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Ground hardness and injury risk in community level Australian football

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Abstract (226 words)

Objective To establish the relationship between ground hardness and injury in community level Australian football (AF).

Design: Prospective injury surveillance with periodic objective ground hardness measurement.

Methods: 112 ground hardness assessments were undertaken using a Clegg hammer at nine locations across 20 grounds over the 2007 & 2008 AF seasons. Details of 352 injuries sustained by community level players on those grounds were prospectively collected as part of a large randomised controlled trial. The ground location of the injury was matched to the nearest corresponding objective ground hardness measure and used for analyses. Clegg hammer readings were classified from unacceptably low hardness (<30 g) to unacceptably high hardness (>120 g).

Results: Clegg hammer readings ranged from 25-301 g. Only 13 of the 352 injuries occurred on test locations classified as having unacceptably high hardness. More severe injuries occurred on grounds with low/normal ground hardness. Overall, 24 injuries resulted in a hospital visit, with 4% in the high/normal hardness category and 8% in each of the low/normal, preferred and unacceptably high categories.

Conclusions: This is the first study to directly link Clegg hammer ground hardness measures with prospective injury data in any sport. Despite adjusting for other factors, ground hardness was not found to be a significant predictor of injury. The results challenge the hypothesis of a link between hard grounds and an increased injury risk in community level AF.

Keywords: Ground hardness, Clegg hammer, Australian football, Injury risk

Introduction

Current climatic changes around the globe have focused attention onto the potential sporting injury risks associated with extreme conditions of sport surfaces.[1] Under drought conditions, for both safety and grounds management imperatives, perhaps the most concerning aspect of ground conditions are hard, dry grounds. Ground hardness refers to the effect that the ground has on absorbing impact forces [2] and this surface characteristic has increasingly been associated with injuries on natural turf playing grounds.[3-6] The contribution of hard grounds to injury risk is postulated to arise through two mechanisms. Firstly, a hard ground provides greater peak reaction forces when a player either lands or applies a force to it than occurs on a soft ground, potentially increasing the risk of injuries such as fractures or non contact overuse injuries .[7] Secondly, hard grounds enable faster game speeds potentially increasing the risk of a higher collision impact either with another player or the ground itself.[8]

Many studies have identified ground and environmental conditions as factors associated with injury, particularly in the football codes of Australian football(AF) [2, 9], American football[10, 11], rugby union[6, 12] and rugby league.[4, 13] Fractures, strains/sprains and haematomas are the most commonly reported injury types related to hard grounds. [4, 9, 12, 14] Hard grounds have been more commonly associated with the hot months of the year and hence have also been linked with the notion of an 'early season bias' in injury occurrence for winter-based sports, that is with more injuries being sustained at the beginning of the season.[5] This has been supported in studies in AF[15], American football[10], rugby union[16] and Gaelic football[17]. As an early season bias has also been reported for indoor court surfaces[18], it is likely that intrinsic factors such as inadequate player conditioning or an increased exposure to competitive game conditions are also partially responsible for the increase in injuries in the early part of the season.[19]

A limitation of the research to date is what is subjectively perceived and often cited as 'ground conditions' is likely to be related to a variety of physical quantitative measurements, such as hardness, traction, grass cover, and volumetric moisture content. In addition, the risk of different types of injuries may be mechanistically linked to different surface properties or different combinations of surface properties, with ground hardness being just one measurable surface property. Another issue with many of the published studies linking hard grounds and injury risk is the subjective nature of their classification of ground conditions (for example, relying on completion of a simple check box assessment used by coaches and support staff to record against a list of options such as hard or soft, wet or dry, muddy or firm).[10] Whilst subjective observational assessments can provide a general indication of ground conditions, they are unable to quantify the actual degree of hardness and the reliability of such subjective classifications remains unknown. Rather surprisingly, the use of objective hardness measures, obtained from instrumented testing devices, has only been previously reported in three injury studies in AF[8, 20] and one in rugby union.[6] There was no significant overall relationship between ground hardness and risk of anterior cruciate ligament injuries in elite AF, but there was a trend towards an increased risk when the ground was harder.[20] There was also no significant relationship between hard ground and community-level rugby union injuries in New Zealand.[6]

