Synthetic playing surfaces increase the incidence of match injuries in elite Rugby Union.

Ben E. W. Cousins[a*], John G. Morris[a], Caroline Sunderland[a], Anthony M. Bennett[b], Golnaz Shahtahmassebi[c] & Simon B. Cooper[a].

a - Sport Performance Research Group, Sport Science Department, Nottingham Trent University, UK.
b - Applied Sport Technology, Exercise and Medicine Research Centre (A-STEM), College of Engineering, Swansea University, UK.
c - Department of Physics and Mathematics, Nottingham Trent University, UK.

***Correspondence:** Simon Cooper; simon.cooper@ntu.ac.uk
Postal Address: Sport Science Department, School of Science and Technology, Nottingham Trent University, Clifton Lane, Nottingham, NG11 8NS, United Kingdom.

Abstract

Objectives: To examine differences in match injury incidence between three playing surfaces in elite Rugby Union. **Design:** Prospective cohort. **Method**: Match injury incidence was assessed in 89 elite Rugby Union players over two-seasons of professional competition (44 matches, 1014 h player exposure). Match injury incidence was assessed on three different playing surfaces; natural grass, hybrid (natural grass combined with approximately 3% synthetic fibres) and fully synthetic (sand and rubber infill). Overall injury incidence, contact and non-contact injury incidence, and the incidence of minor (≤7 d lost) and major (≥8 d lost) injuries were considered using mixed effect models. **Results**: Overall match injury incidence doubled on hybrid and synthetic surfaces compared to natural grass (hybrid: OR=2.58 [95% CI 1.65-4.03], p<0.001; synthetic: OR=2.16 [95% CI 1.07-4.37], p=0.033). Furthermore, the odds of sustaining a contact injury on a pitch containing any synthetic content also increased compared to natural grass (hybrid: OR=2.31 [95% CI 1.41-3.78], p=0.001; synthetic: OR=2.19 [95% CI 1.00-4.77], p=0.049). The hybrid surface elicited a four times greater likelihood of non-contact injury incidence compared to natural grass (OR=4.18 [95% CI 1.16-15.04], p=0.028). However, the playing surface did not affect the severity of match injuries (all p>0.05). **Conclusions**: The present study suggests that even a small percentage (3%) of synthetic content in the playing surface significantly increases match injury incidence, with an effect seen on both contact and non-contact injury incidence. These findings are important to enable practitioners to be aware of the injury implications of playing matches on hybrid and synthetic pitches.

Keywords: Hybrid, synthetic, grass, pitch type, injury.

Introduction

In recent years, innovations in 'sports turf' have seen an increasing number of competitive professional team sports matches taking place on fully synthetic or hybrid (typically 3% synthetic and 97% natural grass, combined) surfaces[1]. Synthetic playing surfaces have evolved considerably since their initial introduction in the 1960s, with synthetic turf routinely installed in professional, university, and community sports fields across the world[1]. The versality and durability in varying climates makes synthetic surfaces ideal for multipurpose facilities, with a number of professional Rugby Union teams ground sharing with other sports such as Football. However, the health and injury ramifications of playing Rugby Union on the various playing surfaces are not fully understood. The match injury incidence reported in elite Rugby Union is alarming (103 per 1000 h match exposure)[2] and is one of the highest reported rates across professional sport. For example, match injury incidence in Rugby Union is much higher when compared to Rugby League (57.0 per 1000 h)[3], Football (27.5 per 1000 h)[4], and Australian Rules Football (25.7 per 1000 h)[5]. Factors affecting injury incidence are thus of great importance, not only from a safety perspective, but also from a performance perspective; whereby high squad availability is a key determinant of successful team performance[6].

