

1 **Abrasion injuries on artificial turf: A systematic review**

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1 **Abstract**

2 Objectives: To review the incidence of abrasion injuries sustained on artificial turf playing
3 fields and the level of evidence existing on player perceptions of abrasion injuries on these
4 surfaces.

5 Design: Systematic review

6 Method: A systematic search was performed using SPORTDiscus, Medline, Web of Science,
7 Scopus and Science Direct databases. Inclusion criteria included: abrasion type injuries
8 measured; conducted on artificial/synthetic turf; type of sport reported; peer-reviewed original
9 research; English language search terms, but no language restrictions. A quality assessment
10 was conducted using the Newcastle-Ottawa quality scale.

11 Results: The search yielded 76 potential articles, with 25 meeting all inclusion criteria.

12 Twenty articles were injury-based and five were perception-based. The differences in injury
13 definition and the lack of details of the playing surfaces produced varying results on the rate
14 of injuries on artificial turf. Regardless of the condition of the surface, the level of play, or the
15 sport, players perceived the fear of abrasion injuries as a major disadvantage of artificial turf
16 surfaces.

17 Conclusions: The review highlighted the current disparity that exists between players'
18 perceptions of abrasion injuries and the level of evidence of abrasion injury risk on artificial
19 turf playing surfaces. There is a need for the inclusion of greater detail of playing surfaces'
20 specifications and condition, and an injury definition sufficiently sensitive to better measure
21 abrasion injury incidence and severity. Without this more detailed information, it is likely that
22 the strongly perceived risk of abrasion injuries will continue as a barrier to the adoption of
23 artificial playing surfaces.

24

25 Keywords: abrasion; artificial turf; player perceptions; skin injuries.

26 **1. Introduction**

27 The physical, psychological and social health benefits of participation in sport and active
28 recreation are well documented.¹⁻³ However, injuries sustained during physical activity have
29 the potential to result in long term physical and mental health consequences.⁴ Consequently,
30 efforts to reduce injury risk, promote safe participation and increase participation rates have
31 been a focus for those responsible for delivery of active recreation and sport for many years.
32 To address the demands of participation, coupled with global changes in climatic conditions
33 and the limited green spaces in areas of rapid urban growth, there has been an increase in
34 the use of artificial turf playing surfaces, particularly at amateur level.^{5, 6}

35 The use of artificial turf as a playing surface began in the late 1960's, and continuous product
36 development has resulted in the latest third generation (3G) artificial turf products more
37 closely replicating the characteristics of natural grass and optimising performance and safety.
38 This development is significant as earlier surfaces were characterised by a lack of impact
39 absorption and high friction/traction that were associated with an increased risk of lower limb
40 ligament injuries and abrasion injuries.⁷⁻⁹ Although softer polyolefin yarns were introduced in
41 the 1970s to replace the older abrasive polyamide yarns, a study of high school American
42 football injuries on third generation artificial turf reported that, despite the artificial turf being
43 promoted as 'non-abrasive', the incidence of abrasions and other skin injuries were
44 significantly higher than on natural grass fields.¹⁰ Recent studies still show higher rates of
45 abrasion injuries on artificial turf surfaces compared to natural grass playing fields.^{11, 12}
46 However, there have also been a few studies that have reported slightly higher percentages
47 of skin related injuries on natural grass compared to artificial turf surfaces.^{13, 14} Without a
48 comprehensive review of the literature, it is difficult to establish the full extent of the problem
49 or the factors contributing to the increased risk of such injuries.

50 Abrasion injuries result in damage only to the surface layer of skin (epidermis) and the
51 healing time generally ranges from 4-8 days using an occlusive dressing.¹⁵ While typically
52 classified as minor in nature, abrasion injuries can be serious if foreign materials become

53 embedded or a large surface area is damaged.¹⁶ Increased risks of staphylococcal
54 infections, including methicillin-resistant *S.aureus* (commonly known as MRSA), have been
55 associated with abrasion type injuries from artificial turf and if not well managed can require
56 hospitalisation.^{17, 18} Furthermore, abrasion injuries can engender substantial player
57 discomfort and consequently result in a change in playing behaviour.¹⁹ Changes in playing
58 behaviour have the potential to increase the risk of other injuries and therefore abrasion
59 injuries may be a more impactful injury than currently realised.

