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Review

Can the natural turf pitch be viewed as a risk factor for injury within Association Football?

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ABSTRACT

Objectives: A review of the current literature is used to propose a 'conceptual model for relative pitch hardness' and how this may affect incidence of injury within Association Football. Based upon the injury risk and causation model of Meeuwisse et al. (Clin J Sport Med 2007; 17(3):215), it may provide researchers a necessary framework to guide future research investigations.
Design: A literature review.
Methods: A comprehensive search of electronic databases available until October 2014, and supplemental hand searching was conducted to identify relevant studies. Studies were deemed relevant if they met the following criteria: published in English, presented or referenced in an epidemiological study or provided data directly and/or related to the surface of the football pitch, ball or boot to surface interaction and injury. Further information was sourced on surface hardness, players' movement patterns and physiological demands within football.
Results: Papers varied in methodological quality, with comparative studies examining injury rates on artificial versus natural turf pitches being most prevalent. No prospective studies were found that objectively measured the relationship between hardness of natural turf and injury risk within football.
Conclusions: The literature review into natural turf pitches and injury within football has largely been unable to confirm that pitch hardness can be viewed as a significant extrinsic risk factor. Methodological concerns, including objectivity in pitch assessment and uniformity in defining injuries undermine the efficacy of available work. Future studies are needed utilising objective assessment tools to draw more definitive conclusions regarding pitch hardness as an extrinsic factor for injury within football.

1. Introduction

For the elite football player, injury rates are high with reported values in training between 1.5 and 7.6 injuries in each 1000 h exposure. This value increases in matches to 12–35 injuries per 1000 h.[1,2] Researchers have attempted to attribute causality to injuries, proposing numerous risk factors that may influence injury occurrence. Consequently, relative injury risk is often broken down into intrinsic risks within the players, such as age, gender and previous injury, or extrinsic factors such as the pitch, opponents' actions, footwear or poor rehabilitation.[3–6] Intrinsic risk factors only become relevant once the player is exposed to the extrinsic environment of either training or matches. Thus, exposure to the external environment initiates a cyclical balance between susceptibility and adaptation, which if unstable may lead to injury. The complexity of such risk factors necessitates a multi-variant approach when examining the contribution of any factor(s) to injury. [7]

This article will consider one extrinsic factor to which all players are exposed, namely the pitch on which the game is played. Historically, grass pitches have been the playing surface in football for both training and matches. Quality standards have been published for the management of natural turf football pitches within England to enhance pitch safety and performance.[8–11] Despite recognition that the natural turf pitch can be a factor for injury[12–16] there has been little in the way of scientific evaluation of its risk value to the players.

This paper will (1) establish the current level of evidence, (2) discuss methodological concerns associated with research into pitch

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hardness, and (3) propose a 'conceptual model' of pitch hardness and injury risk within football which could provide a framework to guide future research.

2. Methodology: Approach to the development of the literature review

Literature was examined using Web of Knowledge, Scopus, MEDLINE, SportsDiscuss, ProQuest Direct Med, Cochrane library, CINAHL, Scirus and Google scholar. Databases were searched using the following terms: Soccer/football injuries, natural turf, grass and inj*, shoe interface and sports surfaces. Due to limited search findings with specific relevance to soccer, supporting evidence from other team sports was included to provide a better understanding of pitches and their effect on injury risk. References were deemed relevant if they met the following criteria: published in English, presented or referenced in an epidemiological study or provided data directly and/or related to the surface of the pitch, ball or boot to surface interaction and injury. In an attempt to add more global understanding to how the surface hardness may affect players' movement patterns and physiological demands (issues that may be related to injury occurrence), further information was sourced on the effects of surfaces on energy expenditure, leg stiffness and running gait.

