Abrasion injuries on artificial turf: A systematic review

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Word Count: 3260

Abstract word count: 247 (250 max)

Number of tables: 2

Number of figures: 1

Abstract

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

Design: Systematic review

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

Results: The search yielded 76 potential articles, with 25 meeting all inclusion criteria. Twenty articles were injury-based and five were perception–based. The differences in injury definition and the lack of details of the playing surfaces produced varying results on the rate of injuries on artificial turf. Regardless of the condition of the surface, the level of play, or the sport, players perceived the fear of abrasion injuries as a major disadvantage of artificial turf surfaces.

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

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

1. Introduction

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

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

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

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

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

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

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

2. Methods

Search Strategy and Screening Procedure

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

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

Inclusion Criteria

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

Assessment of Quality

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

3. Results

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

<Insert Figure 1 about here.>

Injury Studies

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

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

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

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

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

Perceptions

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

generation artificial turf rather than natural grass, and playing position as factors that influenced their dissatisfaction with the abrasiveness of the artificial turf surfaces.[32] Defenders and midfielders expressed greater negative perceptions, possibly due to the increase in slides tackles associated with those positions.

The single study in field hockey by Fleming et al., 2005[33] reported the players' perceptions on a water-based artificial surface. Players felt that when drier the (short pile with no infill) surfaces were more abrasive and had an increased injury risk if fell upon.

<Insert Table 1 and 2 about here>

4. Discussion

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

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

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

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

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

Although not a sport specific epidemiological study, van den Eijnde et al. 2014[19] developed a non-invasive method for quantifying the skin damage from sliding on artificial turf, Skin Damage and Severity Index (SDASI). They asked nine amateur association football players to slide across three different artificial turf products twice and experienced dermatologists rated the images of the skin damage. The rating resulted in a visual scale of clinical parameters used in the SDASI. The SDASI comprised abrasion on a 5-point scale from none – very severe, erythema (redness of the skin) also on a 5-point scale from none to very dark red and type of exudation (fluid emitted from blood vessels) on a 3-point scale from dry to

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

As highlighted by van den Eijnde et al. (2014)[19], abrasion injuries can lead to player discomfort and hence possible changes in biomechanical movement. The increased injury risk due to altered biomechanics has been well established [37] and the recent Subsequent Injury Categorisation model[38] suggests that subsequent injuries may be associated with initial injuries. In addition, skin infection can have significant consequences for the individual player and team.[39] Despite the perceived minor nature of abrasion injuries, they may have a significant impact on the players' comfort, injury risk and performance. Again, understanding the true risk of abrasion injuries will encourage the development of injury prevention strategies and/or lead to a review of the current abrasion testing devices and processes.

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

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

Felipe et al. (2013)[22] suggested that the negativity associated with abrasion injuries on artificial turf would disappear as the products improved. This does not seem to be the case and may be due to the lack of external validity of the test methods used to measure the level of skin friction and abrasiveness of the surface in the laboratory testing prior to installation. The limitations of the current test methods are with the silicone skin and the foam, they provide empirical information only about the relative abrasiveness of the surface but do not simulate the human skin's response when exposed to sliding on an artificial turf surface[19] nor the mechanics of sliding. With limited evidence of the true incidence of abrasion injuries on the current artificial turf products, there is little impetus to validate or improve the existing test methods. It is considered that with more sports adopting artificial turf worldwide, with varying player-surface interactions, it is timely for a systematic review of the validity of the current test methods and modifications to ensure that future artificial turf products are created with an acceptable level for skin friction and abrasion characteristics.

5. Conclusion

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

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

Practical Implications

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

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

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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 (1st 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.