Research exploring the potential relationships between the risk of injury on synthetic turf as opposed to natural grass have offered conflicting findings across a range of sports, including Football[7-11]. A study of 290 Football players from 10 elite European clubs who played their matches on a combination of third generation (3G) synthetic turf and natural grass pitches revealed no differences between match injury incidence on synthetic turf and natural grass (19.6 vs. 21.5 per 1000 h, respectively)[7]. However, data from 1129 elite Football players demonstrated that 91% of all players believed the type of playing surface could affect their injury risk[8]. Perceived soreness and pain were both greater on synthetic turf. Additionally, a 10-season, study of National Football League (NFL) American Football players, reported a greater lower limb injury incidence for matches played on synthetic surfaces, compared to natural

grass[10]. Specifically, in the 5360 matches analysed, the incidence of anterior cruciate ligament sprains (67% higher) and ankle eversion injuries (31% higher) were higher on the synthetic surface.

An increasing number of competitive Rugby Union matches are taking place on fully synthetic surfaces. The data accumulated by the Injury Surveillance Project over the past five seasons has examined match injury incidence on natural grass compared to synthetic turf. Descriptive data demonstrate very little difference in injury incidence between the two different types of surface (natural grass: 81 per 1000 h; synthetic: 77 per 1000 h)[12]. However, no statistical examination was undertaken. Two further studies have explored the differences between synthetic and natural grass playing surfaces in terms of injury risk in Rugby Union[13-14]. Despite no difference in overall injury incidence between synthetic and natural grass playing surfaces in either study[13-14], the incidence of foot injuries on synthetic surfaces was reported as over three times that on natural grass (synthetic: 3.6 per 1000 h vs. natural grass: 0.9 per 1000 h)[14]. This is in line with the increased incidence of lower limb injuries in American Football[9], an effect which may be explained by increased traction on synthetic surfaces[11].

Alongside the fully synthetic playing surfaces that have been introduced into the professional game over the past few years, hybrid pitches (natural grass combined with approximately 3% synthetic fibres) have also become common. However, the hybrid surface has been excluded from the studies exploring injury incidence in Rugby Union[13-14] and thus the impact of a hybrid playing surface on injury incidence is unknown. Additionally, the modality (contact vs. non-contact) and severity (i.e. number of days lost due to injury) of match injury associated with the three playing surfaces in Rugby Union has not been considered, with previous studies just considering overall injury incidence[14]. Therefore, the present study aimed to examine the effect of playing surface (natural grass, hybrid and synthetic) on match injury incidence. Furthermore, the modality (contact vs. non-contact) and severity (minor severity: ≤7 d vs. major severity: ≥8 d) of the injuries that occur on each playing surface was also

explored. Based on the limited research to date in Rugby Union[13-14], it was hypothesised that playing surfaces would have no effect on the incidence, modality or severity of match injuries in elite Rugby Union players.

Methods

The study was a two-season prospective cohort study of Rugby Union players (n = 89, age: 26.5 ± 4.5 years, height: 1.86 ± 0.07 m, body mass: 104.3 ± 13.5 kg) registered in the first team squad of an elite professional English Rugby Union club (season 1, n = 60; season 2, n = 56; with n = 26 common across both seasons). Ethical approval was provided by the host institution's Ethical Advisory Committee and all players provided written consent to participate. In brief, all first team matches (n = 44) were examined across two seasons of competition; season one at Premiership level and season two at Championship level. The playing surface was recorded, alongside the injury incidence, modality of injury (contact or non-contact) and severity of injury (subsequent number of days unavailable for training and/or match selection).

The playing surface on which each match took place was recorded. Across the two seasons, the players were exposed to three different playing surfaces: fully natural grass laid pitches; hybrid grass pitches (also known as GrassMaster®, a playing field surface composed of natural grass combined with approximately 3% synthetic fibres); and synthetic pitches (more commonly termed third generation (3G), which consists of 60 mm synthetic turf, sand and rubber infill). Across the study, there were 18 matches on grass (397 player exposures resulting in 411 h exposure time), 22 matches on hybrid playing surfaces (492 exposures resulting in 509 h exposure time) and 4 matches on synthetic playing surfaces (90 player exposures resulting in 94 h exposure time). Typically, all players in the present study trained on natural grass pitches, unless extreme weather conditions meant the session took place indoors on a synthetic surface.

