THE INFLUENCE OF NATURAL GRASS PITCH HARDNESS ON SOCCER PERFORMANCE AND GAME CHARACTERISTICS

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Introduction: Traditional natural grass pitches are the most prevalent surface at amateur-level soccer. Environmental considerations such as the climate, weather, grass coverage and seasonal variations all have an impact on the natural grass characteristics and affect performance of both player and surface. A key natural grass pitch variable that may influence the performance characteristics is the surface hardness. Therefore, the aim of the project was to examine the influence of natural grass surface hardness on amateur-level soccer performance and game characteristics via a mixed-method, multidisciplinary approach. **Methods**: Four separate studies were carried out, consisting of one performance analysis case study, two experimental studies and one focus group. In the first study, one academy-level (amateur) u-19 soccer player played in eleven competitive matches on soft and hard natural grass pitches. In the second study, ten academy-level (amateur) College soccer players completed a repeated sprint protocol of 40-m performed on two natural grass pitches of contrasting surface hardness. In the third study, performance, biomechanical and physiological responses were assessed during steady state running and an 84-minute soccer simulation protocol on soft vs. hard natural grass pitches. In studies one-to-three surface hardness was measured using a Clegg Impact Hammer and pitches were categorised into either hard or soft. In study four, four participants answered nine open-ended questions in a focus group covering four main areas including the technical, tactical, physical and psychological concepts of playing and coaching soccer on natural grass pitches with contrasting surface hardness. **Results:** In study one there were more turns on the soft vs. hard pitches (effect size; Cohen's d) (i.e., sharp right ($d = 1.4$; $P<0.05$), sharp left ($d = 0.2$; $P>0.05$), smooth ($d = 0.5$; $P>0.05$), V-cut ($d = 0.7$; $P>0.05$), moderate intensity ($d = 0.8$; $P>0.05$), and high intensity ($d = 0.1$; $P>0.05$)), although there were slightly more linear turns on hard vs. soft pitches ($d = 0.1$; $P>0.05$). There was a trend for more movements on soft vs. hard pitches (i.e., high intensity shuffling ($d = 1.7$; $P>0.05$), running ($d = 1.1$; $P>0.05$), low ($d = 1.1$; $P>0.05$), and high intensity activities ($d = 1.2$; $P>0.05$)). In study two there was a trend for faster repeated sprints ($d = 0.6$; $P>0.05$) on the hard vs. soft pitch (mean ± sd; 6.00 ± 0.42 s vs. 6.22 ± 0.33 s, respectively). There was a trend for a greater fatigue in sprint performance ($d = 0.8$; $P>0.05$) on the hard pitch vs. soft pitch (mean ± sd; 7.12 ± 2.28 % vs. 5.20 ± 2.43 %, respectively). In study three mean sprint ($d = 0.1$; $P>0.05$) and cutting times ($d = 0.1$; $P>0.05$) were not different between the two surfaces during the soccer simulation protocol. Mean turn times ($d = 1.4$; $P<0.05$) were faster on the soft vs. hard pitch (mean ± sd; 2.39 ± 0.04 s vs. 2.44 ± 0.09 s) during the soccer simulation protocol. Contact times were shorter during steady state jogging ($d = 1.1$; $P<0.05$) on the hard pitch (mean ± sd; 0.277 ± 0.018 s) vs. soft pitch (mean ± sd; 0.294 ± 0.012 s) and shorter during sprinting movements ($d = 1.0$; $P<0.05$) on the hard pitch (mean ± sd; 0.148 ± 0.007 s) vs. soft pitch (mean ± sd; 0.155 ± 0.007 s) implying that playing surface influenced the mechanics of jogging and sprinting. In study four players and coaches showed inconsistent views on the impact of surface hardness on soccer performance but showed a preference towards playing soccer on hard pitches because of less physical demand and better technical execution (game-related events), tactical options, movements (i.e., linear and turning movements) and improved execution of movements. **Conclusion:** This project illustrates that changes in natural grass surface hardness affects some factors which are important to

soccer performance. Players turn faster and more frequently on soft pitches. Contact times were shorter on hard pitches and there was a trend for faster sprints on the hard pitches during the repeated sprint and simulated soccer test. Physiological responses did not differ between surface which showed the players worked equally hard on both surfaces. Soccer players and coaches predominantly showed a preference towards playing soccer on hard pitches over soft pitches.

Key words: soccer, academy-level (amateur) soccer, movements, game-related activity, path changes, natural grass, soccer, surface hardness, repeated sprint ability, steady state activity, soccer simulation protocol, perceptions.

