EVOLUTION OF NATURAL GRASS PLAYING SURFACES FOR ELITE FOOTBALL

– Written by Athol Thomson, Qatar and David Rennie, United Kingdom

Technical and physical performance parameters in elite football (soccer) have increased significantly in recent years. Players now complete more passes per match, perform more explosive sprints and cover greater running distances than ever before[1].

One factor that has contributed to such a rapid evolution in the game could be advances made in the preparation and maintenance of natural grass playing surfaces. Rain-soaked muddy clay or native soil-based pitches of the past have been superseded with sand-based pitches, reinforced by artificial fibres, overlying gravel drainage systems.

The outcome – more consistent mechanical properties for player-surface interaction (traction and energy/shock absorption) and ball-surface interaction (ball bounce and roll), that are less affected by weather conditions or climate[2].

Where in years past we might have seen the spectacle being lessened by a poor quality pitch, now we are much more likely to see pristine playing surfaces whatever the climatic conditions. This is great as a spectator, but is it so great as a player? While we might love to see Cesc Fabregas dance through opposition midfields on a wet November afternoon in London, there are concerns that these changes to the mechanical properties at the shoe-surface interface may be putting players at increased risk of lower extremity injury[3,4].

In this article we highlight innovations in natural grass playing surface construction for elite football and introduce the main mechanical measurements used to quantify playing surface properties.

PLAYER-SURFACE INTERACTION

Before we examine the playing surface itself we need to understand how players interact with the pitch. Players adjust their leg stiffness, movement strategies and style of play according to the surface they interact with through the shoes on their

Figure 1: Example of a common hybrid method. Polypropylene fibres (dark green) are inserted 200 mm deep into a sand-based rootzone of a natural grass playing surface to provide shear stability and durability.

feet. Extremes in traction (too low/high) or surface compliance (too soft/hard) incur biomechanical adjustments by the player that may directly increase the risk of lower extremity injury – via high traction at the shoe-surface interface[5] for example, or indirectly through fatigue, which may be affected by surface compliance or energy absorption[6].

MODERN-DAY NATURAL GRASS PITCHES ARE SAND-BASED

Essentially, natural grass (NG) pitches consist of a living grass plant anchored, via its root structure, to a soil matrix below. The pitch needs light, nutrients and water to thrive[2].

Historically, clay or silt native soils have been used, however they are susceptible to damage when moisture levels rise. Increasingly, sand-based soils are becoming the sub-soil of choice, predominantly due to far superior drainage capabilities and increased shear strength. In general, the shear strength of sand is less sensitive to increases in water than clay or native soil. Hence, the absence of muddy swamp-like pitches of yesteryear in elite football. But there is a trade-off: sand-based pitches require more intensive maintenance practices like watering and nutrient delivery and this costs money[7], futhermore, sand-based construction can become more compacted and result in much harder NG surfaces when compared to clay or native soil.

HYBRID PLAYING SURFACES

Perhaps the most profound innovation in NG playing surface preparation is the reinforcement of natural grass with artificial fibres (hybrid pitches). In a common hybrid method used in English Premier League and European football, a large portable sewing machine stitches polypropylene fibres 200 mm deep into the rootzone of NG surfaces to provide an anchor that the NG roots grow around (Figure 1). This reinforcement at the rootzone provides shear stability which can enable the player to generate large horizontal forces associated with sprinting and changes in direction, without failure of the surface. Above ground, the synthetic fibres sit just below the mowing height of the natural grass to provide support and improve durability[7].

Other hybrid methods for NG surfaces may have 100% natural grass on the surface, anchored to an artificial rootzone with no artificial fibres protruding above ground. Granulated cork and synthetic microfibers are added to the rootzone along with extra-fine silica sand. The granulated cork may help provide increased shock absorption and energy return (energy restitution) when loaded by the player – and this may improve metabolic efficiency and decrease the effects of fatigue[6].

Yet, while there are mechanical or laboratory studies that have measured the mechanical properties of hybrid pitches, to date there are no prospective studies that have measured mechanical properties and examined any relationship to lower extremity injury in football[8].

