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Review

The relationship between ground conditions and injury: What level of evidence do we have?

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ABSTRACT

Objectives: To identify studies which address the relationship between ground conditions and injury, in a sporting context and to evaluate current practice and provide recommendations for future studies that measure ground conditions and injury risk.
Design: Systematic review.
Methods: A comprehensive search of electronic databases from the earliest records available until the end of 2011, and supplemental hand searching was conducted to identify relevant studies. A classification scale was used to rate the methodological quality of studies.
Results: 79 potentially relevant articles were identified, and 27 met all inclusion criteria. They varied in methodological quality, with analytical observational studies the most common design, although four descriptive observational studies, considered to be of lower quality were also identified. Only five studies objectively measured ground conditions, and of studies that used subjective assessment, only one provided descriptors to explain their classifications. It appears that harder/drier grounds are associated with an increased injury risk but the presence of major limitations necessitates cautious interpretation of many key findings.
Conclusions: There is limited high quality evidence of the relationship between injury risk and ground conditions. Further research with high quality designs, and measurement of ground conditions are required to draw more definitive conclusions regarding this relationship.

1. Introduction

In an array of sports including cricket and the different codes of football, characteristics of ground conditions have been identified as a factor associated with injury risk.[1–7] Ground hardness (the effect that the surface has on absorbing impact energy) and traction (the type of footing or grip a playing surface provides) have been cited as the two main surface characteristics related to injury, particularly the lower limb.[8] Hardness is most highly correlated with soil moisture content and traction with grass cover.[8] While studies investigating the relationship between ground conditions and injuries are evident in the sports medicine and international sports science literature,[1,2,4,5,9–11] the range of approaches used to investigate this relationship have not previously been systematically and comprehensively examined. Accordingly, there are no standardised practices for the measurement of ground conditions, and this has resulted in an intuitive relationship, rather than a solid evidence base linking ground conditions and injury.[1,4,12,13]

Orchard[5] identified that there was a need to make use of, and further develop instruments to measure ground conditions, although as an initial step in advancing current practice, it seems appropriate to recognise and evaluate published studies. While two systematic reviews investigating injury and playing surfaces have been published recently, they have addressed the difference in injury rates on natural and artificial playing surfaces,[14] and the incidence, nature and mechanisms of football injuries on natural turf compared to newer generation artificial turfs.[15] This systematic review differs as it aims to identify and compare studies which address the association between ground conditions and injury, in a sporting context. More specifically, it describes the methodologies and assessment of ground conditions, and highlights the strengths and weaknesses of different approaches. Implications for understanding the relationship between ground conditions and injury risk, and considerations for improving the quality of ground measurement in future studies are discussed.

2. Method

Studies were included in this systematic review if they met all of the following criteria: (1) subjectively and/or objectively evaluated

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ground conditions; (2) reported on a type of sport; (3) included an outcome measure of injury incidence; and were (4) peer reviewed original research articles.

Studies that measured weather variables (i.e. evaporation, rainfall, temperature) and ACL injury were excluded because ground conditions were not evaluated.[16–19] Similarly, a study that generalised that grounds were hard due to drought but did not evaluate the ground was excluded.[13] Other studies[20,21] that objectively measured ground hardness were also excluded if they used an industry standard predictor of injury (The Gadd Severity Index), but did not measure injury incidence. In addition, studies with insufficient details relating to the ground assessment (i.e. only reported data were collected on the surface during the match or training) were excluded.[22] Studies that investigated differences between surfaces (e.g. between natural and synthetic) were excluded unless the surface condition was explicitly described or measured.

To identify relevant studies, multiple electronic databases were searched from the earliest records available until the end of December 2011. Multiple databases were selected as research indicates that a literature search performed in a single database will lead to, on average, a loss of more than half of the available literature.[23] Further, the importance of searching multiple databases for multidisciplinary fields was adhered to.[24] Searching of electronic databases were supplemented by hand-searching of bibliographies of systematic and non-systematic reviews and the reference lists of all other identified studies.

To ensure that relevant studies were identified, a number of search keywords and synonyms were adopted, and recommended guidelines for electronic searching followed[25] (see supplementary material for details of search strategy and terms). Although English language search terms were implemented, no language restrictions were applied.

Relevant studies were identified by screening titles, abstracts and keywords according to the inclusion criteria defined a priori. Obvious exclusions were removed, and full texts were obtained for articles meriting further review. To determine appropriateness, articles were read and assessed against the inclusion criteria by one author. Uncertainties were resolved through discussion and additional review by the authors. Final classification of all studies was agreed upon by both authors.