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Abbreviation:	Nomenclature:
FIFA	Fédération Internationale de Football Association
IFAB	International Football Association Board
IRB	International Rugby Board
CIH	Clegg Impact Hammer
AAA	Advanced Artificial Athlete
AA	Artificial Athlete
IOG	Institute of Groundsmanship
NGSH	Natural Grass Surface Hardness
NG	Natural Grass
NGP	Natural Grass Pitches
AT	Artificial Turf
ATP	Artificial Turf Pitches
FT	Football Turf
SH	Surface Hardness
SH_{MEAN}	Mean Surface Hardness
RSA	Repeated Sprint Ability
SSP	Soccer simulation protocol
SSA	Steady State Activity
S-AR	Speed-Agility Run
R	Recovery
PM	Purposeful Movements
Gmax	Gravitational Maximum
TD	Total Distance
LIR	Low Intensity Running
HIA	High Intensity Activity
LMIA	Low-Moderate Intensity Activity
COM	Centre of Mass
BW	Body Weight
BLa	Blood Lactate
RSATT	Repeated Sprint Ability Total Time
CT	Contact Time
FT	Flight Time
SL	Stride Length
SF	Stride Frequency
St	Stride Time
SwT	Swing Time
HRav	Heart Rate Average

HRpeak	Heart Rate Peak
VMEAN	Mean Velocity
SBR	Styrene-Butadiene-Rubber
GRF	Ground Reaction Force
3G	Third Generation Artificial Turf
2D	Two-Dimensional Space
3D	Three-Dimensional Space
S_H	Sward Height
P_S	Playing Season
SM	Summer Maintenance
PS	Playing Surface
sd.	Standard Deviation
FI	Fatigue Index
PI	Principle Investigator
Peak LR	Peak Rate of Loading
Peak IF	Peak Impact Force
HR	Heart Rate
HRav	Heart Rate Average
HRpeak	Heart Rate Peak
CV	Cardiovascular
ATP-PC	Adenosine Tri-Phosphocreatine
StD	Standard Deformation
FR	Force reduction
Fmax	Maximum Force
ER	Energy restitution
VD	Vertical Deformation
RT	Rotational traction
ES	Effect Size

UNITS OF MEASUREMENT AND SYMBOLS V1

Symbol:	Unit of Measurement:
%DS	Percentage Speed Decrement
%	Percentage
°	Degree
>	Greater Than
<	Less Than
±	Within a Range Around an Answer
≥	Greater Than or Equal to
≤	Less Than or Equal to
~	Approximately
ms	Millisecond
s	Second
min	Minute
h	Hour
d	Day
mm	Millimetre
cm	Centimetre
m	Metre
g	Gram
$m.s^{-1}$	Metres Per Second
$km.h^{-1}$	Kilometres Per Hour
$m.s^{-2}$	Metres Per Second Squared
$kg{\cdot}m{\cdot}s^{-2}$	Newton
m2	Square Metre
m3	Cubic Metre
BW/s	Body Weight Per Second
r/min	Revolutions Per Minute
$Beats{\cdot}min^{-1}$	Beats per minute

CHAPTER ONE. INTRODUCTION AND RESEARCH AIM

1.1.Introduction

Chapter one starts with a broad introduction of natural grass pitches (NGPs) in section 1.1.1. followed by the characteristics of the playing surface in section 1.1.2. and the demands of soccer in section 1.1.3. The justification, purpose, and multidisciplinary approach of the project are discussed in section 1.2. The latter part of chapter one addresses the aims, objectives, and status of the research project and concludes with the layout of the thesis in section 1.3.

1.1.1. Natural grass pitches

International interest in soccer has resulted in many research projects concerned with the internal and external factors, which influence the players' performance (Sanchez-Sanchez et al., 2014). Thus, physiological (Rampinini et al., 2007), physical (Rebelo et al., 2013), biomechanical (Ford et al., 2006), and psychological parameters (Greig et al., 2007) are examples of internal factors that influence a soccer players' performance (Sanchez-Sanchez et al., 2014). Many external factors such as the environmental temperature (Mohr et al., 2012), coaching style (Barić and Bucik, 2009), player and team cohesion (Lowther and Lane, 2002), and sports surfaces (Sanchez-Sanchez et al., 2014) can all affect a game. Hughes et al. (2013) found minor differences in the characteristics of soccer performance when the playing surface changed.