All four studies used penetrometers, a device first developed for the rating of horse racing tracks, to assess ground hardness and subsequently related these measures to the injuries sustained. While the penetrometer has been acknowledged as a suitable objective assessment of soil strength, it may not be valid in determining the hardness on the surface due to the depth of penetration of the device[21], which may help to explain a lack of significant findings. The Clegg hammer has been accepted as a more useful and reliable device for measuring ground hardness[22, 23] and its' measures correlate more closely to player perceptions of hardness, compared with those from a penetrometer.[23, 24] To date, no study has reported the relationship between prospectively collected injury data and ground hardness using the Clegg hammer in any sport.

The evidence linking ground hardness to injury risk has been somewhat inconclusive, often limited to elite players and based on either subjective opinion or sub-optimal testing devices. The purpose of this study is to establish the relationship between objective Clegg hammer ground hardness measures and prospectively collected injury data. In doing so, it also identifies the nature, mechanisms and severity of injuries according to different levels of ground hardness and provides the first profile of the relationship between ground conditions and associated injury risk factors in injury causation for community-level AF.

Methods

Details of all injuries sustained by players from 40 community AF teams in Victoria (VIC) and Western Australia (WA), during the 2007 and 2008 playing seasons, were prospectively collected as part of a large randomised controlled trial called Preventing Australian Football Injuries through eXercise (PAFIX).[25] This included 10 senior grade and 10 reserve grade teams in VIC and 8 senior, 7 reserve and 5 colt (under 19) grade teams in WA over the 2-year period. Full details of the study protocol and methods have been published elsewhere.[25] The PAFIX study was approved by the institutional Human Ethics Committees and informed consent was received from all participants over 18 years of age.

Trained primary data collectors (PDCs) were assigned to each club and recorded all match injuries during the two seasons according to a standardized data collection procedure.[26] An injury was defined as that which caused a player to seek medical attention on the ground (from sports trainer through to medical doctor) or to leave the ground of play for attention. The PDC-reported data included the body region, nature and cause of the injury. In addition, details of usual player position, quarter of the game in which the injury occurred, and the exact location on the ground at the time of injury were recorded. The location of the injury on the ground was then matched to the nearest corresponding objective ground measure recorded and used for analyses. A time-loss injury severity definition was used and coded at three levels: player did not need to leave the field, player left the field but returned to play later in the game, player left the field and was unable to return to play in the same game. Injuries referred to a hospital for treatment were also noted.

Although the PAFIX teams participated in matches every week on a number of grounds, the ground hardness was only measured on a subset of grounds across the two playing seasons due to the time it took to undertake the assessments and the fact that they had to be assessed on the day before a match, so as to avoid any disruption to game schedules.[27] Data were excluded where there was change in ground conditions due to rainfall between testing and the match. A purposive sampling plan was adopted to select the tested grounds so that each PAFIX team played on a ground that was assessed before their game between 8-9 times. Preference was given to selecting grounds on which two of the PAFIX teams were playing against each other to maximise the ability to correlate injury outcomes with ground assessments. When two PAFIX teams were not opponents in the same game, test grounds were preferentially selected on the basis that they were the home ground for a PAFIX team.

To ensure the required quota of ground assessments per team, other grounds were then selected at random.

Nine locations on the AF ground were used for hardness testing based on published protocols [28] (Figure 1). To assess the variability at each test location, four repetitions were recorded within each one meter square. The location of the injury on the ground was directly related to the nearest corresponding ground hardness measure recorded and used for analyses. A Clegg hammer was used to measure ground hardness at each location according to the standard protocol for this device.[29] The Clegg hammer consisted of a 2.25 kg hammer fitted with an accelerometer. This was released from a height of 45 cm through a guide tube and deceleration on impact was recorded in gravities (g). A single drop measure was used according to McNitt.[30] Overall, a total of 20 different grounds were tested, with a total 46 individual ground assessments recorded in 2007 (36 in VIC, 10 in WA) and 66 assessments in 2008 (37 in VIC, 29 in WA).