INNOVATION IN MAINTENANCE

There are a number of innovative practices that have emerged recently with regard to elite football surface maintenance. Full grass coverage and uniform playing surface characteristics such as ground hardness and rotational resistance (rotational traction) are paramount to optimal player-surface and ball-surface interaction. Ground-staff work to keep these characteristics consistent both within a single pitch and across a season.

Artificial lighting systems are an emerging technology that are now commonly used in elite football stadia around the world to augment natural light

Images Top: FIFA-approved studded disc apparatus used to measure rotational resistance (traction) via a two-handled torque wrench.

Image Bottom: Artificial lighting systems are used to augment natural light exposure to the grass plant to ensure grass coverage.

exposure to the natural turf plant. These systems ensure uniform coverage of NG in all areas of the pitch. This is an important innovation as stadia with large stands or those with closed roof designs may limit the exposure of the playing surface to sunlight, thereby making it difficult to ensure grass growth[2].

If a pitch does not have hybrid reinforcement, the ground staff often use different species of NG at specific times of the year to ensure 100% grass coverage. Different grass species and soil constituents affect the traction properties of the playing surface and have been implicated in risk of lower limb injury in other sports such as Australian rules football[9]. Playing surfaces used for elite football (training and matches) in Doha, Qatar use warm-season varieties of grass (Cynodon dactylon, 'Bermuda' or Paspalum vaginatum, 'Paspalum') over the summer months as these species can cope with the hot summers experienced in the Middle East. However, in winter these grasses become dormant as the temperature drops and another grass variety is over-sown (Lolium prenne, 'perennial rye') to ensure uniform grass coverage.

Perhaps one somewhat worrying development in elite football stadia is the addition of artificial turf around the perimeter of the NG pitch. This artificial surface will often have vastly different mechanical properties to the main pitch and may be viewed as a hazard to players. During the course of the game, players frequently have to step off, or on occasion are forced from the field by opponents onto this artificial perimeter. Players may be unaware of or have little time to react to such changes in surface as they are concentrated on the game at hand and not where they are stepping. Season-ending injuries have occurred in both soccer and Australian rules football in this manner.

MECHANICAL PROPERTIES OF NATURAL GRASS SURFACES

Optimal performance and/or risk of injury may be associated with certain playing surface and footwear characteristics. Higher traction at the shoe-surface interface is associated with 2.5 times higher risk of lower extremity injury in American football[8]. At present, it is unknown if this relationship extends to non-contact lower extremity injury in elite soccer.

Running on NG in football boots increases ground reaction force, vertical loading rate and total foot peak plantar pressures when compared to running shoes[10,11]. This increase in load may play a role in the high prevalence of lower extremity injuries in soccer[12].

It is therefore important to understand the subtle variations in grass species, hybrid methods, soil constituents, rootzone density and soil moisture present in NG playing surfaces and how these properties may influence resultant traction and ground reaction forces and hence injury risk for the player[8].

"MEASURE WHAT IS MEASURABLE AND MAKE MEASURABLE WHAT IS NOT SO" – GALILEO

One way to measure some of the important characteristics of the pitch is by using portable testing devices. These devices allow routine objective measurement of surface parameters including traction (grip) and surface hardness (energy absorption). Although these devices do not provide an accurate representation of forces experienced by players when they are actually playing sport, they do allow tracking of surface properties over time and between different surfaces. This means the ground staff can prepare surfaces with similar characteristics (e.g. training ground and match/stadium surfaces at the same club) (Table 1).

When testing different surfaces, ground staff are interested in the answers to three simple questions[2]:

1. Is the surface too hard or too soft?

Table 1

Measurement	Criteria	Unit
Shock absorption (FR)	*60-70*	*%*
Vertical deformation (VD)	*4-10*	*mm*
Energy restitution (ER)	*20-50*	*%*
Moisture percentage in the soil	*30-40*	*%*
Soil temperature	*Grass-dependent*	*C*
Temperature above the pitch	*Player-dependent*	*C*
Humidity	*Player-dependent*	*C*
Top layer compaction	*150-250*	*N/cm2*
Ball roll	*4-10*	*m*
Vertical ball rebound	*0.5-1.0*	*m*
Rotational resistance	*25-50*	*Nm*
Rooting	*More than 100*	*mm*
Thatch	*0-10*	*mm*
Grass density/coverage	*90-98*	*%*
Grass length	*18-25*	*mm*

Table 1: Example of surface/weather properties that can be measured and made available to medical staff. This data along with individual perceived ratings of surface traction obtained by running a functional traction course[20] may help guide the footwear selection for players to best fit into a so-called 'optimal zone' of traction and hardness at the shoe-surface interface.