Soccer has been traditionally played on NGPs, especially at amateur-level but these surfaces are exposed to variable weather conditions that can accelerate wear and tear and negatively affect the performance of a player (Guisasola, 2008). Weather and seasonal conditions in the UK include long winter periods where grass growth is inhibited by low temperatures and a lack of light (Wingler and Hennessy, 2016). Natural grass (NG) is comprised of a mixture of air, soil, water, grass, and living organisms that varies considerably in time and location by weather conditions and the action of players (Guisasola, 2008).

NGPs are used throughout the world as a surface for team sports such as rugby codes, Gaelic sports, lacrosse, American football (Sport England, 2011), hockey, and soccer (Stiles et al., 2011). Soccer is the most popular sport worldwide with approximately 4% of the world population playing the game in some form equating to 265 million players (Haugen and Seiler, 2015). In the UK, 2.1 million adults play soccer on NG at least once a week (Statista, 2020). In soccer, environmental considerations such as the climate, weather, grass coverage, and seasonal variations all have an impact on the NG characteristics (Steffen et al., 2007; Stiles et al., 2009).

Irrespective of the level of soccer, the surface can affect the characteristics and outcome of a match (Capel, 2011). Authorities in soccer have strict guidelines for the quality of NGPs with the 'Performance Quality Standard' (PQS) devised and implemented by the Football Association (FA) to provide a recommended minimum and basic quality standard for the construction, upgrading, and maintenance of NGPs (table 1.1). To be suitable for competitive and recreational soccer activities (up to the Non-League pyramid – step 1), it is recommended that an NGP is flat, has a low-level weed coverage, adequate grass cover, and can drain water effectively (FA, 2004). Other than the PQS, there are currently no other standards NGPs (Fédération Internationale de Football (FIFA), 2010). Therefore, many NGPs at amateur-level may not meet the strict pitch guidelines regarding sward height (grass height), grass coverage, water infiltration rate, evenness, and slope highlighted in table 1.1. Despite such strict criteria associated with NGPs, before a match, the judgement on the suitability of the playing condition and surface is left to the discretion of the referee (Bell and Holmes, 1988; FIFA, 2013).

Most soccer competitions and training sessions are currently played on NG and artificial turf (AT) (Stiles et al., 2009) but NGPs are often of poor quality (Burillo, 2014). It remains questionable whether playing soccer on different types of the same surface (i.e., NG) compromises some playing characteristics of the game (Stiles et al., 2009). Over the past decade, interest has emerged on the variation of pitch surface and the influence it has on soccer performance (Potthast et al., 2010).

One important sports surface variable is surface hardness (SH), which has been defined as "the ability of a surface to absorb the impact energy created by any object striking that surface" (Rogers, 1988). Surface type and SH have been shown to influence sports performance in tennis (Fernandez et al., 2006), cricket (Baker et al., 2001), rugby (Fernando et al., 2015), and soccer (Andersson et al., 2008; Ronkainen et al., 2012). Playing surface (PS) has the potential to influence soccer performance (Kerdok, 2002) and SH represents one of the main soccer performance variables for surface-player interactions (FIFA, 2012). The movement of a player is influenced by the contact with the ground (Binnie et al., 2014) and it remains unclear how a soccer player's loading response during foot contact with the ground is affected when cushioning properties change with the season, temperature, and precipitation (Ford et al., 2006). Evidence suggests a hard playing surface with greater density reduces the cushioning of loads experienced by an athlete (Dixon et al., 2008; Low and Dixon, 2014).

Table 1.1: PQS recommendations for the construction and upgrade of NGPs (adopted from FA, 2004).

Element	Limits
Sward Height (mm)	20-60 P_S 20-75 SM
SH (Gmax)	25-200
Water Infiltration rate (mm/hr)	5
Evenness 2 m straight edge (mm)	<20
Slope (%) – direction of play Across play	<1.25 <2.5
Ground Coverage (%)	>70 for S_H 25-30 >80 for S_H 30-35

(Key: S_H = sward height (grass height); P_S = playing season; SM = summer maintenance)

1.1.2. Characteristics of playing surface

The term 'SH' in the present project indicates the resistance the surface has towards deformation (James, 2011). Subtle changes in surface characteristics may affect an athlete's force production (kinetic) and technique (kinematic), potentially disturbing their

technical skills during competition (Dixon et al., 2000). The level of traction and the surface's ability to absorb and return energy are important properties of any sports surface (Brosnan et al., 2009). The deformation and cushioning properties of a surface seem to have an impact on the stability of a surface and the subsequent movements performed, with players exhibiting more stability and control over their movements on harder surfaces (Nigg et al., 1988).