60 Despite the developments in artificial turf surfaces aimed at reducing the incidents of skin
61 abrasions in the interaction between player and surface, the issue has not disappeared.^{20, 21}
62 Abrasion injuries continue to be reported as a perceived barrier for adoption by players.^{22, 23}
63 The players' perception of abrasion is interesting given that abrasiveness of artificial turf
64 surfaces is measured according to a rigorous set of performance and safety standards
65 before being approved for use. The American Society for Testing and Material (ASTM)
66 standard (F1015, 2009) identifies abrasion as the characteristic to cause 'wear' to a material
67 moving across it.²⁴ It comprises a simple pull-sledge system and measures the loss of mass
68 of a controlled foam material under a controlled normal load pulled a specific distance at a
69 specific rate across the turf sample. In contrast, the Fédération Internationale de Football
70 Association (FIFA) standard (Test method 08) Determination of Skin / Surface Friction
71 utilises the Securisport® Sports Surface Tester to measure both a coefficient of friction and
72 a percentage abrasion value.²⁵ A silicone skin is attached to a test foot which rotates a
73 specific distance at a controlled speed under a fixed normal load (100 Newtons) in a circular
74 motion on the artificial turf sample. The friction is inferred from the force resistance to the
75 circular motion over five revolutions at 40 revolutions per minute (approx. 0.8 m/s). The
76 percentage abrasion is calculated from a change in the dynamic friction coefficient of the
77 silicone skin on a controlled smooth steel substrate before and after the test on the turf
78 sample. It is possible that neither of these devices and associated procedures are valid in
79 replicating player–surface interactions on artificial turf.²¹ Whether mechanical testing is truly
80 ensuring a safe level of abrasion for the current products and expanded use of artificial turf is

81 unknown. This postulation can only be affirmed with a genuine understanding of the
82 incidence rates and an investigation of the perceptions of abrasion injuries sustained on
83 artificial turf playing fields.

84 Therefore, the purpose of this paper is to: (1) review the incidence of abrasion injuries
85 sustained on artificial turf playing fields; and (2) determine the level of evidence existing on
86 player perceptions of abrasion injuries on these surfaces.

87

88 **2. Methods**

89 ***Search Strategy and Screening Procedure***

90 A thorough search of key databases was performed including, SPORTDiscus, Medline, Web
91 of Science, Scopus and Science Direct. Database selection was based on their focus on
92 sport and exercise and were searched using English language only and no date restrictions
93 were imposed. A variety of search terms were used either separately or in conjunction with
94 each other to identify all relevant articles. Search terms included: skin, abrasion, lacerations,
95 injury, perceptions, sport, artificial turf, synthetic turf. After screening titles and abstracts, full
96 texts were obtained for articles for which exclusion could not be clearly determined. A
97 manual search of the reference lists of all selected articles was undertaken to identify any
98 additional articles. A final search using Google Scholar was also undertaken to identify any
99 further articles missed through the database and hand searching.

100 A screening process was completed thereafter to identify the articles that met the full
101 selection criteria for the review. Duplicates were removed and three authors (DT, LP and PF)
102 independently reviewed the papers for eligibility and inclusion using the full text. Any
103 disagreements were resolved by consensus with an independent person.

104

105 ***Inclusion Criteria***

106 Articles were only included on the basis that they met all of the specified selection criteria.
107 The following inclusion criteria were employed for all injury and perception related articles: it
108 measured abrasion type injuries (including both player perceptions or injury studies); the
109 study was conducted on artificial/synthetic turf; reported on a type of sport (including both
110 training and competition); it was peer-reviewed original research articles; earliest available
111 until end of June, 2017; English language search terms, but no language restrictions.

