysis (Williams et al., 2013). However, the concussion incidence of 18 per 1000 match-hours represents a continuation of the steady increases seen over the last few years in both Welsh and English professional rugby (RFU, 2017). Whether this rise represents a real rise in concussion risk, or can be attributed to a heightened awareness of recognising and reporting cushion remains to be established. However, the finding that concussion had a greater incidence on grass than artificial surfaces may provide some direction for research into mechanisms and associated concussion prevention strategies. For example, investigating whether a relatively less stable interface between footwear and grass surfaces (Taylor et al., 2012) predisposes players to postures where they are more likely to sustain injurious head and chest impacts may be indicated. Further studies, potentially investigating footwear-surface interfaces and/or video analysis of injury mechanisms, are required.

Unfortunately, there are not yet any time-motion, tactical or technical analysis studies comparing the style and pace of rugby union played on artificial versus grass surfaces. However, there is evidence from association football that players are less willing to make sliding tackles on artificial versus grass surfaces (Andersson, Ekblom, & Krustrup, 2008). A lower concussion incidence might, at least partially, be explained if there is a similar reluctance to dive or fall onto artificial rugby union pitches, particularly in the act of tackling, or being tackled, which are the activities most associated with concussion (Cross et al., 2017).

Thigh injuries had a high overall incidence, yet only thigh haematoma had a higher incidence on artificial playing surfaces. Whilst thigh haematomas are typically minor they have been recognised from this and other studies (Moore et al., 2015) as a considerable rugby injury problem due to their frequency. Kordi and colleagues (2011) also found a high rate of haematoma on artificial association football pitches but no mechanistic explanation was provided. Between surface tactical and technical differences may again be an influence and multi-factor studies investigating such relationships are encouraged.

Higher rates of ankle sprains on artificial American (Iacovelli et al., 2013) and association football (Kristenson et al., 2013) pitches were not replicated in the current study. However, there was a higher rate of artificial surface foot injuries, particularly midfoot and toe fractures and dislocations which might be related to greater artificial surface traction, stiffness and rotational torque (Thomson, Rod Whiteley, & Bleakley, 2015). Optimising boot-stud and playing surface interaction should be considered within improved footwear design. Although it occurred on an artificial surface, there was only one knee anterior cruciate ligament rupture across the three seasons and both teams, conflicting the notion that artificial surfaces predispose this injury (Dragoo, Braun, & Harris, 2013).

Previous studies in rugby union (Williams et al., 2015) and association football (van den Eijnde, Peppelman, Lamers, van de Kerkhof, & van Erp, 2014) reported a high incidence of abrasions on artificial playing surfaces, although the rugby study did not apply the consensus ‘time-loss’ injury definition criteria. Skin abrasions rarely cause players to be unavailable for

rugby (Williams et al., 2015), which is likely to be the reason why the incidence was low in the current study. Future studies of the effect of surface on injury type should consider surveying the performance impact of specific diagnoses that do not often result in time-loss such as skin abrasions and lower limb tendinopathy.

The finding of a higher injury incidence amongst forwards, including an almost double concussion incidence, and higher chest injury incidence on grass, may be related to surface specific styles of play. A slower, 'tighter' style that preferentially involves forwards in contact events is typically believed to be associated with matches on grass and a faster, more expansive 'back' dominated style often believed to be associated with artificial surface play. The latter possibly being associated with the higher incidence of injury to players being tackled on artificial surfaces. If confirmed in future comparative match-play time-motion analyses, it will re-affirm the importance of coaching and contact technique regulation (World-Rugby, 2017) to minimise head impact and other tackle related injuries.

A strength of this paper is that it captured comprehensive longitudinal match injury data from the only two UK Clubs that played all their home matches on artificial surfaces over the three-season survey period. However, in epidemiological terms the database remains relatively small and only includes teams who play regularly on artificial surfaces. Ongoing data capture and analysis will be vital in confirming the findings and to understand whether injury types and rates are different for teams not as accustomed to artificial pitches. An associated limitation is that a few relatively long-term injuries can skew comparisons, meaning injury severity analysis could only be conducted where the sample size was sufficiently large. However, no between-surface differences in injury severity were found.

Conclusions

Overall rugby union match injury risk is comparable between grass and artificial playing surfaces. However, there was a higher risk of concussion and chest injuries on grass, and higher incidence of thigh haematoma and foot injuries on artificial surfaces. There was also a higher injury incidence within forwards playing on grass surfaces. It is recommended that future work includes comparative injury mechanism video analysis and investigates time-motion, technical and tactical risk factors along with optimal footwear to surface interaction on both surfaces, particularly surface specific aspects of tackle technique.