The evaluation of SH is often achieved (in research and by FIFA) using a Clegg Impact Hammer (CIH), which is a device that is easy to operate, portable, efficient, and cost-effective (Al-Amoudi et al., 2002). Sporting organisations continue deliberating on which type of playing surface is the best surface for performance (Gallardo et al., 2009). Elite-level soccer is often played on high quality, uniform NGPs where the ball behaviour is more predictable (Zamparo et al., 1992; Stiles et al., 2009). With lower amateur-level based soccer, the condition, deformation, and consistency of natural grass surface hardness (NGSH) may be more likely to adversely affect performance (Stiles et al., 2009) due to lack of maintenance and severe weather conditions.

1.1.3. The demands of soccer

The ergonomic interaction between a soccer player and playing surface is complex with more research needed to assess and quantify the influence of contrasting NGSH on human movement. Soccer performance demands physical, physiological, and psychological requirements, and the ability of a player is influenced by a multitude of variables depicted in figure 1.1 (adopted from Reilly, 2003, p.4).

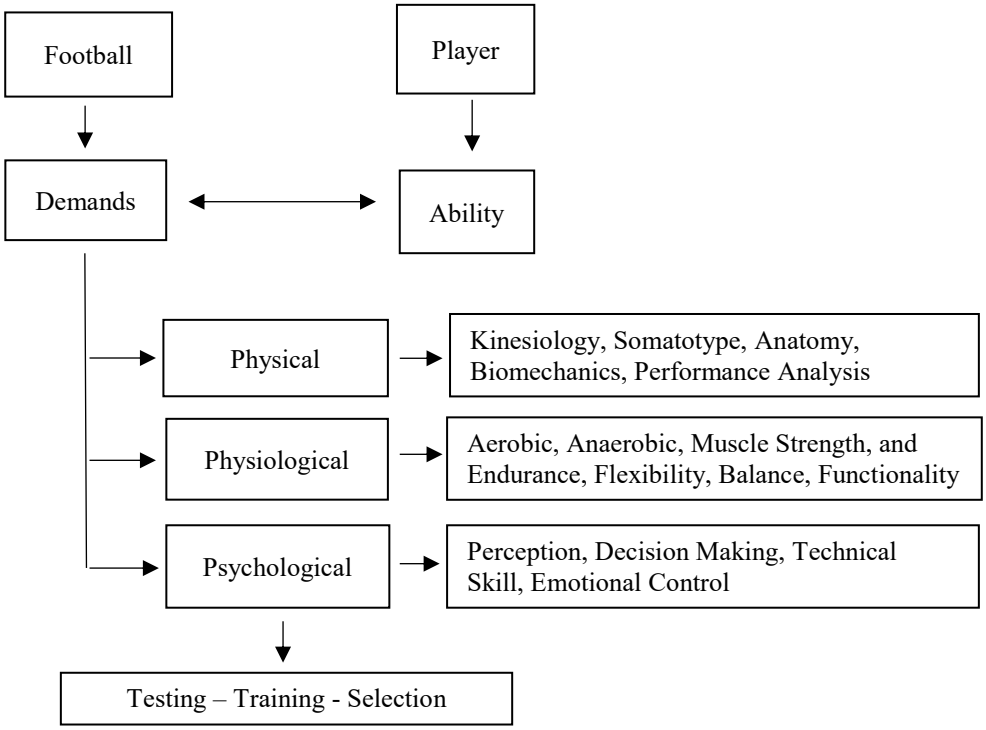


Figure 1.1: An ergonomic model of soccer participation (adopted from Reilly, 2003, p.4).

Soccer players are required to move in a high-intensity, intermittent fashion that includes multi-planar multiple-movements (Little and Williams, 2005). A soccer player must perform various game-related activities during training and match-play. A summary of the range of movements and game-related activity is illustrated in table 1.2. (Mohr et al., 2003; Bloomfield et al., 2004; Bloomfield et al., 2007; Andersson et al., 2008; Carling et al., 2008).

Table 1.2. The range of movements and game-related activities cited in time-motion analysis. (Mohr et al., 2003; Bloomfield et al., 2004; Bloomfield et al., 2007; Andersson et al., 2008; Carling et al., 2008).