112

113 ***Assessment of Quality***

114 The quality of the studies was assessed using the Newcastle – Ottawa quality scale.²⁶ This
115 scale uses a star system to score quality based on three items: selection, comparability and
116 outcomes. The selection component was based on the cohort in the studies, comparability
117 on the design and analysis, and the outcome aspect on the assessment of any bias in the
118 results reported. A maximum of nine points can be assigned and for this review scores < 4
119 were considered low quality and not included.²⁷

120

121

122 **3. Results**

123 The database search yielded 67 articles, with an additional nine articles identified through
124 searching reference lists of those articles. After an initial review, 40 articles were rejected as
125 copies of the same article or unrelated to the main theme of the review. On assessing the full
126 text, studies of injuries on artificial turf were primarily eliminated because they did not
127 specifically report the incidence of abrasion injuries. Twenty-five studies fulfilled the eligibility
128 criteria and the quality assessment and were deemed eligible for inclusion by all authors, 20
129 injury-related and five perception-related. (Figure 1).

130

131 **<Insert Figure 1 about here.>**

132

133 ***Injury Studies***

134 There were 20 studies that reported abrasion injuries on artificial turf surfaces and of those
135 16 presented a comparison between natural grass and 3G artificial turf. The inclusion studies
136 covered a range of sports, with the majority (85%) undertaken in one of the football codes:
137 American football, rugby union or association football (soccer) (Table 1). The level of
138 competition varied across the studies from professional level to school-based data but most
139 studies were based on sub-elite cohorts. Details of the surfaces, both natural and artificial,
140 were not provided in 65% (13/20) and in the 35% with detail, only one described the age and
141 quality of the playing surface.²⁸ In that study, a specific section was dedicated to describing
142 the playing surface, providing details of the grass coverage and evenness of the natural
143 grass playing field and the age and composition of the artificial turf surface.²⁸

144 The definition of injury is an important element in any injury-related study and it is evident
145 from Table 1 that several definitions were utilised across the studies. These included the
146 commonly used time-loss based definition, “any physical complaint sustained by a player
147 during a match that prevented the player from taking a full part in training or match play
148 activities for one or more days beyond the day of injury”²⁹; medical attention requirement; or
149 a combination of both. One study was based on emergency department presentations and
150 the definition of injury was not reported, however, it can be assumed that the injuries required
151 medical attention.

152 Overall, the incidence of abrasion injuries was most frequently presented as a percentage of
153 all injuries rather than an incident rate relative to exposure. The greatest proportion of
154 abrasion injuries on 3G artificial turf was reported in a study of amateur lacrosse players, with
155 abrasions injuries accounting for 19.8% of all injuries on the artificial turf.³⁰ The greatest
156 difference between abrasion injuries on 3G artificial turf compared to natural grass was also
157 in this study of lacrosse players, 19.8% compared to 0.5 %, respectively. Notably, the
158 proportion of injuries sustained on artificial turf was higher when the definition of injury was

159 based on medical attention (19.8% highest) rather than time loss (8.6% highest). In many
160 studies, all skin injuries were combined and reported as surface/epidermal injuries or
161 lacerations/skin lesions. Only 50% of the injury studies (10/20) reported abrasion injuries on
162 their own and of those, only five found abrasion injuries greater on artificial turf compared to
163 natural grass. Interestingly, within a study that reported training and match play, the rate of
164 abrasion injuries was greater on natural grass in matches (2.1% compared to 1.8%) but
165 greater on artificial turf in training (3.6% compared to 1.7%).⁷

166 Akkaya et al. (2011)⁶ investigated the injuries identified while playing association football on
167 an artificial turf playing field that presented to the emergency department of a university
168 hospital in Turkey over a four year period (2007 – 2011). They reported that the most
169 common injuries were contusions, abrasion and haematomas (364 = 37% of all injuries). As
170 abrasions were only one of the injuries in that combination, it is difficult to ascertain the true
171 extent of the abrasion injuries. However, they also mentioned that ruptures, perforations and
172 grazes were seen in 98 cases = 9.9% of all injuries. It is notable that these were injuries
173 deemed in need of medical attention at a hospital and therefore, it is possible that it
174 underestimates the true incidence of abrasion injuries.