2. Is there adequate but not excessive traction at the shoe-surface interface?
3. Is ball-surface interaction suitable?

We will concentrate on the player-surface measurements in which it is suggested that an optimal zone of traction and surface hardness may exist to optimise performance and reduce injury risk[13].

ROTATIONAL TRACTION

An important measurement is rotational traction (RT), which has been associated with increased injury risk in other codes of football[8,9]. RT is a measure of the rotational force required to release the studs through the playing surface in a rotational manner, sometimes known as rotational resistance. FIFA have recommended guidelines for the amount of rotational resistance required for an elite football playing surface. However, such recommendations were developed to compare artificial surfaces to NG surfaces which is somewhat over-simplistic given the huge variation within these types of playing surfaces.

The FIFA approved device – known as a studded disc apparatus – weighs 46 kg and is dropped from a set height so the studs penetrate the surface. The device is rotated via a two-handled torque wrench that records the peak RT.

However, it must be remembered that the properties of both the playing surface and the footwear used by the player affect the RT. Therefore, the studded disc can only help compare different surfaces or consistency across the same surface at different areas on the pitch, rather than give an indication of true shoe-surface interaction[14].

ROTATIONAL TRACTION ON HYBRID PITCHES

The rotational torque of a hybrid pitch (Desso GrassMaster 7% polyethylene, 93% natural grass) is similar to rotational torque measured on a natural grass pitch (75% perenial Rye, 25% Kentucky or Bermuda) when measured with a custom-built device in which different soccer footwear could be placed. Bladed boots have higher RT than moulded studs on NG and hybrid surfaces[15]. Of particular interest is that RT measured on the hybrid pitch changed only minimally when tested under dry or wet conditions and, as such, hybrid was considered the most stable surface tested.

The similarity in rotational torque between hybrid and natural grass pitches, regardless of weather conditions, is important because players often use football shoes with higher traction (longer studs which are fewer in number) on wet days to improve traction and avoid the chance of slipping. This may however be unnecessary and even increase the risk of injury, if the shoe-surface combination causes increased RT on the hybrid surface.

Optimum penetration of the stud into the surface is paramount in achieving the maximum traction (which is beneficial to performance) and reducing plantar pressure points on the foot[16]. Surface hardness therefore affects traction and comfort for the player depending on the type of shoe outsoles used.

SURFACE HARDNESS (ENERGY ABSORPTION)

Football is a game which extends across all climatic seasons; it is therefore not surprising that the surface hardness of NG pitches can vary greatly in relation to the prevailing climatic conditions. Such variability in pitch hardness can affect both the individual player (injury risk/player load) and the game itself (bounce/roll of the ball). In an attempt to minimise such variation, Pitch Quality Standards have been proposed to enhance the management, safety and performance of NG pitches. To guide and improve NG standards necessitated

objectivity in measuring surface hardness. Consequently, devices such as the going stick and penetrometer have been used in sports but generally speaking within football, the most pragmatic, and well-used, in both research and maintenance is the Clegg Impact Soil Tester[17]. The device consists of a 2.25 kg cylindrical missile containing an accelerometer. The missile is dropped down a guide tube from a pre-determined height of 0.45 m onto the surface and impact hardness is quantified by the peak deceleration (g) of the missile on impact.

While the readings from the Clegg Impact Soil Tester are not reflective of the impact forces of a player, it permits objective analysis of surface hardness which has been found to be both reliable and valid[18]. More practically, it does not adversely affect the surface of the pitch and as such can be used to evaluate the surface hardness prior to any training session or match.