Time - motion studies	Bloomfield et al. (2004)	Bloomfield et al. (2007)	Carling et al. (2008)	Mohr et al. (2003)	(Andersson et al. (2008)
Movements:					
Walking	✓	✓	✓	✓	✓
Standing	✓	✓	✓	✓	✓
Backward			✓	✓	
Backward Running			✓	✓	✓
Low-Intensity Running				✓	✓
Jogging	✓	✓	✓	✓	✓
Cruising			✓		
Moderate-Intensity Running				✓	✓
Running	✓	✓	✓	✓	
High-Intensity Running				✓	✓
Sprinting	✓	✓	✓	✓	✓
Skipping	✓	✓	✓		
Shuffle	✓	✓	✓		
Slow Down	✓	✓	✓		
Sideway Running			✓		
Change of Direction			✓		
Track Opponent			✓		
Alteration in pace			✓		
Execution of specific skills			✓		
Jump	✓	✓			
Land	✓	✓			
Slide	✓	✓			
Dive	✓	✓			
Get Up	✓	✓			
Fall	✓	✓			
Stop	✓	✓			
Impact	✓	✓			
Turn	✓	✓			
Swerve	✓	✓			
Game-related Activity:					
Pass	✓	✓			✓
Receive	✓	✓			✓
Dribble	✓	✓			
Crosses					✓
Free-kick					✓
Shots	✓	✓			✓
Shots on Target					✓
Goals Scored					✓
Trick	✓	✓			
Tackle	✓	✓			
Other	✓	✓			

1.2. Statement of purpose and justification of the project

1.2.1. Justification and purpose of the project

Elite soccer is often played on high quality uniform NGPs where ball behaviour is predictable whereas, amateur-level soccer is often played on low quality NGPs that vary considerably in terms of the mechanical and surface characteristics (i.e., consistency, deformation, condition and hardness) (Stiles et al., 2009). There are 8.2 million participants in the UK actively playing some form of the game (FA, 2015) and 2.1 million adults playing soccer on NG at least once a week (Statista, 2020). Soccer research is dominated but elite level soccer players and high quality uniform natural grass playing surfaces where the ball behaviour is predictable (Stiles et al., 2009). Reasons why NGPs are often noncompliant at amateur-level may be attributable to exposure to environmental (i.e., wind), climatic (i.e., temperature), grass coverage (i.e., sward density and height) and seasonal (i.e., summer and winter) factors changing significantly during a soccer season with little or no maintenance (et al., 2007; Stiles et al., 2009).

Soccer laws were amended in 2004 and the International Football Association Board (IFAB) introduced the FIFA Quality Concept for AT which developed the FIFA 1 and 2 Star recommended rating system (FIFA, 2010). This allowed for soccer training and competition to take place on AT as it offered a more congruent playing surface (Strutzenberger et al., 2014). AT pitches are a key aspect to amateur soccer and stringent standards must be met for the installation of AT pitches (FIFA, 2010). Research is striving to continuously improve the quality of AT (FIFA, 2010). The FIFA 1 and 2 star rating system is used to standardise AT pitches, but to what extent is that the case for NGPs and does variation in NGPs affect the characteristics of the game and the safety of the players. Soccer authorities and soccer coaches should be concerned with preserving the nature of the game and not endangering players. They seem actively concerned about this regarding AT pitches but is there reason to be equally concerned with NGPs.

The project aimed to determine the surface hardness of the NGPs used in amateur-level soccer which relates to category 1 in the PQSs (compliance and minimum standards). The project aimed to assess the spatial (pitch) variation of the NGPs used in amateur-level soccer which is associated with category 2 in the PQSs where the focus is to assess the overall quality across different tiers of sport. The project did aim to compare surface hardness data to accepted and recommended minimum standards for soccer in general, but did not compare data back to elite level pitch data. The project aimed to inform management interventions (construction and maintenance) by assessing surface hardness data of NGPs used for new grass pitch construction and the improvement of existing natural grass pitches. Despite not looking directly at category 4 of the PQSs (to inform research into sports surface engineering, equipment development, the biomechanics of sports performance, and sports injury), it did aim to address safety consideration by measuring surface hardness which has implications should values fall outside of the minimum standards set by the soccer authorities. The main focus of the project was to develop valuable information on performance factors (surface and players), and safety factors (surface hardness data) while soccer players performed soccer activity on NGPs as they are required to meet the needs of sport provision in the UK (Stiles et al., 2009).

Artificial Turf (a surface of synthetic fibres made to look like natural grass (AT)) vs. NGPs have been compared both in the laboratory (Clarke & Carre, 2010), in the field (Kirk et al., 2007; Severn, 2011; Wannop, et al., 2012), and comparisons have been made between different NG conditions i.e., soft vs. hard pitches (Low and Dixon, 2014). Surface hardness can change throughout different times of the year and this influences the loads experienced by players (Low and Dixon, 2014). Research that tests players on outside NGPs offers the chance to reproduce specific movements to strengthen the ecological validity and generalisability of the findings (Zanetti et al., 2013). Field-based research solely focusing on contrasting NGPs is sparse (Stiles et al., 2009; Brito et al., 2012) and the reason may be attributable to uncontrollable variables such as temperature, precipitation (Low and Dixon, 2014), altitude and wind, (Haugen and Buchheit, 2016). Field-based practical-settings were selected in studies one-to-three in the present project and involved in-game scenarios, game simulations and competitive soccer matches to

strengthen the validity of the project (Cummins et al., 2013; Barnes et al., 2014; Castellano et al., 2014).