References

Andersson, H., Ekblom, B., & Krustrup, P. (2008). Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *J Sports Sci, 26*(2), 113-122. doi: 10.1080/02640410701422076

Bittencourt, N. F., Meeuwisse, W. H., Mendonca, L. D., Nettel-Aguirre, A., Ocarino, J. M., & Fonseca, S. T. (2016). Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition-narrative review and new concept. *Br J Sports Med*. doi: 10.1136/bjsports-2015-095850

Cross, M., Tucker, R., Raftery, M., Hester, B., Williams, S., Stokes, K., . . . Kemp, S. (2017). Tackling Concussion in Professional Rugby Union: An Investigation of Tackle-Based Risk Factors and Recommendations for Primary Prevention. *British Journal of Sports Medicine, In press*

Dragoo, J. L., Braun, H. J., & Harris, A. H. (2013). The effect of playing surface on the incidence of ACL injuries in National Collegiate Athletic Association American Football. *Knee, 20*(3)

Efron, B., & Tibshirani, R. J. (1994). *An introduction to the bootstrap*: CRC Press.

Eirale, C., Tol, J. L., Targett, S., Holmich, P., & Chalabi, H. (2015). Concussion surveillance: do low concussion rates in the Qatar Professional Football League reflect a true difference or emphasize challenges in knowledge translation? *Clin J Sport Med, 25*(1), 73-74. doi: 10.1097/JSM.0000000000000066

Fuller, C. W., Clarke, L., & Molloy, M. G. (2010). Risk of injury associated with rugby union played on artificial turf. *Journal of Sports Sciences, 28*(5), 563-570. doi: 10.1080/02640411003629681

Fuller, C. W., Molloy, M. G., Bagate, C., Bahr, R., Brooks, J. H., Donson, H., . . . Wiley, P. (2007). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *British Journal of Sports Medicine, 41*(5), 328-331. doi: 10.1136/bjsm.2006.033282

Gu, K., Ng, H. K., Tang, M. L., & Schucany, W. R. (2008). Testing the ratio of two poisson rates. *Biometrical Journal, 50*(2), 283-298

Hagglund, M., Walden, M., Magnusson, H., Kristenson, K., Bengtsson, H., & Ekstrand, J. (2013). Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med, 47*(12), 738-742. doi: 10.1136/bjsports-2013-092215

Hopkins, W. G. (2010). Linear models and effect magnitudes for research, clinical and practical applications. *Sportscience, 14*, 49-57

Iacovelli, J. N., Yang, J., Thomas, G., Wu, H., Schiltz, T., & Foster, D. T. (2013). The effect of field condition and shoe type on lower extremity injuries in American Football. *Br J Sports Med, 47*(12), 789-793. doi: 10.1136/bjsports-2012-092113

Kristenson, K., Bjorneboe, J., Walden, M., Andersen, T. E., Ekstrand, J., & Hagglund, M. (2013). The Nordic Football Injury Audit: higher injury rates for professional football clubs with third-generation artificial turf at their home venue. *Br J Sports Med, 47*(12), 775-781. doi: 10.1136/bjsports-2013-092266

Massey, F. J. (1951). The Kolmogorov-Smirnov Test for Goodness of Fit. *Journal of the American Statistical Association, 46*(253), 68-78

Moore, I. S., Mount, S., Mathema, P., & Ranson, C. A. (2017). Application of the Subsequent Injury Categorisation (SIC) model for longitudinal injury surveillance in elite rugby and cricket: Inter-sport comparisons and inter-rater reliability of coding. *British Journal of Sports Medicine, online March 2017*

Moore, I. S., Ranson, C., & Mathema, P. (2015). Injury Risk in International Rugby Union: Three-Year Injury Surveillance of the Welsh National Team. *Orthop J Sports Med, 3*(7), 2325967115596194. doi: 10.1177/2325967115596194

Orchard, J. W., Ranson, C., Olivier, B., Dhillon, M., Gray, J., Langley, B., . . . Finch, C. F. (2016). International consensus statement on injury surveillance in cricket: a 2016 update. *Br J Sports Med, 50*, 1245-1251 doi: 10.1136/bjsports-2016-096125

Rae, K., & Orchard, J. (2007). The Orchard Sports Injury Classification System (OSICS) version 10. *Clin J Sport Med, 17*(3), 201-204. doi: 10.1097/JSM.0b013e318059b536

Rennie, D. J., Vanrenterghem, J., Littlewood, M., & Drust, B. (2016). Can the natural turf pitch be viewed as a risk factor for injury within Association Football? *J Sci Med Sport, 19*(7), 547-552. doi: 10.1016/j.jsams.2015.07.009

RFU (2017). *England professional rugby injury surveillance project: 2015–2016 season report*. Twickenham: RFU.