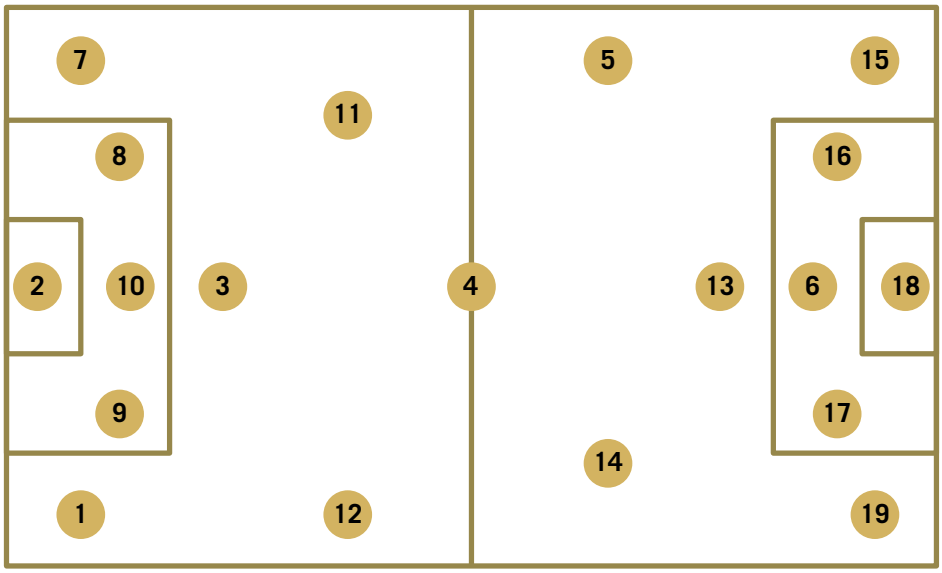

Figure 3: Measurements are taken at 19 different areas across the same pitch[2].

Images: Clegg Impact Soil Tester (2.25 kg) being used to assess pitch hardness prior to a match.

SURFACE HARDNESS ON HYBRID PITCHES

The characteristics of NG pitches throughout the English Football League is non-uniform with a higher proportion of the 'hybrid' Desso Grassmaster pitches in the English Premier League, in comparison to the sand/soil mix often found in the lower leagues. Whether driven through the aesthetic requirements of television coverage or an attempt to minimise variation in performance and playability, NG pitches have evolved into robust and reliable surfaces which are capable of withstanding increased footfall, and adverse climatic variation, while providing a uniform and reliable surface on which to play the game. Today's modern hybrid pitches such as the Desso Grassmaster and Fibresand, do promote a more consistent hardness over the season in comparison to native soil pitches[3]. However, it is also worth noting that variability in hardness between Desso Grassmaster and Fibresand pitches also exists[3]. This is an important finding, as the relative expense of a Desso Grassmaster pitch may preclude teams installing it at both their stadium and their training ground. As a result, players may train and play on two mechanically different surfaces, where the training ground demonstrates more variability in both hardness and traction than that of their home stadium – a factor which may be viewed as detrimental to their preparation, performance and risk of injury. Physiotherapists, sports scientists and coaches need to understand that variations in pitch hardness may adversely affect workload of their players making them susceptible to either poor performance or injury[6,19].

What is becoming clearer is the role ground staff play in the development and maintenance of NG pitches, which is central to the way the game is evolving. Harder surfaces are mirrored by increased game speed today in the Premier League, however, what remains unclear are the effects that such increases in pitch hardness may have on a player's relative risk of injury.

Acknowledgements: the authors would like to thank Wayne Holmes, Head of Turf Management at Aspire Logistics, and John Ledwidge, Grounds Manager at Leicester City Football Club.