To analyse the quality of selected studies, both the study design and method utilised to assess ground conditions were considered. To date, no scale or checklist is universally accepted.[26] Accordingly, for the purpose of this review two scales assessing common study designs in public health and injury prevention were identified,[27,28] and a classification scale for studies measuring ground conditions and injuries was derived from these (Fig. 1). This scale allowed all identified studies to be critically analysed and classified according to capacity to eliminate or minimise bias. A second scale ensured a systematic and explicit approach was implemented for making judgments about the assessment of ground conditions (Fig. 1).

3. Results

Searching identified 79 potentially relevant citations, although after screening against the inclusion criteria 27 studies were selected. Studies that did not meet inclusion criteria were eliminated principally because no measures of ground conditions were reported or injury incidence was not considered. Of the eligible studies, the majority ($n = 23$) were analytic observational study designs and case–control and cohort studies were the most common. The remaining studies were descriptive observational designs and these were considered to provide lower evidence.[1,29–31] Only five studies objectively measured ground conditions,[2,5,9–11] and all measured ground hardness. Only one study[4] that subjectively measured ground conditions provided detailed descriptions to explain the categorisation implemented. All other studies ($n = 17$) utilised subjective assessment with broad terms and no additional details, thus demonstrating that there is a paucity of high quality evidence examining the role of ground conditions as a risk factor for injury.

The assessment of ground conditions and injuries has been explored primarily within the different football codes including American football,[4,32–39] Australian Rules football,[5,9,10,40,41] rugby union and rugby league,[6,7,11,12,29–31,42,43] soccer,[3,44,45] and Gaelic football.[1] Recently, the first study examining the relationship between ground hardness and injuries in junior cricket has also emerged.[2] The following sections describe studies that have examined the relationship between ground conditions and injuries within each sporting context.

Many studies[4,32–36,38,39] have explored the relationship between ground conditions and injury in American football, although a major limitation to date is that all studies subjectively assess ground conditions (Table 1).

Andresen et al.[4] was the only study to provide descriptors to explain their subjective classifications of 'good', 'wet/slippery', 'hard', and 'muddy' in their attempt to determine associations between injuries and both environmental and playing conditions. All data were obtained by direct observation and recorded on a standardised form by the medical support staff at each game but it is unclear exactly where or how the observations were undertaken.

Findings demonstrated a significant difference in injuries (defined as "an insult that prevented the player from continuing play or for which medical attention was requested", p. 28) under different pitch conditions.[4] 'Good' conditions were associated with the highest injury frequency (3.3 injuries per game) and 'wet/slippery' conditions the lowest (1.7 injuries per game). Comparable injury rates were observed for 'hard' and 'muddy' conditions (2.3 and 2.1 injuries per game, respectively).

Overall, the relationship between ground conditions and injury risk in American football appears inconclusive. There is some evidence to suggest that more minor injuries are sustained on drier grounds but objective measurements or detailed descriptions of both the classification and methods of subject assessment are warranted.

Two cohort studies have investigated ground hardness and anterior cruciate ligament injuries in the Australian Football League (AFL).[5,10] The earlier study objectively measured ground hardness at 571 elite level AFL matches using a penetrometer.[5] While the study failed to provide specific details of the instrument, typically a penetrometer consists of a shaft [metal rod with a conical tip] and a hammer [specified weight that falls onto the strike plate/anvil around the rod], with the hammer lifted to a predetermined height and dropped.[46] This action pushes the shaft into the soil and the resultant depth of penetration is the measurement taken.[46] As the penetrometer was an established and reliable measure for determining track hardness in horse racing,[47] a pilot study was conducted in the first year to develop a method to measure football ground hardness.[5] To achieve consistency with horse racing values, ground hardness was measured at 20 sites, with the average of three consecutive drops at each site taken as the final reading. The 20 sites corresponded to the 18 player positions on an AFL field and two additional readings were taken in the centre square. The penetrometer was not moved between the three drops and as a result, the third drop provided the highest reading in all instances.[5] The protocols for testing ground hardness over the following seasons were the same, with two exceptions in the instructions. First, for grounds with a cricket pitch, no more than four readings were to be conducted on the cricket surface. Second, ground staff were encouraged to prepare grounds with "a degree of give in the surface" (p. 221) with extra