All injuries sustained during match play were categorised by the club's medical staff and were defined as any physical complaint that resulted in that individual being unable to take a full part in any subsequent field- or gym-based training session or match, in line with the consensus statement defined by the International Rugby Board in 2007[15]. The modality (contact or non-contact) and severity of injury were also recorded. Severity was based upon the number of days that a player was unavailable for training and/or matches as a result of an injury; and was categorised as either minor (≤7 d) or major (≥8 d), based on the work of Brooks et al. (2005)[16]. The site at which the injury occurred was also recorded in alignment with the consensus statement[15].

All players who played any part in a match (full match, starter, replacement) were included in the analyses. The first section of the results presents descriptive data on the injury incidence across the three playing surfaces (natural grass, hybrid, synthetic). All analyses were performed using the open access R software package (www.r-project.org). To assess the impact of playing surface on match injury incidence, mixed effect models were conducted using the *glmer* function (as suggested by Windt et al., 2018)[17]. All models were fit with a Bernoulli (binomial) outcome distribution and random effects for player, season, and match number were included in all models. Initial models examining overall differences between the playing surfaces were conducted. Then each playing surface was applied as a factor to assess the differences in injury incidence (injury or no injury) and severity of injury (minor or major) between each of the different playing surfaces. To assess modality, separate models were run for contact (response variable: contact injury or no contact injury) and non-contact (response variable: non-contact injury or no non-contact injury) injuries. To calculate the odds ratios (OR) from models, the exponential of the parameter estimate was used, and 95% CI (1.96 * standard error) were also calculated. For all analyses, statistical significance was accepted as $p<0.05$.

Results

Across the two seasons, there were 44 matches played across the three different playing surfaces, with a total of 139 match injuries. On the natural grass playing surface a total of 34 injuries at an incidence of 82.8 per 1000 h and a mean severity of 26.9 d (95% CI 14.6 d -39.2 d), a total of 90 injuries at an incidence of 176.9 per 1000 h was seen on the hybrid playing surface, mean severity 23.1 d (95% CI 15.5 d – 30.8 d) and on the synthetic playing surface a total of 15 injuries at an incidence of 160.3 per 1000 h, mean severity 33.3 d (95% CI 7.6 d – 58.9 d), as shown in Table 1.

(Insert Table 1 here)

The initial mixed effect model demonstrated that injury incidence was affected by playing surface (parameter estimate: -0.422; standard error: 0.176; $p = 0.016$). The overall match injury incidence was approximately two times greater for the playing surfaces containing some synthetic content compared to the natural grass playing surface. Additionally, the percentage of injury occurrence versus no injury occurrence on each playing surface is presented in Figure 1. When players were exposed to the natural grass playing surface an injury occurred 9% of the time, whereas an injury occurred on 18% of the player exposures to the hybrid playing surface and on 17% of the player exposures to the synthetic playing surface.

Following the initial model which demonstrated that injury incidence was affected by the playing surface, post-hoc testing was undertaken, with playing surface applied as a factor to analyse the difference between the individual surfaces (Table 2).

(Insert Table 2 here)

The odds of getting injured was more than twice as great on the hybrid playing surface (OR = 2.58, $p<0.001$) and synthetic playing surface (OR = 2.16, $p = 0.033$) compared to natural grass. However, there was no difference between the hybrid and synthetic surfaces ($p = 0.590$).