<Insert Figure 1 about here>

All data were de-identified, coded and double-entered into a database before being exported to the SPSS statistical software (SPSS Inc., Chicago IL). Eight players each sustained two injuries in the same injury event/incident. Whilst both injuries were related to the same ground hardness assessment, all analyses were based on reported injuries, not injured players. There were no recurrent injuries recorded in this study. Injuries were assessed against the ground hardness measure corresponding to the nearest specific test location where the injury occurred on the ground.

The average of the four Clegg hammer readings from across the location was computed as the location-specific ground hardness measure. These averages were then categorized according to the published recommended grading of ground hardness measures for AF grounds[31]: unacceptably high (>120 g), high/normal (90–120 g), preferred range (70–89 g), low/normal (30–69 g) and unacceptably low (<30 g).

Descriptive statistics and frequency distributions were calculated to describe the most common body regions, nature, mechanisms and severity of injury according to the Clegg hammer hardness categories. Injury rates (IR) and 95% Confidence Intervals (95%CI) were computed as the number of injuries per 1000 playing hours on the tested grounds for all games, where grounds were objectively measured on the previous day. The number of player hours was calculated by multiplying the exact game time, which varied from 1.75–2.5 hours depending on grade, by the number of PAFIX players in each game.

Results

A total of 402 injuries were recorded on the assessed grounds: 165 in the 2007 season and 237 in the 2008 season. The exact location of the injury incident on the ground was unknown for 50 injuries, and so only 352 injuries were able to be related to ground hardness. In 2007, there were 7 occasions and in 2008 14 occasions when no injuries were reported on the tested grounds. The overall rate of injury was 39.2 injuries per 1000 playing hours (95%CI: 35.2–43.3) and this did not differ significantly across the two seasons with 32.9 injuries per 1000 playing hours (95%CI: 27.4–38.5) in 2007 and 40.1 (95%CI: 34.9-45.3) in 2008.

The Clegg hammer readings from all test locations ranged from 25-301 g across the two seasons with significantly harder grounds tested in 2008 (range: 25–301 g) compared with 2007 (range: 28-164 g) (mean difference 8.4 g, 95%CI: 3.6-13.1). Clegg hammer hardness categories from low/normal to high/normal were associated with the majority of injuries, with very few injuries on locations with unacceptably high hardness i.e. >120 g, (Table 1). Only 3.7% (13 injuries) occurred on test locations with an unacceptably high hardness reading. Relative to the number of readings recorded within each category, a higher percentage of injuries occurred on unacceptably low (13/25) and unacceptably high (1/2) hardness (Table1).

<Insert Table 1 about here>

Overall, injury numbers were low. The lower limb was the most common body region injured (191/352 injuries) and accounted for more than half of the low number of injuries (7/13) on grounds with unacceptably high hardness (Table 2). Soft tissue injuries, such as sprains, strains and cork/bruises, accounted for the majority of injuries (226/352) with muscular strains and cork/bruises (8 /13) most common on grounds with unacceptably high hardness. No concussion injuries and only one out of the 32 fractures were sustained on grounds with unacceptably high hardness. The majority of injuries that involved player contact (246/352) occurred across all categories of ground hardness. Of the 13 injuries on unacceptably high grounds, 8/13 were the result of collision with another player (e.g., struck while attacking) and the remainder were landing from a jump or mark. The more severe injuries occurred with low/normal ground hardness and the highest percentage of injured players in this category (69/144) did not return to the field of play. The locations with unacceptably high hardness recorded the highest percentage of injuries that did not leave the field of play for treatment (31% compared with 13 – 25% for other categories). Overall, 24 injuries resulted in a hospital visit, with 11/144 (8%) injuries in the low/normal category, 9/112 (8%) in the preferred, 3/82 (4%) in the high/normal, and 1/13 (8%) in the unacceptably high categories.