Taylor, S. A., Fabricant, P. D., Khair, M. M., Haleem, A. M., & Drakos, M. C. (2012). A review of synthetic playing surfaces, the shoe-surface interface, and lower extremity injuries in athletes. *Physician and Sports Medicine, 40*(4), 66-72

Thomson, A., Rod Whiteley, R., & Bleakley, C. (2015). Higher shoe-surface interaction is associated with doubling of lower extremity injury risk in football codes: a systematic review and meta-analysis. *British Journal of Sports Medicine*

van den Eijnde, W. A., Peppelman, M., Lamers, E. A., van de Kerkhof, P. C., & van Erp, P. E. (2014). Understanding the Acute Skin Injury Mechanism Caused by Player-Surface Contact During Soccer: A Survey and Systematic Review. *Orthop J Sports Med, 2*(5), 2325967114533482. doi: 10.1177/2325967114533482

Williams, S., Trewartha, G., Kemp, S., & Stokes, K. (2013). A Meta-Analysis of Injuries in Senior Men's Professional Rugby Union. *Sports Med*. doi: 10.1007/s40279-013-0078-1

Williams, S., Trewartha, G., Kemp, S. P., Brooks, J. H., Fuller, C. W., Taylor, A. E., . . . Stokes, K. A. (2016). Time loss injuries compromise team success in Elite Rugby Union: a 7-year prospective study. *Br J Sports Med, 50*(11), 651-656. doi: 10.1136/bjsports-2015-094798

Williams, S., Trewartha, G., Kemp, S. P., Michell, R., & Stokes, K. A. (2015). The influence of an artificial playing surface on injury risk and perceptions of muscle soreness in elite Rugby Union. *Scand J Med Sci Sports*. doi: 10.1111/sms.12402

World-Rugby. (2014). *Member unions*. Retrieved from http://www.worldrugby.org/member-unions

World-Rugby. (2016). Regulation 22. Standard relating to the use of artificial rugby turf. Dublin, Ireland.

World-Rugby. (2017). Rugby union: Laws of the Game (reckless and accidental tackles). http://laws.worldrugby.org/?domain=9&guideline=10: World Rugby.

Table 1. Match injury rates on grass and artificial playing surfaces by body location. Ranked by total incidence (90% confidence interval) per 1000 match-hours - proportion relates to the percentage of all injuries for that surface type and severity (90% confidence interval) is the mean number of days-lost for that injury type. Body areas in **bold** have a significant difference in incidence.