192 The differences in the incidence of contact and non-contact injuries by playing surface are presented
193 in Table 3. The odds of sustaining a contact injury on the hybrid playing surface (OR = 2.31, p = 0.001)
194 and synthetic playing surface (OR = 2.19, p = 0.049) were two times greater than on natural grass. In
195 terms of non-contact injury, the only relationship observed was a four-fold increase on the hybrid
196 playing surface (OR = 4.18, p = 0.028) when compared to the likelihood of sustaining a non-contact
197 injury on natural grass.
198
199 The likelihood of sustaining a major (≥8 d lost) injury over a minor (≤7 d lost) injury was not different
200 between the playing surfaces (hybrid vs. natural grass: OR = 1.20, p = 0.746; synthetic vs. natural grass:
201 OR = 1.17, p = 0.861; synthetic vs. hybrid: OR = 1.41, p = 0.687).
202
203 When observing each playing surface in isolation (Supplementary Table 1), the highest injury incidence
204 rate was 53.4 per 1000 h for knee injuries sustained on a synthetic playing surface, which was 1.8
205 times higher than the next highest single site injury incidence (head / face on hybrid surface: 29.5 per
206 1000 h). The highest injury incidence rate on natural grass was 17.0 per 1000 h for head / face injury.
207 Additionally, the incidence of knee injury was 7 times higher on synthetic playing surface compared
208 to natural grass (53.4 per 1000 h vs. 7.3 per 1000 h) and 3 times higher on the hybrid surface compared
209 to natural grass (27.5 per 1000 h vs. 7.3 per 1000 h).
210
211 **Discussion**
212 The aim of the present study was to test the hypothesis that there would be no difference in incidence,
213 modality and severity of match injuries between the three common playing surfaces (natural grass,
214 hybrid and synthetic) in Rugby Union. The main findings of the present study were that, for overall
215 injury incidence, the two surfaces with some synthetic contact (hybrid and fully synthetic) elicited
216 more than double the match injury incidence when compared to natural grass pitches. When
217 considering the modality of injury, the odds of sustaining a contact injury on a pitch containing some

synthetic content were more than double that of a natural grass surface. Furthermore, non-contact injury incidence was greater on the hybrid playing surface compared to natural grass. However, there was no effect of playing surface on the severity of the injuries that occurred. Therefore, despite seeing an increase in overall, contact and non-contact injury incidence on playing surfaces with some synthetic content (i.e. hybrid and synthetic), no difference in the severity of the subsequent injuries was seen.

The present study is the first to assess the differences in injury incidence, modality and severity between the three most common playing surfaces that players encounter in elite Rugby Union. The findings of the present study suggest that any playing surface that contains some element of synthetic material (hybrid or synthetic) resulted in approximately double the match injury incidence. This is contrary to previous work in Rugby Union exploring playing surface and match injury[13-14], which found no differences. This could be explained by the inclusion of the hybrid playing surface in the current study (which elicited the highest injury incidence of 176.9 per 1000 h), whilst previous studies compared only grass and synthetic surfaces. However, it should also be noted that the post-hoc analysis revealed more than double the odds of injury incidence for both the hybrid and synthetic surfaces compared to grass (OR = 2.58 and 2.16, respectively). This is in contrast to the previous studies reporting no difference between grass and synthetic surfaces[13-14]. However, the possibility that synthetic surfaces may increase the risk of injury incidence is of potentially great interest to applied practitioners.

A further novel aspect of this study was that it considered the potential influence of the playing surface on the incidence of both contact and non-contact injuries in elite Rugby Union. The contact injury rate on surfaces containing some synthetic content (i.e. hybrid and synthetic) was double that of the natural grass playing surface. The present study therefore provides important novel evidence of an increased incidence of contact injuries on synthetic (both hybrid and synthetic) playing surfaces.