175

176 ***Perceptions***

177 To date, player perceptions of abrasion injuries have primarily been investigated in
178 association football, with one study in hockey (Table 2). Regardless of the condition of the
179 surface or the level of play, all association football players perceived abrasion injuries as one
180 of the main disadvantages of playing their sport on 3G artificial turf.^{22, 23, 31, 32} This view was
181 not limited to players, but coaches and referees also shared a consistent view.²³ In the study
182 of professional and semi-professional association football players from a range of European
183 countries, the players stated that, not only was the risk of abrasion injury an issue but, they
184 altered their play by avoiding slide tackling to reduce the risk.²² Association football players in
185 another study identified type of infill, all weather conditions except rainy days, field type –third

186 generation artificial turf rather than natural grass, and playing position as factors that
187 influenced their dissatisfaction with the abrasiveness of the artificial turf surfaces.³²

188 Defenders and midfielders expressed greater negative perceptions, possibly due to the
189 increase in slides tackles associated with those positions.

190 The single study in field hockey by Fleming et al., 2005³³ reported the players' perceptions
191 on a water-based artificial surface. Players felt that when drier the (short pile with no infill)
192 surfaces were more abrasive and had an increased injury risk if fell upon.

193

194 <Insert Table 1 and 2 about here>

195

196

197 **4. Discussion**

198 An increasing number of sports are considering artificial turf fields as a feasible alternative to
199 natural grass to meet the growing demands of their sports in high population growth areas
200 and to counteract the extremes in weather conditions. Consequently, understanding the
201 impact of abrasion injuries is critical to their adoption. The present review clearly
202 demonstrates that abrasion injuries do occur on artificial turf. While the data is not extensive
203 on player perceptions, the opinions about abrasion injuries is consistent across all studies
204 and strongly identifies the fear of abrasion injuries as a major disadvantage of artificial turf
205 surfaces.

206 Third generation artificial turf is the term used to describe the latest artificial turf systems
207 comprising longer fibres (40mm – 65mm) that are supported with a combination of a lower
208 layer of sand and an upper layer of crumbed rubber or organic material infill. As with any
209 commercial product, variations exist between manufacturing companies and the performance
210 of an artificial turf field depends on many factors, such as the installed components and build
211 quality, the intensity of usage and age, and the maintenance.²³ The key structural
212 components of the artificial turf system that influence the risk of abrasion type injuries are
213 reportedly the fibre type and the infill system.²¹ Recent work has demonstrated the somewhat
214 complex interaction of fibre type (fibrillated or monofilament), infill type and depth and their
215 individual and combined abrasive effect on the simulated skin used in the Securisport
216 mechanical test.²¹ The lack of detail of the artificial turf system specifications, and their
217 condition, makes comparison across studies very challenging and often meaningless. It has
218 been shown that the mechanical and environmental degradation of artificial turf pitches has
219 impacted significantly on the mechanical properties of the surface.³⁴⁻³⁶ Changes to skin
220 friction properties have been recorded with fibre flattening and fibrillation, and infill
221 compaction causing system hardening; however the effect of these on abrasion injuries is
222 unknown. The condition of the natural grass playing fields are also rarely described in injury

223 surveillance studies and the simplistic association between the type of playing surface and
224 injury risk may be misleading. The addition of details of the specification and condition of the
225 playing surface in future sports injury studies is essential to understand the true associations
226 between abrasion injury risk and playing surfaces.

227 Consistent with much of the injury epidemiological literature, time loss and medical attention
228 were commonly used to define an abrasion injury. As abrasion injuries are often not
229 associated with time loss, it is possible that the number of abrasion injuries sustained on
230 artificial turf is underestimated in the literature. It is evident in this review that studies that
231 used 'requiring medical attention' as opposed to 'time loss' as the definition of an injury,
232 captured more abrasion injuries. Notably, only studies that explicitly mentioned abrasion
233 injuries were included in this review, however, a further 18 studies reported injuries on
234 artificial turf playing fields and did not record abrasion injuries. This may be due, in part, to
235 the injury definitions used and again supports the notion that abrasion injuries are
236 underestimated.

237 Another limitation apparent in the injury studies is the coupling of abrasion injuries with other
238 skin related injuries. In many studies, the term 'skin injuries' or 'laceration/skin lesions' were
239 used to describe the nature of the injury. These broad terms include other skin related
240 injuries such as cuts, lacerations, puncture wounds, and may again mask the true incidence
241 of abrasion injuries.