3. Current evidence that natural turf pitches affect injury incidence within Association Football

An extensive review across all football codes, reports that links between ground conditions and injury were mostly intuitive. From the available research papers ($N = 79$) only five studies objectively measured pitches with none reporting strong associations between pitch hardness and an increased risk of injury.[17] The majority of studies have instead adopted subjective means of pitch assessment, were poorly standardised and lacking sufficient definition. This makes it difficult to draw firm conclusions regarding the relationship between pitch hardness and injury.[18]

The paucity of research specifically related to Association Football is apparent as three studies were reported within this sport.[17] All of the available data used subjective assessments of pitch conditions reporting associations of 24%[19,20] and 21%[21] between pitches and injury. It is unclear whether subjective measures provide a true reflection of pitch hardness and linking them to injury is difficult. Twomey et al.[18] showed only 50–60% concordance between subjective and objective assessment of pitch hardness. The failure to denote a more comprehensive relationship between these approaches makes it questionable if subjective assessment is sufficiently robust to establish links between injury and pitch hardness. This is therefore a major limitation in the available data sets.

Within football objective measures of pitch hardness derived from devices such as the Clegg hammer[8–11] have been reported but no studies have linked the values to the incidence of injuries. Other sports have used equipment such as the Clegg hammer,[18,22,23] or the Penetrometer[22,24–26] to gain objective measurements of hardness though a lack of consistency with respect to the equipment and protocols used impacts on transferability and applicability.[22] Consequently, the available research may not have (a) effectively determined a true representation of the pitch hardness or (b) evaluated how this variable may directly influence the risk of injury. On the whole then there seems to be little available research that effectively directly investigates the impact of pitch surface on injury. This would seem to be an important omission for both our theoretical understanding of injury mechanisms and practical approaches to injury prevention.

Indirect evidence that pitch hardness may adversely affect injury has been drawn from research that (a) compares injury incidence between artificial and natural turf pitches; (b) proposes a seasonal bias for injuries; or (c) critically interprets how the pitch may impact factors that can lead to injury such as biomechanical load, speed of the game and player movement.

Pitch hardness: Injury incidence on artificial versus natural turf: The majority of research in football relating pitches to injury focuses on comparative studies outlining the incidence of injury on artificial or natural grass surfaces.[12–16] First Generation artificial turf pitches in the 1970's with their short nylon fibres were reported as being hard.[27] This made the playing characteristics different from natural grass pitches with many studies reporting a significant increase in the incidence of injuries, particularly abrasions and sprains.[12–15] The artificial pitches of today are more representative of their grass counterparts with longer fibres and rubber granular infill promoting more acceptable levels of hardness.[16] Such are the improvements in artificial surfaces that many studies report no significant differences in injury incidence between them and the natural turf pitch.[16,27,28] Nevertheless, evidence remains indicating persistent differences between injuries sustained on the two different surfaces.[29–33]

None of these studies reported what characteristics of the playing surface were directly attributable for the injury rates witnessed, nor did they objectively scrutinise the pitches. This suggests an inherent assumption amongst some researchers that pitches remain constant over time. This however is not the case as even artificial pitches demonstrate large degrees of temporal and spatial variation.[34] Natural turf pitches are living things and will exhibit greater temporal and spatial variation than their artificial counterparts. Research using 'natural turf' as an undefined variable in injury studies may mask the variation within and among such surfaces. This observation could be highly significant in investigations of this nature.[35]

Seasonal bias, pitch hardness and injuries: In England, one of the largest epidemiological studies in football reported evidence for an early season bias for injury. The study reported peaks in training injuries in July while match injuries seemed to be at their highest in August.[36] Surface dryness (hardness) over the pre-season period was associated with 70% of injuries a value which fell to 51% during the season. Wet or muddy pitches were recorded in 40% of all in season injuries whereas they were only noted in 8% of those injuries sustained in pre-season. These findings were supported by the results from the UEFA Champions League study which prospectively tracked injury data from 27 top clubs, across ten European countries between 2001 and 2012.[37] This longitudinal approach corroborating the findings of Hawkins[36] highlights the apparent robustness of an increase in injury during the early season period when pitches are frequently reported as being harder.[38,39]

Such relationships are also noted in the Australian Football League (AFL) where the prevailing climatic conditions in the northern territories of Australia lead to drier, harder, pitches. These conditions were associated with a 2.8 fold increase in rates of Anterior Cruciate Ligament (ACL) injuries than the softer wetter pitches of the southern regions.[26] Variable climatic conditions were also highlighted in the Champions League study[40] where geographically regionalised injury differences were reported. This may suggest that the prevailing climatic conditions of varied countries and therefore their pitch conditions (hard or soft) may influence the injury rates recorded. However, unlike the AFL study,[26] the Champions League study[40] did not evaluate the pitch conditions at time of injury.