Furthermore, whilst non-contact injury incidence was similar between the natural grass and synthetic playing surfaces, the odds of sustaining a non-contact injury on the hybrid playing surface was over four times that of natural grass (albeit with wide 95% confidence intervals of 1.16-15.04), again suggesting that even a small proportion of synthetic content is associated with greater injury risk. It has been hypothesised that the increase in traction and momentum as a result of the synthetic surfaces, alongside the momentum kinetics involved in contact actions in elite Rugby Union, may explain the greater incidence of both contact and non-contact injuries [18, 11]. However, further research regarding the underlying mechanisms that cause higher injury incidence on playing surfaces that contain synthetic content is warranted.

Additionally, the present study is the first to document that, despite differences in injury incidence, the severity of the resulting injuries was not different between natural grass, hybrid and synthetic playing surfaces. With no differences seen in the severity of injury, it suggests a similar 'seriousness' of injuries on all playing surfaces. However, the injuries occur more frequently on the hybrid and synthetic surfaces compared to natural grass, as demonstrated through the higher incidence rates (hybrid: 176.9 per 1000 h; synthetic: 160.3 per 1000 h; natural grass: 82.8 per 1000 h). This is in agreement with the findings of the two previous studies in Rugby Union where no difference in the severity of match injury was seen between synthetic and natural grass pitches[13-14]. Therefore, whilst playing surfaces that contain a synthetic component (i.e. fully synthetic or hybrid) do not affect injury severity, they do increase injury incidence.

The highest single site injury incidence for any playing surface in this study was knee injuries sustained on the synthetic surface (53.4 per 1000 h, Supplementary Table 1), more than 1.8 times higher than the next highest single site of injury incidence. This is in agreement with the Professional Rugby Injury Surveillance Project and a study of American footballers (NFL)[12, 10], whereby there was an increase in lower limb injury incidence on synthetic playing surfaces. It has been suggested that this may be due

to an increase in rotational traction on synthetic surfaces, a common cause of knee injury[10-12]. The present study would support these suggestions but did not have adequate power to statistically consider separately the site of injury between playing surfaces, a potential avenue for further investigation.

This study provides a novel examination of the potential differences in injury incidence, modality, and severity between the common playing surfaces (natural grass, hybrid and synthetic) in elite Rugby Union, providing practitioners (Rugby coaches and performance and medical staff) with an awareness of the potential implications when playing matches on different surfaces. However, the present study is not without limitations. It must be noted that the findings of the present study are based on data from a single professional club (over two seasons of competition), therefore the applicability of the findings to all clubs is unknown. Furthermore, the relatively low exposure to the synthetic playing surface should be acknowledged, with only 4 matches (94 h exposure time) over the two seasons. Future research could consider sampling numerous clubs over multiple seasons on the three playing surfaces. Despite the limited sample size in the current study, marked differences in the injury rates between playing surfaces were observed. The difference in both contact and non-contact injury, and more specifically knee injuries sustained on synthetic pitches warrants further investigation in larger cohorts. The specific interactions between footwear and the playing surface, traction properties and momentum kinetics are avenues which could be explored and may provide mechanistic insight regarding the underlying causes of incidence and modality of injury on different playing surfaces. Furthermore, the inclusion of multiple clubs across several seasons, alongside training data into future datasets (playing surface and injury incidence), may provide additional findings of great importance to support staff at elite Rugby Union clubs. This work could also focus on specific sites of injuries which are shown to have a high incidence in the present study (e.g. head/face and knee). Furthermore, particular consideration should be given to the potential relationship between the surface that the

team typically train on, and how this may affect injury incidence when exposed to different surfaces during matches.

Conclusion

The findings of the present study suggest that the playing surface on which match play occurs has a significant impact on overall, contact and non-contact injury incidence. Specifically, a pitch containing any synthetic component (hybrid or synthetic) approximately doubles the odds of sustaining an injury compared to playing on natural grass. The odds of sustaining a contact injury increased two-fold on the hybrid and synthetic surfaces compared to natural grass; whilst there was a four-fold increase in the odds of a non-contact injury occurring on the hybrid playing surface compared to natural grass. These findings suggest that even a small percentage (3%) of synthetic content within the playing surface can have a substantial impact on match injury incidence; and thus, squad availability and performance. Therefore, the 'risk' associated with playing matches on synthetic pitches is an important factor that is vital for applied practitioners to consider and be aware of.