242 Although not a sport specific epidemiological study, van den Eijnde et al. 2014¹⁹ developed a
243 non-invasive method for quantifying the skin damage from sliding on artificial turf, Skin
244 Damage and Severity Index (SDASI). They asked nine amateur association football players
245 to slide across three different artificial turf products twice and experienced dermatologists
246 rated the images of the skin damage. The rating resulted in a visual scale of clinical
247 parameters used in the SDASI. The SDASI comprised abrasion on a 5-point scale from none
248 – very severe, erythema (redness of the skin) also on a 5-point scale from none to very dark
249 red and type of exudation (fluid emitted from blood vessels) on a 3-point scale from dry to

250 blood. They also recorded perceived skin irritation and perceived sliding friendliness from the
251 players, and correlated it with the clinical scores. They concluded that the level of damage
252 strongly correlated with player discomfort. In addition, they believed that the ability to quantify
253 the severity of skin injuries using this reliable and simple method would improve the
254 identification of the severity of abrasion type injuries in the future. The use of the Skin
255 Damage and Severity Index (SDASI) by the medical support staff may be a reliable and
256 simple method to improve the identification of the severity of abrasion type injuries in future.¹⁹

257 As highlighted by van den Eijnde et al. (2014)¹⁹, abrasion injuries can lead to player
258 discomfort and hence possible changes in biomechanical movement. The increased injury
259 risk due to altered biomechanics has been well established ³⁷ and the recent Subsequent
260 Injury Categorisation model³⁸ suggests that subsequent injuries may be associated with
261 initial injuries. In addition, skin infection can have significant consequences for the individual
262 player and team.³⁹ Despite the perceived minor nature of abrasion injuries, they may have a
263 significant impact on the players' comfort, injury risk and performance. Again, understanding
264 the true risk of abrasion injuries will encourage the development of injury prevention
265 strategies and/or lead to a review of the current abrasion testing devices and processes.

266 Despite the low rates of abrasion injuries reported, regardless of the sport or level of play,
267 players perceive a high risk of an abrasion injury on artificial turf and consider it a major
268 disadvantage of these playing surfaces. If the studies were based on players with little
269 experience of the 3G artificial turf surfaces, it may be possible that their perceptions are
270 based on older versions of the surfaces rather than experience. However, players in the
271 studies included in this review had multiple exposures to the 3G surfaces, some up to six
272 years. The benefits of artificial turf surfaces compared to natural grass including extended
273 playing hours; playability in all weather conditions; and the associated health benefits of
274 increased participation, are lost if players are unwilling to embrace the surfaces.

275 Furthermore, the evidence of players altering their performance and potentially changing the

276 characteristics of the sport due to the fear of abrasion injuries is of concern and may further
277 discourage the adoption of artificial turf by sporting organisations.

278 Felipe et al. (2013)²² suggested that the negativity associated with abrasion injuries on
279 artificial turf would disappear as the products improved. This does not seem to be the case
280 and may be due to the lack of external validity of the test methods used to measure the level
281 of skin friction and abrasiveness of the surface in the laboratory testing prior to installation.
282 The limitations of the current test methods are with the silicone skin and the foam, they
283 provide empirical information only about the relative abrasiveness of the surface but do not
284 simulate the human skin's response when exposed to sliding on an artificial turf surface¹⁹ nor
285 the mechanics of sliding. With limited evidence of the true incidence of abrasion injuries on
286 the current artificial turf products, there is little impetus to validate or improve the existing test
287 methods. It is considered that with more sports adopting artificial turf worldwide, with varying
288 player-surface interactions, it is timely for a systematic review of the validity of the current
289 test methods and modifications to ensure that future artificial turf products are created with
290 an acceptable level for skin friction and abrasion characteristics.

291

292 **5. Conclusion**

293 In conclusion, this review has identified that abrasion injuries do occur on artificial turf playing
294 field but the reported incidence rates are relatively low relative to other more severe injuries
295 and vary across sports and level of play. The review has also highlighted the current disparity
296 that exists between players' perceptions of abrasion injuries and the level of evidence of
297 abrasion injury risk on artificial turf playing surfaces. It has identified the need for reporting in
298 future research work greater detail of playing surfaces' specifications and condition, and an
299 injury definition sufficiently sensitive to better measure abrasion injury incidence and severity.
300 Without this more detailed information, it is likely that the strongly perceived risk of abrasion
301 injuries will continue as a barrier to the adoption of artificial playing surfaces. It is also clear

302 that there is a need for improvement in the test methods for abrasion and skin friction to
303 better align with player perceptions and support innovations in surface system manufacture.