Body Location	Total		Artificial			Grass			Incidence Comparison
	Incidence	Severity	Incidence	Proportion	Severity	Incidence	Proportion	Severity	Rate Ratio
Head	**19.1 (15.8 - 23.1)**	**11.6 (9.9 - 13.8)**	**13.5 (9.5 - 18.8)**	**16.8%**	**12.7 (9.5 - 17.0)**	**23.9 (18.8 - 30.0)**	**29.2%**	**11.0 (9.1 - 13.5)**	**0.57 (0.38 - 0.84)**
Thigh	**13.6 (10.8 - 17.0)**	**20.3 (15.7 - 25.9)**	**17.2 (12.6 - 23.0)**	**21.4%**	**16.4 (12.4 - 21.1)**	**10.6 (7.3 - 14.9)**	**12.9%**	**25.4 (16.3 - 37.3)**	**1.62 (1.04 - 2.52)**
Ankle	9.6 (7.2 - 12.5)	27.3 (19.4 - 37.2)	10.9 (7.3 - 15.8)	13.6%	22.9 (15.0 - 32.9)	8.4 (5.5 - 12.3)	10.3%	31.9 (18.2 - 49.4)	1.30 (0.77 - 2.19)
Shoulder	8.1 (6.0 - 10.8)	36.4 (23.3 - 51.8)	6.8 (4.0 - 10.8)	8.5%	40.9 (16.8 - 73.0)	9.3 (6.2 - 13.4)	11.4%	32.9 (19.3 - 49.2)	0.73 (0.41 - 1.30)
Knee	7.9 (5.8 - 10.6)	36.6 (24.7 - 50.8)	8.9 (5.6 - 13.3)	11.1%	29.8 (16.9 - 47.6)	7.1 (4.4 - 10.8)	8.7%	43.4 (24.6 - 65.8)	1.25 (0.71 - 2.22)
Lower Leg	5.0 (3.4 - 7.2)	18.1 (12.9 - 24.0)	4.7 (2.4 - 8.2)	5.9%	15.4 (8.7 - 23.8)	5.3 (3.1 - 8.6)	6.5%	20.0 (12.8 - 28.2)	0.88 (0.43 - 1.82)
Wrist and Hand	3.3 (2.0 - 5.2)	29.6 (15.9 - 45.6)	3.6 (1.7 - 6.8)	4.5%	36.3 (19.1 - 55.6)	3.1 (1.5 - 5.8)	3.8%	22.4 (5.9 - 50.4)	1.18 (0.49 - 2.84)
Neck	3.1 (1.8 - 4.9)	12.8 (8.6 - 17.8)	2.6 (1.0 - 5.5)	3.2%	9.6 (6.8 - 12.6)	3.5 (1.8 - 6.4)	4.3%	14.8 (8.5 - 22.4)	0.74 (0.29 - 1.88)
Chest	**2.6 (1.5 - 4.4)**	**23.1 (13.1 - 37.9)**	**1.0 (0.2 - 3.3)**	**1.2%**	**8.0 (5.0 - 11.0)**	**4.0 (2.1 - 6.9)**	**4.9%**	**26.6 (14.7 - 44.3)**	**0.26 (0.07 - 0.95)**
Lumbar Spine	2.4 (1.3 - 4.1)	6.9 (5.3 - 9.0)	3.6 (1.7 - 6.8)	4.5%	7.0 (4.9 - 9.9)	1.3 (0.4 - 3.4)	1.6%	6.7 (5.3 - 8.0)	2.75 (0.88 - 8.55)
Hip and Groin	2.2 (1.1 - 3.8)	7.0 (5.6 - 8.4)	3.1 (1.4 - 6.2)	3.9%	7.7 (5.7 - 9.5)	1.3 (0.4 - 3.4)	1.6%	5.7 (5.0 - 6.3)	2.35 (0.74 - 7.53)
Foot	**2.2 (1.1 - 3.8)**	**62.3 (32.6 - 96.0)**	**3.6 (1.7 - 6.8)**	**4.5%**	**72.0 (33.0 - 112.6)**	**0.9 (0.2 - 2.8)**	**1.1%**	**31.5**	**4.12 (1.10 - 15.40)**
Other	1.7 (0.8 - 3.2)	13.0 (7.0 - 18.0)	0	0.0%	0	3.1 (1.5 - 5.8)	3.8%	13.0 (7.0 - 18.0)	0
All Injuries	81.1 (74.0, 88.7)	22.8 (20.1 - 25.8)	80.2 (69.9, 91.7)	100%	22.8 (18.8 - 27.4)	81.9 (72.2, 92.5)	100%	22.7 (19.1 - 26.7)	0.98 (0.82 - 1.17)

Table 2. Ankle injury types and rates on grass and artificial playing surfaces. Ranked by total incidence (90% confidence interval) per 1000 match-hours - proportion relates to the percentage of all injuries for that surface type and severity (90% confidence interval) is the mean number of days-lost for that injury type.

Ankle Injuries	Total		Artificial			Grass			Incidence Comparison
	Incidence	Severity	Incidence	Proportion	Severity	Incidence	Proportion	Severity	Rate Ratio
Lateral ligaments	4.1 (2.6 - 6.1)	17.0 (10.4 - 27.1)	5.7 (3.2 - 9.5)	52.3%	19.7 (10.0 - 34.5)	2.7 (1.2 - 5.2)	32.1%	11.8 (7.3 - 17.2)	2.16 (0.94 - 4.97)
Syndesmosis	1.9 (1.0 - 3.5)	53.5 (34.4 - 72.2)	1.6 (0.4 - 4.0)	14.7%	42.3 (14.7 - 70.0)	2.2 (0.9 - 4.7)	26.2%	60.2 (36.6 - 83.4)	0.71 (0.21 - 2.35)
Deltoid	1.7 (0.8 - 3.1)	19.6 (13.3 - 26.4)	2.1 (0.7 - 4.8)	19.3%	24.5 (16.5 - 32.5)	1.3 (0.4 - 3.4)	15.5%	13.3 (8.3 - 18.3)	1.57 (0.45 - 5.51)
Other	1.9 (1.0 - 3.5)	29.9 (8.1 - 69.5)	1.6 (0.4 - 4.0)	14.7%	12.0 (6.3 - 17.7)	2.2 (0.9 - 4.7)	26.2%	40.8 (6.6 - 104.0)	0.71 (0.21 - 2.35)
All Ankle	9.6 (7.2 - 12.5)	27.3 (19.4 - 37.2)	10.9 (7.3 - 15.8)	100%	22.9 (15.0 - 32.9)	8.4 (5.5 - 12.3)	100%	31.9 (18.2 - 49.4)	1.30 (0.77 - 2.19)