Practical Implications

- The findings of this study provide practitioners with a novel understanding of the potential increased likelihood of match injury (contact and non-contact) when competing on surfaces containing some element of synthetic content (hybrid or synthetic pitches).
- A playing surface containing any artificial content (hybrid and synthetic) doubles the overall match injury incidence compared to natural grass pitches in elite Rugby Union players.
- The likelihood of sustaining a non-contact injury increased on hybrid playing surfaces compared to natural grass.
- The likelihood of sustaining a major (≥8 d) as opposed to a minor (≤7 d) injury was not different between the three playing surfaces.

- Professional Rugby clubs can also use these findings to make informed decisions about the playing surfaces they use for trainng.

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Table 1. Match injury rates (absolute and relative to 1000 h exposure), mean severity (95% confidence intervals) and median severity (interquartile range) for injuries sustained on the three different playing surfaces (natural grass, hybrid and synthetic).

Playing surface	Number of injuries	Injury incidence [per 1000 h]	Mean severity (95% CI) [d]	Median severity (interquartile range) [d]	Contact Injuries		Non-contact injuries	
					n	Incidence	n	Incidence
Grass	34	82.8	26.9 (14.6, 39.2)	9 (5.0, 28.5)	31	75.5	3	7.3
Hybrid	90	176.9	23.1 (15.5, 30.8)	8 (4.0, 17.0)	76	149.4	14	27.5
Synthetic	15	160.3	33.3 (7.6, 58.9)	15 (4.0, 45.5)	14	149.6	1	10.7

Table 2. Multilevel models examining the relationship between match injury incidence and for each playing surface versus alternative surfaces.

Playing surface	Parameter estimate	Std. error	z-value	p-value	Odds ratio	95% CI	
						Lower	Upper
Hybrid vs. grass	0.948	0.228	4.163	<0.001 *	2.58	1.65	4.03
Synthetic vs. grass	0.769	0.360	2.136	0.033 *	2.16	1.07	4.37
Hybrid vs. synthetic	0.179	0.332	0.538	0.590	1.20	0.62	2.29

Note: The second pitch acts as the baseline in each comparison (e.g. hybrid vs. natural grass represents the OR of getting injured on a hybrid playing surface compared to a natural grass playing surface; i.e. natural grass OR = 1.00). In each comparison, the inverse of the OR can be used to calculate the OR for injury on the opposing surface; e.g. OR for sustaining an injury on natural grass compared to a hybrid pitch is 0.39 (i.e. 1 / 2.58 = 0.39). * denotes significant difference between the surfaces ($p < 0.05$).

Table 3. Multilevel models examining the relationship between contact and non-contact match injury incidence for each playing surface versus alternative surfaces.

Contact injuries							
Playing surface	**Parameter estimate**	**Std. error**	**z-value**	**p-value**	**Odds ratio**	**95% CI**	
						Lower	**Upper**
Hybrid vs. grass	0.837	0.252	3.317	0.001 *	2.31	1.41	3.78
Synthetic vs. grass	0.783	0.398	1.967	0.049 *	2.19	1.00	4.77
Hybrid vs. synthetic	0.054	0.370	0.146	0.884	1.06	0.51	2.18
Non-contact injuries							
Playing surface	**Parameter estimate**	**Std. error**	**z-value**	**p-value**	**Odds ratio**	**95% CI**	
						Lower	**Upper**
Hybrid vs. grass	1.431	0.653	2.193	0.028 *	4.18	1.16	15.04
Synthetic vs. grass	0.458	1.181	0.388	0.698	1.58	0.16	16.00
Hybrid vs. synthetic	0.983	1.064	0.923	0.356	2.67	0.33	21.51

Note: The second pitch acts as the baseline in each comparison (e.g. hybrid vs. natural grass represents the OR of sustaining a contact or non-contact injury on a hybrid playing surface compared to a natural grass playing surface; i.e. grass OR = 1.00). In each comparison, the inverse of the OR can be used to calculate the OR for contact or non-contact injury on the opposing surface; e.g. the OR for sustaining a contact injury on natural grass compared to a hybrid pitch is 0.43 (i.e. 1 / 2.31 = 0.43). * denotes significant difference between the surfaces ($p < 0.05$).