304

305 **Practical Implications**

306 • The inclusion of details of the type and condition of the playing surface in future
307 sports injury studies is essential to understand the true associations between
308 abrasion injury risk and artificial turf playing surfaces.

309

310 • Improvement to the abrasive nature of artificial turf products, improved test methods
311 or injury prevention strategies, such as clothing changes, are required to reduce the
312 strong negative perceptions of abrasion injury risk.

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437 union sevens series. *Am J Sports Med* 2012; 40(1):179-184.
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439 **Table 1: Summary of Injury Studies.**

Authors & Year	Surfaces/Sport Played	Sport/Level	Injury Definition	Abrasion Injury Rates
Akkaya et al., 2011 ⁶	3G artificial turf.	All sports – Emergency Department Presentations; 4 years – 985 male cases.	Not reported.	37% of all injuries were contusions, abrasion and haematomas. Graze injuries reported separately (98 cases) but also included ruptures and perforations.
Almutawa et al., 2014 ⁴⁰	Natural grass and 3G artificial turf.	Professional male association football; 49 players across 102 training sessions and 13 matches.	Medical Attention.	Nature of skin injuries were collapsed, so included lacerations. 9.7% of all injuries on 3G artificial turf (3.7per 1000h) and 9.8% on natural grass (5.4 per 1000h).
Ekstrand et al., 2011 ⁷	Natural grass and 3G artificial turf.	Professional association football; 6 seasons – 15 male and 5 female teams.	Time loss.	Matches: 1.8% on artificial turf (0.06 per 1000h) 2.1% on natural grass (0.07 per 1000h) Training: 3.6% on artificial turf (0.81 per 1000h) 1.7% on natural grass (0.37 per 1000h)
Fuller et al., 2007, Part 1 ²⁹	Natural grass and 3G artificial turf.	American college football matches; 2 seasons – 106 men’s team and 136 women’s teams.	Time loss.	Laceration/skin lesions accounted for 8.6% of all injuries on artificial turf and 3.7% on natural grass.
Fuller et al., 2007, Part 2 ⁴¹	Natural grass and 3G artificial turf.	American college football training; 2 seasons – 106 men’s team and 136 women’s teams.	Time loss.	Laceration/skin lesions accounted for 2.1% of all injuries on both surfaces alike.
Fuller et al., 2010 ⁴²	Natural grass and 3G artificial turf.	Rugby Union division 1; 2 seasons – 282 Hong Kong players in matches	Time loss.	Skin injuries accounted for 3.8% of all injuries on artificial turf and 3.6% on natural grass.

		and 169 England players in training.		
Hinton et al., 2005 ³⁰	Natural grass and 3G artificial turf.	Lacrosse – high school and summer camp; 3 years with 387,358 athletic exposures.	Medical attention.	Abrasions accounted for 19.3% of all injuries on artificial turf and 0.5% on natural grass.
Jamison, S & Lee, C, 1989 ²⁸	Natural grass and AstroTurf.	State level hockey; 2 seasons – 205 players.	Not reported.	Abrasions accounted for 14% of all injuries on artificial turf and 13% on natural grass.
Kaur et al., 2008 ⁴³	Natural grass and 3G artificial turf.	Hockey – all levels; 407 player surveys.	Not reported.	More abrasions on grass from falls or diving due to its quality, only reported as a percentage of all head injuries.
Keene et al., 1980 ⁴⁴	Natural grass and Tartan Turf.	American university football; 235 players surveyed for 15 retrospective years and injury records for 2 years in one university team.	Medical attention.	Significantly more scrapes on the artificial turf (1 st Generation) (41.1%) than on the natural grass (14.5%).
Kordi et al., 2011 ⁵	3G artificial turf and dirt field.	Male amateur association football; 1 season – 157 matches.	Any physical complaint.	Lacerations and skin lesions were 4.5 times greater on the dirt fields than artificial turf (16.34 per 1000h compared to 3.62 per 1000h).
Kristenson et al., 2013 ⁴⁵	Natural grass and 3G artificial turf.	Professional male association football; 2 seasons – 26 teams in 2010 and 29 teams in 2011.	Time loss.	Only 8 lacerations/skin lesions reported; 0.7% of all injuries, 2 injuries on artificial turf and 6 on natural grass.
Lopez et al., 2012 ⁴⁶	Natural grass and 3G artificial turf.	Amateur rugby sevens; 4 tournaments – 269 games.	Any physical complaint.	Overall 48 injuries across four 1-day tournaments. 18.3% of all injuries were abrasions but surface wasn't specified.