Practical Implications

- *The authors suggest ongoing contact with experienced ground staff to understand the nuances of NG playing surfaces which may change over the course of the season or even within the same pitch.*
- *Objective measurements of the playing surface mechanical properties in conjunction with subjective ratings from the player after running a functional traction course[20] may help guide footwear selection for a given playing surface.*
- *Researchers need to explore the link between pitch hardness/traction and injury in professional football.*

References

1. *Barnes C, Archer DT, Hogg B, Bush M, Bradley PS. The evolution of physical and technical performance parameters in the English Premier League. Int J Sports Med 2014; 35:1095-100.*
2. *Dixon S, Fleming P, James I, Carré MJ. The science and engineering of sport surfaces. Routledge Research in Sports Technology and Engineering 2015.*
3. *Caple M, James I, Bartlett M. Mechanical behaviour of natural turf sports pitches across a season. Sports Engineering 2012; 15:129-141.*
4. *Davidson M. Paying the price for the beautiful game. The Telegraph (London). 2015. Available from: http://www.telegraph.co.uk/sport/football/11997637/Paying-the-price-for-the-beautiful-game.html Accessed August 2016.*
5. *Dowling AV, Corazza S, Chaudhari AM, Andriacchi TP. Shoe-surface friction influences movement strategies during a sidestep cutting task implications for anterior cruciate ligament injury risk. Am J Sports Med 2010; 38:478-485.*
6. *Rennie DJ, Vanrenterghem J, Littlewood M, Drust B. Can the natural turf pitch be viewed as a risk factor for injury within Association Football? J Sci Med Sport 2016; 19:547-552.*
7. *James IT. Advancing natural turf to meet tomorrow's challenges. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology 2011:1754337111400789.*
8. *Thomson A, Whiteley R, Bleakley C. Higher shoe-surface interaction is associated with doubling of lower extremity injury risk in football codes: A systematic review and meta- analysis. Br J Sports Med 2015; 49:1245-1252.*
9. *Orchard JW, Chivers I, Aldous D, Bennell K, Seward H. Rye grass is associated with fewer non-contact anterior cruciate ligament injuries than bermuda grass. Br J Sports Med 2005; 39:704-709.*
10. *Smith N, Dyson R, Janaway L. Ground reaction force measures when running in soccer boots and soccer training shoes on a natural turf surface. Sports Engineering 2004; 7159-7167.*
11. *Ford KR, Manson NA, Evans BJ, Myer GD, Gwin RC, Heidt RS et al. Comparison of in-shoe foot loading patterns on natural grass and synthetic turf. J Sci Med Sport 2006; 9:433-440.*
12. *Nigg BM, Ekstrand J. Surface-related injuries in soccer. Sports Med 1989; 8:56-62.*
13. *Nigg BM, Segesser B. The influence of playing surfaces on the load on the locomotor system and on football and tennis injuries. Sports Med 1988; 5:375-385.*
14. *Twomey DM, Connell M, Petrass L, Otago L. The effect of stud configuration on rotational traction using the studded boot apparatus. Sports Engineering 2013; 16:21-27.*
15. *Smeets K, Jacobs P, Hertogs R, Luyckx JP, Innocenti B, Corten K et al. Torsional injuries of the lower limb: An analysis of the frictional torque between different types of football turf and the shoe outsole. Br J Sports Med 2012; 46:1078-1083.*
16. *Kirk RF, Noble ISG, Mitchell T, Rolf C, Haake SJ, Carré MJ. High-speed observations of football-boot-surface interactions of players in their natural environment. Sports Engineering 2007; 10:129-144.*
17. *Clegg B. An impact testing device for in situ base course evaluation. 8th ARRB Conference; 1976; Perth, Australia; 8:1-6*
18. *Twomey DM, Otago L, Ullah S. Reliability of equipment for measuring the ground hardness and traction. Proc Inst Mech Eng, J Sports Eng Technol 2011; 225:131-137.*
19. *Stiles VH, James IT, Dixon SJ, Guisasola IN. Natural turf surfaces: the case for continued research. Sports Med 2009; 39:65-84.*
20. *Sterzing T, Müller C, Hennig EM, Milani TL. Actual and perceived running performance in soccer shoes: A series of eight studies. Footwear Science 2009; 1:5-17.*

Athol Thomson B.Biomed.Sci., B.App.Sci.
Sports Podiatrist
Research Scientist
Aspetar – Orthopaedic and Sports Medicine Hospital
Doha, Qatar

David Rennie B.Sc. (Hons) Physiotherapy, B.Sc. (Hons) Sports Science and Psychology
Head Physiotherapist
Leicester City Football Club
Leicester, United Kingdom

Contact: Athol.thomson@aspetar.com