Laboratory-based research offers more reproducible conditions; however, tests are repeated on the same surface area and participant behaviour and range of motion are often limited (Kirk et al., 2007). Field-based research can be problematic due to uncontrollable variables and may explain the lack of research in the area (Low and Dixon, 2014). Measurements obtained in the field are susceptible to large variability due to human error and climatic conditions but despite this, field testing allows exact reproduction of movement characteristics (Low and Dixon, 2014). To detect 'true' changes in performance, highly rigorous methodological procedures are required (Haugen, and Buchheit, 2016).

AT pitches are a key aspect to amateur soccer and stringent standards must be met for the installation of AT pitches (FIFA, 2010). Research is striving to continuously improve the quality of AT (FIFA, 2010). The FIFA 1 and 2 star rating system is used to standardise AT pitches, but to what extent is that the case for NGPs and does variation in NGPs affect the characteristics of the game and the safety of the players. Soccer authorities and soccer coaches should be concerned with preserving the nature of the game and not endangering players. They seem actively concerned about this regarding AT pitches but is there reason to be equally concerned with NGPs.

Without NGPs, full sports surface provision (surfaces available for recreational and elite sport) cannot be met therefore advancements in the sustainability, construction and engineering may help in the long-term sustainability and development of NGPs (Stiles et al., 2009). The present project aims to establish knowledge about the physical and psychological responses to playing soccer on soft vs. hard NGPs at amateur-level.

The present project focused on recording multiple trials across a number of variables related to four disciplines including performance analysis, physiology, biomechanical and psychological responses (Taylor et al., 2010). Real-matches, in-game scenarios, and

match simulations were selected for the present project. The project will help yield information applicable to understanding how SH influences the characteristics of soccer performance.

1.2.2. Multidisciplinary approach

Gannon (2001) recommended that a 'research practitioner's' model was "athlete-centred, coached-based, and sports-science driven". A researcher often pursues a research problem in the context of their discipline, be that as a performance analyst, biomechanist, physiologist, or psychologist, whereas a coach needs to solve a problem related to an individual athlete, which may call for answers that are multidisciplinary in nature (Sands, 1999). Adopting a multidisciplinary approach in the present project aimed to answer the same specific research question to broaden understanding and enhance the ability to generalise the findings. A multidisciplinary approach involving contrasting NGSH (soft vs. hard pitches) and specific human responses was included to try and fully understand and evaluate soccer-based movement responses and performance characteristics (Stiles et al., 2009; Potthast et al., 2010).

1.3. Project Aims and Objectives

1.3.1. Aims of the project

The project aimed to examine the influence of NGSH on amateur soccer performance and game characteristics via a mixed-method multidisciplinary approach including performance analysis, physiological, biomechanical, and psychological concepts. The project aimed to detect how differences in SH affect the movements, turns, and game-related activity during real matches and match simulations. The project also aimed to evaluate the perceptions of players and coaches (two of each) on the influence of SH on soccer play.

1.3.2. Objectives

To achieve the aim, the following objectives were identified to:

1) Explore the influence of NGSH on path changes, movements, and game events of an amateur-level (Academy) soccer player through analysing performance measures during competitive matches.

2) Characterize the physiological and performance responses of soccer players while performing repeated sprint activity on soft and hard NG.

3) Quantify and explain the effect of contrasting NGSH on physiological, biomechanical, and performance responses during steady-state activity (SSA) and a match simulation (soccer simulation protocol - SSP).

4) Evaluate the perceptions of players and coaches on the effect of playing soccer on soft and hard NGPs.

1.3.3. Publication

The majority of chapter four is an exact copy of the peer-reviewed publication related to study one (Appendix 11.4) apart from only a few minor amendments: Sleat et al., (2016). The influence of natural grass surface hardness on path changes, locomotive movements, and game events in soccer: a case study. *International Journal of Performance Analysis in Sport*, 16, 216-233.