<Insert Table 2 about here>

Discussion

This is the first study to investigate the link between injury and ground hardness using the Clegg hammer as an objective measure of hardness. Moreover, it is the first study of its type to focus on community level AF. Despite the fact that unacceptably high Clegg hammer hardness readings were recorded from a low number of locations and only a few injuries occurred at these locations, the relative proportion of injuries was highest on the unacceptable hard locations. However, the severity of the injuries sustained on grounds with unacceptably high hardness was lower than for the other categories of hardness.

All previous injury research reporting the link between ground hardness and injury using objective ground measurements has? used a penetrometer.[6, 8, 28] The reason for using the Clegg hammer in this study was two-fold. Firstly agronomists advocate its use as a more accurate measure of surface shock absorbency than the penetrometer.[21, 33] Secondly, it is currently being used by local government authorities in Australia to establish the playability of community level AF grounds[1] and is specified in the recently recommended Australian standards for synthetic turf for AF and cricket.[34] Moreover, different penetrometer models, can result in variable penetration velocity based on the physical strength and leverage of the operators.[33]

The most common nature and contact mechanisms of injury were consistent with previous work.[3, 4, 13, 36] Soft tissue injuries were the most common injury and muscle strains and cork/bruises were the most frequent injury types on unacceptably high grounds. Faster running speeds associated with harder grounds may have been responsible for these injuries but was not recorded in this study. Future prospective injury studies which collect objective ground condition data should also monitor game and player speed, which is now possible through Global Positioning Systems (GPS). [40]

It would seem reasonable to expect more abrasion injuries as surfaces get harder and grass coverage less, given that sliding for ball pick-up and tackling a player to the ground are inherent characteristics of the AF game, however only one abrasion injury was recorded on the unacceptably hard grounds. This finding suggests that perhaps player adopt risk compensatory behaviors when playing on hard grounds. In contrast to previous research[9, 12], only one fracture was recorded on unacceptably high grounds and that was to a player's jaw when struck by an opponent which is unlikely to be related to ground hardness. The differences between these results and previous findings may be due to the objective nature of ground hardness assessments compared with the subjective rating in previous research.

As with previous studies[3], more injuries were reported on the preferred range of hardness and softer grounds than on hard grounds. However, when this was adjusted for the number of measures recorded within each category, the highest percentage of injuries occurred on test locations classified as unacceptably low or high. This is an important finding as across a ground that is subjectively rated overall as soft or indeed hard, there may be unidentified variability. To ensure an accurate interpretation of the link between ground hardness and injuries, future studies need to report the ground hardness at the specific location of the injury. A limitation of this study was the inability to collect location-specific exposure data. As players in Australian football are not restricted to specific parts of the ground during the game, it is challenging to calculate the injury rates relative to location on the ground without an accurate measure of playing time within each of the nine locations on the ground.

Another limitation of this study is the relatively low number of injuries sustained on the grounds tested and particularly at readings over 120 g. Given the injury rates previously reported in community level AF players, it was unexpected that there would be instances in which no injuries were sustained on the day after the assessment. The reason for the lack of injuries during these games remains unclear as they included a range of locations, teams, score margins and time of season.

An important study design factor was the inclusion of two different Australian states, which experience varied climatic conditions. Although harder grounds were recorded in Victoria, the rate of injury was similar across the two states. Whilst the hardness measures sometimes exceeded 300 g, most were within the acceptable range of 30–120 g. It is possible that more extreme conditions exist in regions of more severe drought and consequently that this study may not truly represent the extent of the problem of injuries on hard grounds. The sampling plan used in this study was based on the venues where the PAFIX teams were playing to maximise the number of possible injuries. For future studies, it may be more appropriate to purposively sample on the basis of ground hardness to ensure a fuller range of playing field profiles.

Conclusions

This is the first study to directly match Clegg hammer hardness measures with prospective injury data in any sport and after adjusting for other factors, ground hardness was not found to be a significant predictor of injury. There is a need for further prospective injury studies to objectively measure the quality of natural turf playing surfaces. Finally, this study challenges any hypothesized link between hard grounds and an increased injury risk in community level AF.

