Measurement of Football Ground Hardness using the Racetrack Penetrometer

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Objective

To develop an objective and reliable method for measuring surface hardness for grounds in the Australian Football League (AFL) that may be able to assess ground risk for Anterior Cruciate Ligament (ACL) injury.

Setting

The AFL is the premier competition of Australia's most popular sport, played in cities across Australia on natural grass fields. Anterior cruciate ligament injuries are amongst the most prevalent and costly injuries in the AFL (Orchard et al., 1998). Recent study has shown that high water evaporation (RR 3.03, 95% CI 1.52-6.03) and low rainfall (RR 1.93, 95% CI 1.12-5.10) significantly increase the risk of non-contact ACL injury in the AFL (Orchard et al., 1999). As a consequence of higher evaporation, games played in cities to the north of Melbourne (see figure 1) have a higher rate of ACL injury than those played in Melbourne or to the south (p <0.001).

Although the weather patterns are not reversible, it is likely that the basis for this relationship is in modification of the condition of the playing surface (turf), which can be altered. There is a need to develop easy and portable methods for measurement of ground conditions such as hardness and traction. If hardness and/or traction have a direct relationship with ACL risk, then grounds can be prepared differently to lower this risk for football games played on natural grass.

The Penetrometer is an internationally used instrument to measure the hardness of horse racetracks which is objective, reliable and which correlates with race times (Neylan et al., 1998). It measures depth of penetration of a shaft into the turf after dropping a weight from a set height. Other devices, such as the Clegg hammer, measure hardness by deceleration of a weight (Clegg, 1976) but are more expensive than Penetrometers (US$2500 versus US$600).

Figure 1. Cities in Australia (location of match venues)

Figure 2. The author with a Penetrometer

Method

Nine penetrometers (Gill Engineering, Melbourne), as seen in figure 2, were obtained for the major AFL venues around Australia. Readings were made on the morning of games during the 1997 and 1998 seasons. Penetrometer readings were measured in centimetres as an average of three drops at twenty different locations spread evenly around the playing field (figure 3). Daily weather variables (rainfall and evaporation) were obtained by the Bureau of Meteorology at central locations in each city studied.

Position	Location on ground	1st	2nd	3rd
1	R back pocket (20m diagonally out from point post)	3.1	4.7	6.3
2	Full back (just outside front of square)	2.5	3.9	5.5
3	L back pocket (20m diagonally out from point post)	2.6	3.9	5.1
4	L half back (15m diagonally away from corner of	2.3	3.7	4.8
5	10m diagonally inside corner of centre square (L back)	1.1	1.7	2.5
6	CHB (½way between 50m line & centre square)	1.4	2.4	3.1
7	10m diagonally inside corner of centre square (R	1.6	2.5	3.4
8	R half back (15m diagonally away from corner of	2.6	4.5	6.4
9	R wing (30m from square on centre line)	1.7	2.9	4.0
10	2m outside centre circle (R back side)	0.9	1.6	2.3
11	Inside centre circle	0.7	1.2	1.8
12	L wing (30m from square on centre line)	3.4	6.0	7.8
13	L half forward (15m diagonally from corner of square)	2.5	4.1	5.6
14	10m diagonally inside corner of centre square (L	2.4	3.7	4.8
15	CHF (½way between 50m line & centre square)	2.1	3.7	4.9
16	10m diagonally inside corner of centre square (R	2.4	3.8	4.8
17	R half forward (15m diagonally from corner of square)	2.0	3.6	4.9
18	R forward pocket (20m diagonally out from point post)	3.0	4.9	6.6
19	Full forward (5m outside front of square)	2.3	3.7	5.1
20	L forward pocket (20m diagonally out from point post)	3.1	5.4	7.4
	Averages	2.185	3.595	4.855
	Final reading		3.5	

Figure 3. Sample recording sheet for Penetrometer readings

Results

There were 168 matches (at 9 venues in 6 cities) where Penetrometer readings were taken and preceding rainfall and evaporation measures were available. The average Penetrometer reading was 4.7 cm (range 2.9-6.3). A higher reading (greater penetration of the weight) indicates a softer playing surface.

Composite rainfall and evaporation variables were created (measuring the totals for the previous 7, 14, 18, 90 and 365 days).

A multiple regression model was created with the Penetrometer reading as the dependant variable. Using composite rainfall and evaporation variables a significant (P<0.0001) regression equation was developed:

Penetrometer reading (cm) = 5.677 - 0.000742*(**365-day evaporation**) + 0.00352*(**14-day rainfall**).

In this equation the t values with 165 degrees of freedom were -7.493 for 365-day evaporation (P<0.0001) and 3.763 for 14-day rainfall (P=0.0002).

An alternative equation using a rainfall deficit (evaporation - rainfall) composite variable was also significant (P<0.0001):

Penetrometer reading (cm) = 5.639 - 0.000637*(**365-day evaporation**) - 0.00343*(**14-day evaporation - rainfall**).

Discussion

Previous study has found that 365-day rainfall and 28-day evaporation are significant risk factors for ACL injury in Australian Football (Orchard et al., 1999).

This study has found that 365-day evaporation and 14-day rainfall correlate highly (p<0.0001) with ground hardness as measured by the penetrometer.

These two studies show an association between ground hardness and risk of ACL injury. This may be either because hardness is a direct risk factor for injury or because it correlates highly with a confounding factor (such as traction) which is a risk for injury. As the weather variables that predict ACL risk and ground hardness are not exactly the same, it is likely that other surface-related factors are implicated in the risk of ACL injury.

Hardness of natural turf is mainly controlled by moisture content whereas traction is related more to grass cover (Baker, 1991). Hardness does correlate positively and significantly with traction on natural turf (Bell et al., 1988).

Boots with more numerous and prominent cleats, providing greater traction, have been associated with an increase in the risk of ACL injury in American football (Lambson et al., 1996). A preliminary analysis of weather and ground conditions associated with ACL injuries in the NFL suggested that more injuries occur on dry natural turf than in wet or frozen conditions (Scranton et al., 1997). This study did not control for games where there was no injury.

Changing ground conditions, whilst more costly than changing boot types, is more likely to be accepted by football players, as boots which have lower traction (and hence lower injury risk) are most likely to be detrimental to the individual's grip (and performance).

Grass type and length relate to both traction and weather conditions. Couch (bermuda) grass (cynodon dactylon) is a species which does not grow well in climates with low sunshine (evaporation) and provides high surface traction. It may be a higher risk for ACL injury than rye grass (lolium), which grows better in conditions of lower sun exposure, but provides a more slippery playing surface.

Sowing grasses with less traction, increased watering during times of low rainfall and covering turf from sun exposure during times of high evaporation are all interventions likely to lower the risk of ACL injury in football on natural grass.

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