Table 3. Injury rates on grass and artificial playing surfaces by mode of onset. Ranked by total incidence (90% confidence interval) per 1000 match-hours - proportion relates to the percentage of all injuries for that surface type and severity (90% confidence interval) is the mean number of days-lost for that injury type.

Mode of injury onset	Total		Artificial		Grass		Incidence Comparison
	Incidence	Severity	Incidence	Severity	Incidence	Severity	Rate Ratio
Sudden onset	41.4 (36.4 - 46.9)	31.0 (26.2 - 36.2)	42.7 (35.3 - 51.3)	32.8 (25.8 - 41.0)	40.3 (33.6 - 47.9)	29.1 (23.1 - 35.9)	1.06 (0.83 - 1.36)
Impact	35.4 (30.8 - 40.6)	13.7 (11.5 - 16.5)	33.3 (26.8 - 41.0)	11.0 (9.2 - 13.2)	37.2 (30.8 - 44.6)	15.8 (12.3 - 20.3)	0.90 (0.68 - 1.18)
Gradual onset	2.9 (1.7 - 4.7)	18.7 (8.9 - 35.0)	2.6 (1.0 - 5.5)	10.4 (8.0 - 12.8)	3.1 (1.5 - 5.8)	25.6 (8.0 - 52.3)	0.84 (0.32 - 2.20)
Insidious	1.4 (0.6 - 2.8)	14.8 (9.0 - 21.5)	1.6 (0.4 - 4.0)	21.3 (14.3 - 28.3)	1.3 (0.4 - 3.4)	8.7 (5.0 - 12.3)	1.18 (0.31 - 4.51)
Total	81.1 (74.0, 88.7)	22.8 (20.1 - 25.8)	80.2 (69.9, 91.7)	22.8 (18.8 - 27.5)	81.9 (72.2, 92.5)	22.7 (19.1 - 26.8)	0.98 (0.82 - 1.17)

Table 4. Contact event injury rates on grass and artificial playing surfaces. Ranked by total incidence (90% confidence interval) per 1000 match-hours. Severity (90% confidence interval) is the mean number of days-lost for that injury type. Contact events in **bold** have a significant difference in incidence.

Contact Event	Total		Artificial		Grass		Incidence Comparison
	Incidence	Severity	Incidence	Severity	Incidence	Severity	Rate Ratio
Tackling	22.0 (18.4 - 26.2)	17.5 (13.7 - 22.5)	18.8 (13.9 - 24.8)	19.6 (13.5 - 28.4)	24.8 (19.6 - 31.0)	15.9 (11.3 - 22.1)	0.76 (0.53 - 1.08)
Tackled	**17.7 (14.5 - 21.5)**	**21.8 (15.9 - 29.2)**	**21.4 (16.2 - 27.7)**	**20.1 (12.5 - 30.7)**	**14.6 (10.7 - 19.5)**	**23.4 (15.3 - 34.5)**	**1.46 (1.00 - 2.15)**
Rucks	6.5 (4.6 - 8.9)	27.1 (16.7 - 40.1)	4.7 (2.4 - 8.2)	29.4 (13.1 - 54.7)	8.0 (5.1 - 11.8)	25.4 (13.5 - 41.2)	0.59 (0.30 - 1.15)
Collisions	4.1 (2.6 - 6.1)	18.0 (9.5 - 29.2)	3.1 (1.4 - 6.2)	8.0 (4.3 - 11.8)	4.9 (2.7 - 8.1)	23.6 (10.9 - 40.0)	0.64 (0.28 - 1.48)
Scrum	1.7 (0.8 - 3.1)	35.1 (7.9 - 81.6)	2.1 (0.7 - 4.8)	47.8 (4.5 - 133.8)	1.3 (0.4 - 3.4)	20.0 (11.7 - 28.3)	1.57 (0.45 - 5.51)
Unknown	1.2 (0.5 - 2.5)	26.0 (12.4 - 40.8)	1.6 (0.4 - 4.0)	37.0 (25.0 - 49.0)	0.9 (0.2 - 2.8)	9.5	1.77 (0.39 - 7.93)