1.3.4. Thesis layout

The nature of the research project reflects a multidisciplinary approach that includes four disciplines including performance analysis (objective-one; chapter four - study one), physiology (objective-two; chapter five - study two; and chapter six - study three), biomechanics (objective-three; chapter six - study three) and psychology (objective-four;

chapter seven - study four). The research project poses the following main question: what impact does NGSH have on soccer performance and game characteristics? Chapter one broadly introduces NG as a playing surface for soccer and concepts related to the standard, quality, variation of NGSH, and how they impact on soccer performance in general. Chapter two reviews the literature related to the following areas: soccer, natural grass, human responses, testing procedures, impacts of SH on soccer and focus group procedures. Chapter three introduces the generic methods relating to studies one, two, and three. Chapters four-to-seven all contain the abstract, introduction, specific methods, results, discussion, and conclusion sections related to studies one to four respectively. Chapter eight discusses the general points of the project including the contribution of knowledge. Chapter nine concludes the general points of the project and provides recommendations for future research. The references and appendices are contained in sections ten and eleven respectively.

CHAPTER TWO. LITERATURE REVIEW

2.1. Soccer

2.1.1. General Concepts of Soccer

Soccer is the most widely played team sport with almost 265 million players worldwide (FIFA, 2008; Randers et al., 2014; Haugen and Seiler, 2015), 112,000 registered elite players (FIFA, 2006), and almost 8.2 million participants in the UK actively playing some form of the game (FA, 2015) and 2.1 million adults playing soccer on NG at least once a week (Statista, 2020). A standard adult soccer match is generally played over 90-minutes and consists of two periods of 45-minutes separated with a 15-minute break, known as half-time. Soccer players require a combination of both technical and physical factors in complex interplay (Bradley et al., 2013) and participation promotes cardiovascular fitness, muscular power and strength, muscular endurance, flexibility (Krustrup et al., 2010; Morgans et al., 2014) and motor fitness (Singh and Singh, 2016). The interaction of physical, technical, tactical, and psychological aspects of the game determines the success of soccer match performance (Dellal et al., 2008; Carling, 2010). A wide range of movement intensities are required to play soccer, some movements are low intensity and slow, whereas other passages of play demand high intensity bursts of exercise (Orendurff et al., 2010). Soccer is deemed an intermittent physical activity with an irregular activity profile (Page et al., 2010) involving rapid variations and changes in game-related activity and movements (Stølen et al., 2005). Stone et al. (2011) highlighted that the repeated sprint ability and multidirectional nature of soccer were the fundamental characteristics of the game. The ability to perform agility manoeuvres is an important physical performance-related component for soccer (De Clercq et al., 2014; Pandey and Chaubey, 2015). It is estimated that during a match the number of times a soccer player changes the type of movement ranges between 1000-1500 times and each movement change ranges from 5-6 s with a 3 s stationary pause every 2 minutes (Drust et al., 2000; Strudwick et al., 2002; Mohr et al., 2003; Reilly, 2003). During a soccer match an elite soccer player performs between 90-250 brief, intense actions (Drust et al., 2000; Strudwick et al., 2002; Mohr et al., 2003) with a typical cycle consisting of 3 ± 2 s of high intensity activity followed by 30-45 s of low intensity activity (Gabbett et al., 2008).

During a soccer match, a player performs between 50 and 110 technical involvements (Bloomfield et al., 2007; Carling, 2010) such as passing, kicking, tackling, dribbling, and heading which require high force production to be executed successfully (Rampinini et al., 2011). Path changes are important movements performed during a soccer game with turning (Low and Dixon, 2014) and cutting movements (Stacoff et al., 1996) being common examples.

Adult players typically cover a total distance (TD) ranging from 9-14 km with an average value of 10.1 km during a 90-minute match with high intensity running accounting for 8-10% (Bangsbo et al., 1991; Rampinini et al., 2011). In soccer, time-motion analysis has shown that low to moderate intensity aerobic activity accounts for approximately 80-90% of the total energy expenditure (Bangsbo et al., 1994; Iaia et al., 2009) with activities such as walking and jogging making up large periods of game time (Bangsbo, 1994; Rienzi et al., 2000; Russell et al., 2011). High intensity activities contribute around 10-20% of total energy expenditure (Reilly and Thomas, 1976; Bangsbo, 1994a; Bangsbo, 1997; O'Donoghue, 1998; Rienzi et al., 2000). Despite the significant aerobic contribution, the importance of anaerobic contribution with cruising and sprinting representing 10% of the TD covered in a match (Stølen et al., 2005). Regardless of the small proportion to the overall motion activity during a game, sprint efforts have a major impact on the match outcome (Reilly, 1997). During soccer match-play, heart rate ranges from 85-98% of maximal values (Bangsbo, 1994a), work-rate intensity ranges from 70-80% of maximal oxygen uptake (VO_{2max}) (Helgerud et al., 2001), and blood lactate (BLa) concentration ranges from 2-14 mmol/l (Bangsbo et al., 1991; Reilly, 1997).