Some caution must be exercised when attempting to make causal attributions regarding seasonal bias for injury and pitch hardness. Reduced early seasonal fitness levels, changes in footwear and the high exposure to training loads over the

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pre-season period may also contribute to the increased risk of injury.[41] Consequently, reduction in injury rates over the season may be more attributable to the physiological adaptations associated with match/training exposure than any change in pitch hardness accountable to seasonal change.

Thus far researchers have attempted to establish direct links between injury risk, and pitch hardness, through subjective reporting of pitch conditions. The failure to match objective pitch hardness measurements with the precise injury location on the pitch makes conclusions somewhat erroneous.[17] Adopting a more integrated approach, incorporating an engineering and biomechanical analysis of natural turf and its effect on human movement, may promote better understanding of the processes by which the pitch may underpin injury within football.[35]

Pitch hardness and biomechanics: As objective information on pitch hardness within the literature is sparse, it may be prudent to examine laboratory based studies that have collected biomechanical data investigating the effect that the surface has on the individual. This data may support the inference linking pitch hardness and injury. Any surface on which a player runs will affect them kinetically, through the forces to which they are exposed and kinematically, in the way they adapt their movement to accommodate such forces. Consequently, an understanding of how the body adapts to such loading may provide the cornerstone of any rationale as to how the pitch may influence injury within football.

Few biomechanical studies have been performed using a natural grass surface. The tools required for such objective testing are considered difficult to apply within a field setting as complicating extraneous variables negatively impact the objective data recorded. Some researchers have, however, attempted to analyse the effect of different natural turf constructions and hardness, on kinetic data within the laboratory setting.[42–45] These researchers cultivated grass within 45 trays which were used to form a runway overlaying a force platform permitting ground reaction force data to be obtained. Such research suggests that significant differences are evident in rates of loading between different experimental turf hardness conditions. Ground reaction forces in both running and turning movements were noted as being surface dependent. More specifically, harder surfaces resulted in increased loading values when compared to softer counterparts.[42] This data is however limited in its ability to generalize insights into injury mechanisms and/or injury risk in elite players due to small subject numbers ($n = 8$), the population used (university students) and the speed at which the trials were executed (3.83 m/s). These speeds are substantially slower than those observed in games (5.5–6.9 m/s = high speed run and over 7 m/s = sprint).

Despite its limitations, such research suggests that the surface hardness of natural turf may affect the loads and movement adopted by the players. An examination of the literature surrounding 'running gait' corroborates this, highlighting that runners adjust the stiffness of their leg to accommodate the surface stiffness beneath their foot.[45] Additionally, whilst running, the individual will co-ordinate the actions of many muscles, tendons and ligaments so that the leg behaves like a single mechanical spring during the ground contact.[46,47] Ferris[46] concluded that such adaptation to the relative surface compliance is regulated within the first step on the surface. Runners show a decreased leg stiffness of 29% between the last step on a soft surface and the first step on the hard surface. The ability to change leg stiffness quickly allows the individual to maintain dynamic stability when running on varied and unpredictable terrain. This is pertinent within football as pitch construction varies resulting in non-uniform surface hardness with respect to the prevailing climatic conditions. Consequently, there is marked variability between pitches and within the same pitch. The ability of players to adapt quickly to changes in hardness is therefore an asset, but may incur a cost, namely increased energy expenditure, which in turn may predispose players to fatigue.[45–47] Within amateur football, players' running speeds and the metabolic energy costs were studied on natural grass, artificial surface or asphalted track.[48] No differences were found in running speed for the players', however a significant main effect for surface was noted, with the natural and artificial turf being of similar compliance resulting in similar levels of energy expenditure. Increases in surface dependent energy expenditure singularly may not appear significant however, utilising Meeuwisse's[7] model of injury risk and once considered collectively over a football-season, the cumulative effects may predispose the player to fatigue/overload induced injuries. The relative hardness or softness of the pitch therefore determines how hard the players have to work during any given match or training session. The players still achieve the requirements of the task, namely to complete the match or training session, but the energy required to do so may be enough to make them susceptible to injury in the near future.[45–47]