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References

1. Otago L, Donaldson A, Payne W, Finch C. Safe physical activity environments - to what extent are local government authorities auditing the safety of sporting grounds? ACHPER Healthy Lifestyles Journal. 2009;56(2/3):5 - 9.

2. Orchard J, Seward H, McGivern J, Hood S. Rainfall, evaporation and the risk of non-contact anterior cruciate ligament injury in the Australian Football league. Medical Journal Australia. 1999;170:304 - 6.

3. Grimmer K, Williams J. Injury in junior Australian Rules footballers. Journal of Science & Medicine in Sport. 2003;6(3):328 - 38.

4. Hodgson L, Standen P, Batt M. An analysis of injury rates after season change in rugby league. Clinical Journal of Sports Medicine. 2006;16(4):305 - 10.

5. Orchard J. Is there a relationship between ground and climatic conditions and injuries in football? Sports Medicine. 2002;32(7):419-32.

6. Takemura M, Schneiders A, Bell M, Milburn P. Association of ground hardness with injuries in rugby union. British Journal of Sports Medicine. 2007;41:582 - 7.

7. Milburn P, Barry E. Shoe-surface interaction and the reduction of injury in rugby union. Sports Medicine. 1998;25(5):319 - 27.

8. Norton K, Schwerdt S, Lange K. Evidence for the aetiology of injuries in Australian football. British Journal of Sports Medicine. 2001;35:418 - 23.

9. McMahon K, Nolan T, Bennett C, Carlin J. Australian Rules football injuries in children and adolescents. The Medical Journal of Australia. 1993;159:301 - 6.

10. Andresen BL, Hoffman MD, Barton LW. High school football injuries: field conditions and other factors. Wisconsin Medical Journal. 1989;88(10):28.

11. Scranton PE, Whitesel JP, Powell JW, Dormer SG, Heidt RJ, Losse G, et al. A review of selected noncontact anterior cruciate ligament injuries in the National Football League. Foot & Ankle International. 1997;18(12):772 - 6.

12. Davidson RM. Schoolboy rugby injuries, 1969-1986. The Medical Journal of Australia. 1987;147:119-20.

13. Gabbett T, Minbashian A, Finch C. Influence of environmental and ground conditions on injury risk in rugby league. Journal of Science and Medicine in Sport. 2007;10:211 - 8.

14. Lee A, Garraway W. The influence of environmental factors on rugby football injuries. Journal of Sports Science. 2000;18 91 - 5.

15. Orchard J, Seward H, McGivern J. Intrinsic and extrinsic risk factors for anterior cruciate ligament injury in Australian footballers. American Journal of Sports Medicine. 2001;29(2):196 - 200.

16. Phillips L, Standen P, Batt M. Effects of seasonal change in rugby league on the incidence of injury. British Journal of Sports Medicine. 1998;32:144 - 8.

17. Wilson F, Caffrey S, King E, Casey K, Gissane C. A 6-month prospective study of injury in Gaelic football. British Journal of Sports Medicine. 2007;41:317 - 21.

18. Stevenson M, Hamer P, Finch C, Elliott B, Kresnow M. Sport, age, and sex specific incidence of sports injuries in Western Australia. British Journal of Sports Medicine. 2000;34:188 - 94.

19. McManus A, Stevenson M, Finch CF, Elliott B, Hamer P, Lower A, et al. Incidence and risk factors for injury in non-elite Australian Football. Journal of Science and Medicine in Sport. 2004 Sep;7(3):384 - 91.

20. Orchard J. Intrinsic and extrinsic risk factors for muscle strains in Australian football. American Journal of Sports Medicine. 2001;29(3):300 - 3.

21. Lush WM. Objective assessment of turf cricket pitches using an impact hammer. Journal of the Sports Turf Research Institute. 1985;61:71 - 9.

22. Rogers J, Waddington DV. Portable apparatus for assessing impact characteristics of athletic field surfaces. In: Schmidt R, Hoerner E, Milner E, Morehouse CA, editors. Natural and artificial playing fields characteristics and safety features, ASTM STP 1073. Philadelphia: American Society for Testing and Materials; 1990. p. 96 - 110.