Meyers & Barnhill, 2004 ¹⁰	Natural grass and 3G artificial turf.	American high school football; 5 seasons – 240 games.	Time loss or medical attention.	Surface/epidermal injuries accounted for 5.8% on artificial turf compared to 0.8% on natural grass.
Meyers, 2010 ¹³	Natural grass and 3G artificial turf.	American college football; 3 seasons – 465 games.	Time loss or medical attention.	Surface/epidermal injuries accounted for 1.0% on artificial turf compared to 1.3% on natural grass.
Meyers, 2013 ¹¹	Natural grass and 3G artificial turf.	American college women's soccer; 5 seasons – 355 games.	Time loss or medical attention.	Surface/epidermal injuries accounted for 5.1% on artificial turf compared to 2.9% on natural grass.
Peppleman et al., 2013 ¹⁶	Natural grass and 3G artificial turf.	Association football – amateur; 14 male players.	Not reported.	No evidence of more skin related traumatic injuries after sliding on natural grass compared to artificial turf. Natural grass resulted in more erythema but less abrasions compared to artificial turf.
Soligard et al., 2010 ¹⁴	Natural grass and 3G artificial turf.	Association football Under 13-19 years. Four years of tournaments, – 7848 matches.	Medical attention.	Abrasion injuries accounted for 2.4% (0.8 per 1000h) on artificial turf compared to 2.5% (1.0 per 1000h) on natural grass.
Williams et al., 2016 ¹²	Natural grass and 3G artificial turf.	Rugby Union Division 1. 2013/2014 season – 27 matches.	Time loss for main study but visible abrasion injuries rated by a researcher.	More abrasions on the artificial turf 57 versus 9 on natural grass but only two required time loss.

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443 **Table 2: Summary of Player Perception Studies.**

Authors & Year	Surfaces	Sport/Level	Perceptions re abrasion injuries
Burillo et al., 2014 ²³	Natural grass and 3G artificial turf with 50-60mm pile and sand & rubber infill. About 3.9 years old.	Association football: 627 male subjects; 404 players, 101 coaches and 122 referees.	Skin abrasions got the lowest mean rating of satisfaction for safety aspects, 2.9/10-; players 2.71, coaches 2.75, referees 3.66. Skin abrasions were also ranked as the biggest disadvantage 33.2%; 39.2% players, 19.8% coaches, 23% referees.
Felipe et al., (2013) ²²	Natural grass and 3G artificial turf – no details.	Professional association football: 32 players and 25 coaches.	One of the main disadvantages was abrasion injuries from tackles and consequently that they avoid tackles.
Fleming et al., (2005) ³³	Water based artificial turf.	Hockey: 22 premier and first division players.	Player felt that drier pitches were more abrasive and unpleasant to fall on.
Roberts et al., (2014) ³¹	Condition of field or details were not recorded.	Professional association football: 1129 players across 43 countries.	Over 60% felt that artificial turf playing fields were more abrasive.
Zanetti (2009) ³²	Eight approved 3G artificial turf fields, three with styrene butadiene rubber and three with thermoplastic rubber granules infill.	Amateur association football: 1671 male players aged 15 – 35.	Of the factors measured, abrasion was the only factor that was judged to be worse on artificial turf compared to natural grass and the type of infill, weather, playing position and field type all significantly influenced it.

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447 Figure 1: Flow chart of search results

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