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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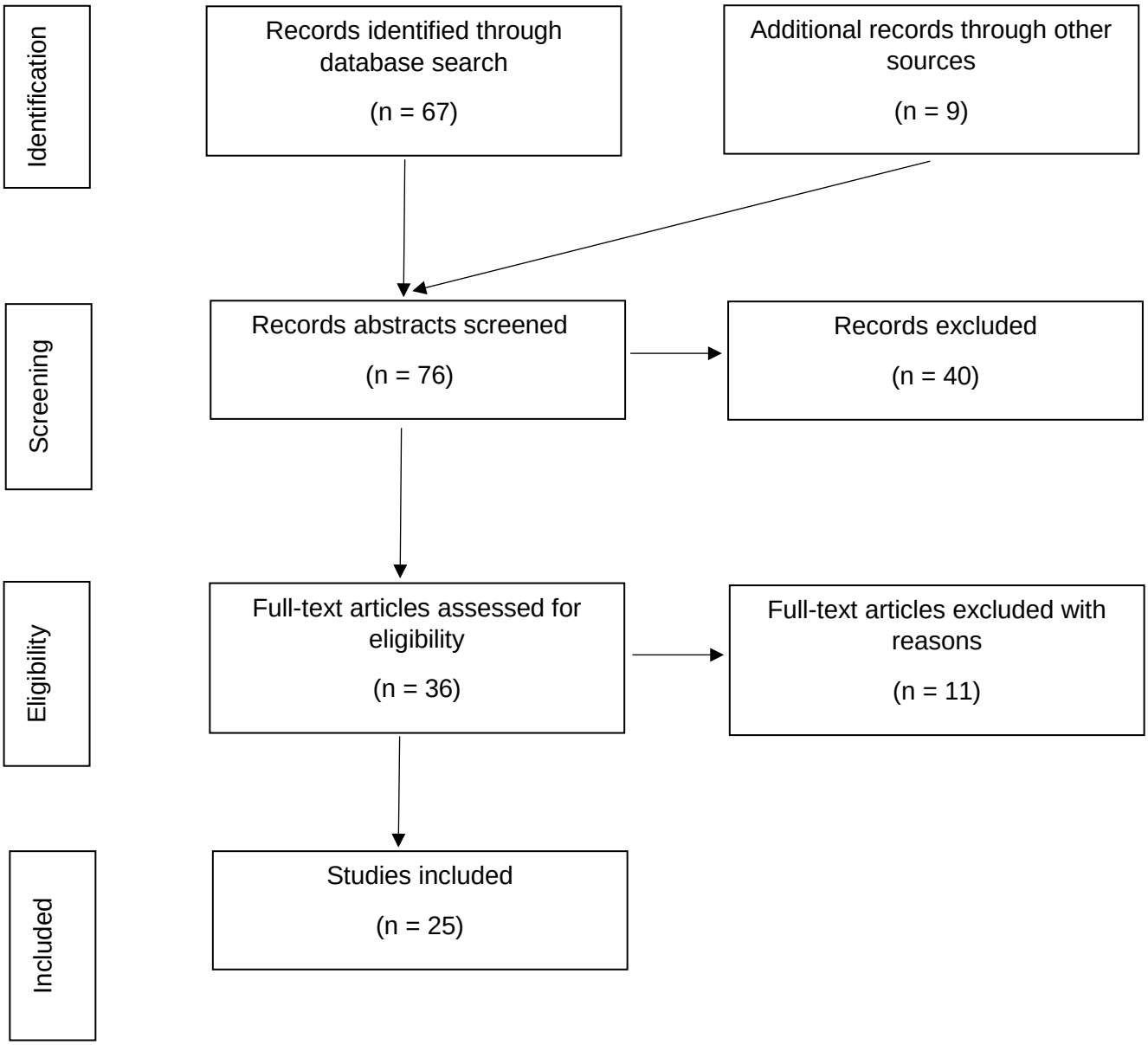
Figure 1: Flow chart of search results


Identification
Records identified through database search
(n = 67)
Additional records through other sources
(n = 9)
Screening
Records abstracts screened
(n = 76)
Records excluded
(n = 40)
Eligibility
Full-text articles assessed for eligibility
(n = 36)
Full-text articles excluded with reasons
(n = 11)
Included
Studies included
(n = 25)