Pitch hardness affects game speed and injury: As research and development into artificial pitches has progressed, so too have developments and innovation associated with grass surfaces. Such developments may have been an attempt to answer user requirements for faster, harder, higher traction pitches. They may also be attributable to media/spectator expectations for a more consistent playing surface. Such surfaces provide the platform upon which the modern player can exploit their strength, power, and speed.[35] Research by Norton[25] offers a link between pitch hardness and its effect on the game and the individual. They examined the effect of pitch hardness on the speed of the game, concluding that pitch hardness was significantly correlated with game speed within the AFL. They noted hard pitches witnessed faster play, more scoring shots and significantly longer stoppages in play than games played on softer pitches. Collision rates were also increased which coupled with the increased mean player speed led to a higher incidence of injuries on the harder surfaces. If indeed harder pitches promote quicker speeds, players may spend a greater proportion of any game within high intensity or sprint zones, which may have a twofold effect on the player. Firstly, they may experience higher levels of fatigue and thereby increase their likelihood of becoming injured in the later stages of games. Secondly, exposing the players to excessive or prolonged loading at such speeds may overload the musculoskeletal system, increasing their susceptibility to potential injury.[25] Unfortunately, as there have been no studies in football regarding the hardness of pitches and their effect on match speed or fatigue, any assumptions are purely hypothetical but warrant research in the future.

Pitch Hardness: Methodological concerns: Undoubtedly, methodological issues are important factors that impact the quality of the evidence available. Knowledge of the mechanisms by which the pitch may affect injury rates is limited by our current understanding of the pitch, exposure rates of players, the loading experienced by players and by the means for reporting and recording mechanism for injuries. Evidence supporting the pitch's involvement in injury within football thus far, lies within epidemiological studies from which, one can draw no direct link to the proposed models of injury risk.

Currently, the evidence that natural turf pitches can be viewed as a risk factor for injury in Association Football is constrained by the subjective methodology adopted. A major limitation is that pitch conditions are open to interpretation and are likely to be an amalgam of a number of variables such as hardness, traction, grass cover and moisture.[49] The subjective nature of classifications such as wet/soft or dry/hard lack detailed descriptions of whether this truly reflects the entire surface or the area in which the injury occurred. Furthermore, the use of retrospective recall and the absence of reported reliability for both the subjective tests used and of the assessors performing them, makes their reported findings

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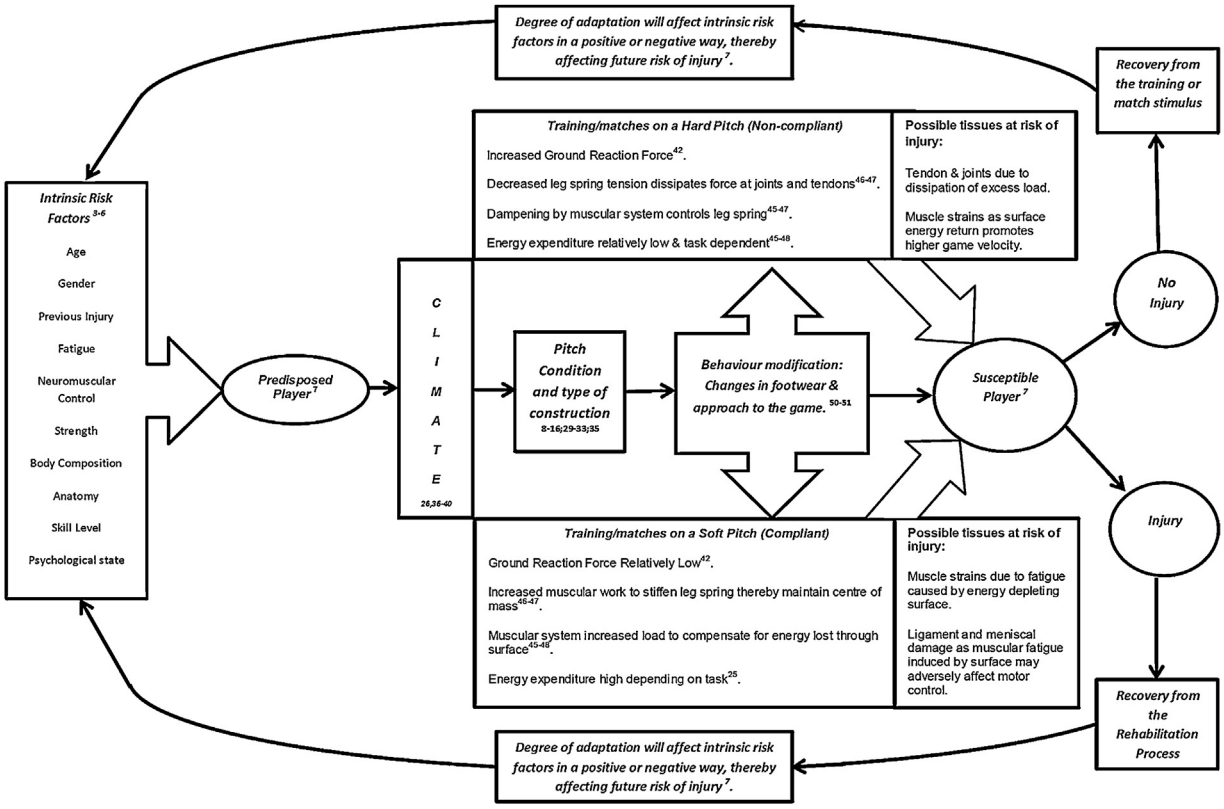