Supplementary Table 1. Injury incidence (by body site) expressed relative to 1000 match exposure hours on each playing surface (natural grass, hybrid and synthetic).

Site	Grass	Hybrid	Synthetic
Head / face	17.0	29.5	0.0
Neck / cervical spine	0.0	9.8	0.0
Sternum / ribs / upper back	2.4	5.9	0.0
Abdomen	2.4	2.0	0.0
Low back	0.0	9.8	10.7
Sacrum / pelvis	0.0	0.0	0.0
Shoulder / clavicle	4.9	21.6	21.4
Upper arm	0.0	2.0	0.0
Elbow	2.4	3.9	0.0
Forearm	0.0	0.0	10.7
Wrist	0.0	0.0	0.0
Hand / finger / thumb	0.0	3.9	0.0
Hip / groin	4.9	5.9	10.7
Anterior thigh	14.6	11.8	0.0
Posterior thigh	2.4	5.9	0.0
Knee	7.3	27.5	53.4
Lower leg / Achilles tendon	4.9	9.8	21.4
Ankle	14.6	9.8	10.7
Foot / toe	4.9	17.7	21.4
Total	**82.8**	**176.9**	**160.3**

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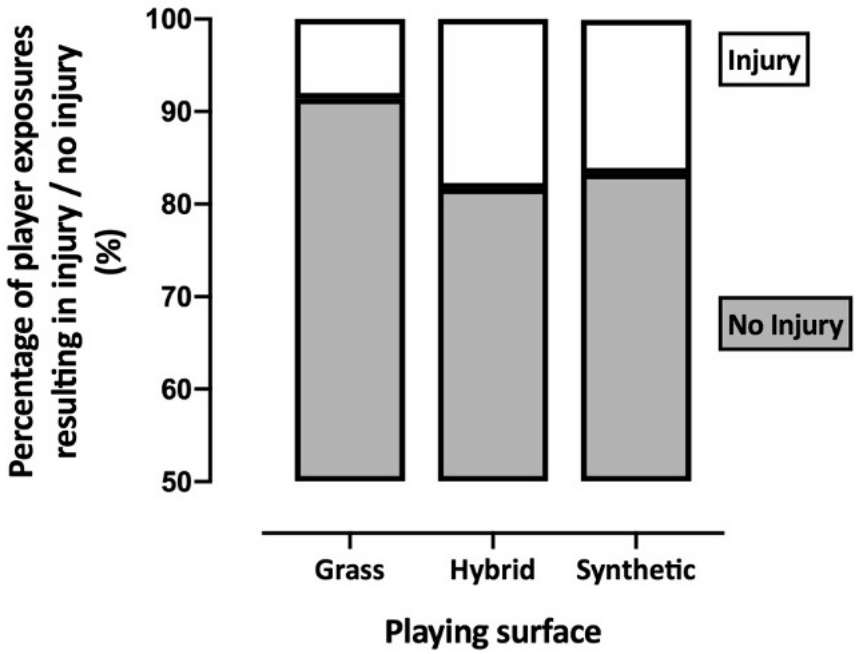

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461 **Figure 1.** Match injury incidence percentage (injury or no injury) by playing surface (natural grass,
462 hybrid and synthetic), at an individual player exposure level (i.e. the percentage of player exposures
463 to each surface that resulted in an injury vs. no injury).