23. Baker SW, Canaway PM. Concepts of playing quality: criteria and measurement. International Turfgrass Society Research Journal. 1993;7:172-81.

24. Aldous D, Chivers I, Kerr R. Player perceptions of Australian Football league grass surfaces. International Turfgrass Society Research Journal. 2005;10:1-9.

25. Finch C, Lloyd D, Elliott B. The Preventing Australian Football Injuries with Exercise (PAFIX) Study: a group randomised controlled trial Injury Prevention. 2009;5(e1).

26. Twomey D, Finch C, Doyle T, Elliott B, Lloyd D. Level of agreement between field-based data collectors in a large scale injury prevention randomised controlled trial. Journal of Science and Medicine in Sport. 2010;In Press.

27. Swan P, Otago L, Finch C, Payne W. The policies and practices of sports governing bodies in relation to assessing the safety of sports grounds. Journal of Science & Medicine in Sport. 2009;12:171 - 6.

28. Orchard J. The AFL penetrometer study: work in progress. Journal of Science and Medicine in Sport. 2001;4(2):220 - 32.

29. Clegg B, editor. An Impact Testing Device for In-Situ Base Course Evaluation. Proceedings of the 8th Australian Road Research Board Conference; 1976.

30. Evaluation of playing surface characteristics of various in-filled systems. [database on the Internet]. PennState, Department of Crop and Soil Sciences

2006 [cited. Available from: http://cropsoil.psu.edu/mcnitt/infill7a.cfm.

31. Chivers I, Aldous D. Performance monitoring of grassed playing surfaces for Australian Rules football. Journal of Turfgrass and Sports Surface Science. 2004;70:73 - 80.

32. Murray D. Design and analysis of group-randomized trials. New York: Oxford University Press; 1998.

33. Herricks J, Jones T. A dynamic cone penetrometer for measuring soil penetration resistance. Soil Sci Soc Am J. 2002;66:1320 - 4.

34. Twomey D, Otago L, Saunders N, Schwarz E. Development of standards for the use of artificial turf for Australian football and cricket. Ballarat: University of Ballarat; 2008 Contract No.: Document Number|.

35. Braham R, Finch C, McIntosh A, McCrory P. Community level Australian football: a profile of injuries. Journal of Science and Medicine in Sport. 2004;7(1):96 - 105.

36. Gabbe B, Finch C, Wajswelner H, Bennell K. Australian football: injury profile at the community level. Journal of Science and Medicine in Sport. 2002 Jun;5(2):149-60.

37. Fuller CW, Dick RW, Corlette J, Schmalz R. Comparison of the incidence, nature and cause of injuries sustained on grass and new generation artificial turf by male and female football players. Part 1: match injuries. British Journal of Sports Medicine. 2007 August 1, 2007;41(suppl_1):i20-6.

38. Mohan D, Bowman B, Snyder R. A biomechanical analysis of head injury impacts to children. Journal of Biomechanical Engineering. 1979;101:250 - 60.

39. Laforest S, Robitaille Y, Lesage D, Dorval D. Surface characteristics, equipment height, and the occurrence and severity of playground injuries. Injury Prevention. 2001;7(1):35-40.

40. Wisbey B, Montgomery, Pyne D, Rattray B. Quantifying movement demands of AFL football using GPS tracking. Journal of Science & Medicine in Sport. 2009;In Press, doi:10.1016/j.jsams.2009.09.002

Figure Caption

Figure 1: Schematic of the nine locations tested on each ground.
Note: The four lines at either end represent the goal posts and the square in the centre represents the centre square. With the exception of location 5, which is in the centre square, all other locations are mirror images of each other representing certain key playing positions in AF. Locations 1 & 9 are at the edge of the goal squares denoting full back and full forward positions, locations 2 & 6 represent left half back and left half forward positions respectively, locations 3 & 7 represent centre half back and centre half forward positions and locations 4 & 8 denote right half back and right half forward positions.