Fig. 1. A conceptual framework for the natural turf pitch and how it may influence a footballers risk of injury.

questionable and generalisation difficult. Unquestionably, technical difficulties are evident when it comes to testing pitch hardness. Equipment costs, portability, reliability, validity and availability are all potential obstacles. Nevertheless, to evaluate such surfaces and investigate their role within football injuries, researchers will need to adopt, develop and improve objective measures to evaluate the surface. These, must then be incorporated into longitudinal studies and compared prospectively with incidence of injury data collated in line with universally agreed definitions of injury and corroborated with time exposure data.[57]

A further confounding methodological reason why the literature does not support an associated rise in injury with increased pitch hardness may be found in the theory of 'modifiable risk', which sees individual players modify their behaviour in accordance with the demands of the situation or their past experiences.[50] Such behaviour modification was reported in a comparative study of Swedish elite footballers during competitive games on artificial turf and grass.[51] No differences were observed between players on artificial turf and natural grass in terms of total distance covered, high intensity running, number of sprints, standing tackles or headers per game. However, there were statistically significant fewer sliding tackles on artificial turf than grass. This may be indicative of modifiable risk on the part of the players. Additional, behaviour modification was noted in the passing strategies adopted, with more short and midfield-to-midfield passes on the artificial turf than grass. The players' perception was also affected by the surface with the male players reporting a negative overall impression, poorer ball control, and greater physical effort on the artificial turf. This behaviour modification may in part account for the stability in injury incidence within professional soccer when surfaces are compared. It is possible the player self regulates their activity or behaviour on any given pitch so as to minimise their risk of injury. Such behaviour modification may therefore make any interpretation of pitch hardness or injury incidence data and research difficult.

Perhaps researchers in the applied setting need to take a more pragmatic approach which provides reliable, objective data about the pitch without adversely affecting the playing surface. This will allow testing to be performed close enough to the match or training session to allow inference to be drawn at the appropriate time to both exposure and injury surveillance data. This would enable a more accurate real time reflection of the interaction of pitches and their effect on the player and their risk of injury.

4. A conceptual framework for the natural turf pitch and its influence on risk of injury

To conceptualise a model for the football pitch and how it may influence injury necessitates recognition of methodological limitations within available research and an awareness of factors affecting human locomotion. Thus far research has focused on the pitch as a primary risk factor where exposure results in injury. Clearly this is limited as not all players who encountered the surface on that day were injured. Perhaps researchers need to consider the dynamic, recursive nature of player-pitch interaction investigating how single and cumulative exposures to varied hardness's of pitches affect injury risk. Such an approach supports a conceptual model founded upon the work of Meeuwisse.[7]

Analysis of player movement patterns has enabled researchers to determine the physiological demands of such movement.[52–54] Consequently, football can be viewed as an intermittent sport punctuated by bouts of repeated high intensity exercise.[54] Players continually change direction and speed, adopting unorthodox movement patterns enabling them to execute the technical skills required to outperform their opponents.[52,54] Such movement profiles may affect the energy expenditure, musculo-skeletal load, fatigue and injuries seen in professional football. Additionally, as surface compliance is known to affect both energy expenditure[45–48,57] and musculo-skeletal load,e[42,58] one may

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consider the impact of the natural turf pitch conditions on such physiological demands. The relative hardness of any natural turf pitch being transient and affected by extraneous variables such as the weather, will change throughout the season, thereby altering the demands of any given pitch-player interaction.

The conceptual model in Fig. 1, addresses the extrinsic risk that pitch hardness may play within football injuries. It highlights how interactions between the player and the pitch can alter the 'intrinsic' make-up of the player, subsequently affecting how susceptible the player is to future injury. To aid understanding of the proposed model, a number of examples of how the natural turf pitch could affect physiological demands, and thereby the potential for injury are highlighted below.

For any given task an appropriate degree of muscle contraction is required to achieve the desired displacements and velocities of the body on the pitch.[55] Additionally, the player's muscles must (1) generate additional force to compensate for the inevitable energy dissipated through surface compliance, (2) modify the required force according to the level of strain development in the tendons, and (3) minimise the peak impact forces experienced by their joints during loading of the stance leg.[45–47,55] Consequently, a player running on a compliant (soft) pitch expends more energy for any given running velocity when compared to running on a less compliant (hard) pitch in order to compensate for energy dissipated through the surface. Soft pitches negatively affect the ability of the muscles to utilise the elastic properties of their tendons leading to an over dependence on the muscles to maintain performance leading to fatigue. This has been confirmed through demonstration of a negative relationship between surface compliance and oxygen consumption.[56] As a result, muscles need to work harder due to the energy depleting nature of the surface. Therefore, considered in isolation, playing on more compliant surfaces may induce localised muscle fatigue. Over a more cumulative time frame the additional muscular effort may cause an increased risk of muscle strains. Conversely, the player running on a hard pitch will experience increased loading through joints and tendons due to increases in impact forces.[42–45] The musculoskeletal system 'dampens' this by reducing leg stiffness, effectively cushioning each step. In the short term, these excessive ground reaction forces may be dissipated through the aforementioned spring system,[45–47,55] though the efficacy of this would decrease the more fatigued the players became. Consequently, the pitch can affect the musculoskeletal system of players in both an acute and chronic manner. Previous injury, repetitive impacts or insufficient adaptation/recovery between exposures would reduce the load required to initiate tissue breakdown and resulting injury.

This proposed model suggests the pitch can play a significant factor in the physiological and biomechanical demands of any given task. Thus, the relative hardness or softness of a pitch may influence the loads and fatigue experienced by the musculo-skeletal system.[43,44,56] Failure to provide players with sufficient time for musculoskeletal adaption following pitch exposure could increase their risk of injury. This could be acute, causing immediate injury or through repeated exposure result in more chronic overuse injury[7] (Fig. 1).

5. Summary

The literature regarding natural grass pitches and injury within football has largely been unable to confirm the contention that the pitch hardness can be considered a significant extrinsic risk factor in injury. The adoption of comparative studies, where the temporal grass pitch, is compared with its artificial counterpart, has limited research into the effects of the grass surface and its influence on injury. Such research masks the variation within and among such natural turf surfaces. Anecdotal evidence for the effects that grass football pitches have on injury has been reported but no studies have included objective measurement. Although biomechanical analysis of natural turf is difficult there are trends suggesting researchers are realising the importance of such work and commencing studies to address the need for such data. Perhaps most pertinently, the literature outlines a negative relationship between surface compliance and energy expenditure suggesting that the pitch affects the physiological demands of any given training session or match. This may be one link in the chain between pitch hardness and the relative injury risk of each player. It is hoped with increased use of objective pitch testing, a better understanding of how the player and pitch interact will help us to understand how relative pitch hardness contributes to injury.

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