To be successful, soccer players require specific tactical and technical skills combined with physical conditioning to fulfil the different positional roles involved in the game (Dellal, 2008; Carling et al., 2010). The physical demands for each specific playing position vary considerably with midfielders (central and wide) covering a greater TD and fullbacks and wide midfielders producing greater high intensity running (HIR) profiles compared to attackers and defenders (Bradley et al., 2009). In soccer, the physical requirements needed over a prolonged period elicit fatigue (Mohr et al., 2005). Fatigue is

defined as "the inability to sustain the required workload resulting in an acute impairment of performance" (Gandevia, 2001). The decline in physical capability results in a reduced capacity and inability to generate muscle force or power and an increase in perceived exertion (Hawley and Reilly, 1997; Gandevia, 2001). The combination of unorthodox movements, multiple technical skills, changes in direction, and bouts of acceleration and deceleration contribute to the energy expenditure (Bangsbo, 1997; Reilly, 1997). The demands of a soccer match elicit fatigue both temporarily during a game and especially towards the latter periods (Mohr et al., 2005). Complex control mechanisms within the human body involving the nervous, skeletal, and muscular systems are smoothly and constantly adjusted during soccer performance. The repeated bouts of high intensity activity (HIA) elicit an elevation in blood lactate concentration which contributes to fatigue (Reilly, 1997). Match-related fatigue has been shown to reduce sprinting performance, jumping ability, and maximal strength (Millet and Lepers, 2004; Krustrup et al., 2006; Andersson et al., 2008) which may also affect technical skills such as passing precision, kicking, tackling, dribbling and heading (Rampinini et al., 2008). Harper et al. (2014) and Lago-Penas et al. (2010) suggest that soccer-specific exercise appears to inhibit skill proficiency executed during normal durations (i.e., 90 min) of match-play.

Soccer is played throughout the world on an array of surfaces including football turf (FT) (termed football turf using FIFA terminology but also termed artificial turf), reinforced NG, hard surfaces (sand, clay and, wood), and NG (Ronkainen et al., 2012). The research into playing surface shows that changes in it are likely to affect football characteristics and the style and pace of soccer (Dragoo and Braun, 2010). Match performance characteristics and outcomes are affected by surface type and SH (Baker et al., 2001; Fernandez et al., 2006; Andersson et al., 2008; Stiles et al., 2009; Potthast et al., 2010; Poirier et al., 2011) and subtle changes in surface characteristics may affect a player's movements (Hughes et al., 2013), potentially disturbing their technical skills during competition (Dixon et al., 2000).

In 2004, the Laws of the Game were amended and the International Football Association Board (IFAB) introduced the FIFA Quality Concept for AT which developed the FIFA 1 and 2 Star recommended rating system (FIFA, 2010). This amendment generated many

studies and involved both the physical, technical and psychological aspects of a soccer player's performance and made comparisons between AT vs. NG (Ford et al., 2006; Steffen et al., 2007; Andersson et al., 2008; Zanetti, 2009; Muller et al., 2010; Hughes et al., 2013; Roberts et al., 2014). The motive behind this amendment was based on public, political, economic, practical, climatic and financial factors (Strutzenberger et al., 2014). One reason for this is that at amateur-level soccer it is difficult to maintain the quality of NGPs when environmental, and climatic conditions change. A second reason is that the consistency of an AT pitch offers a more congruent playing surface (Strutzenberger et al., 2014).

Numerous soccer studies exist focusing on the difference between an array of AT vs. AT and AT vs. NG surfaces in terms of injury rate and occurrence (Steffen et al., 2007; Williams et al., 2011), mechanical behaviour of surfaces (Sánchez-Sánchez et al.,2014), performance analysis (Andersson et al., 2008), players' psychological perceptions (Andersson et al., 2008; Zanetti, 2009; Gallardo-Guerrero, et al., 2010; Roberts et al., 2014; Sánchez-Sánchez et al., 2014), performance responses (Fleming, 2011; Brito et al., 2012; Hughes et al., 2013; Stone et al., 2014), biomechanical responses (Ford et al., 2006; Stiles et al., 2011; McGhie and Ettema, 2013) and physiological responses (Hughes et al., 2013; Stone et al., 2014). Soccer performance and movement characteristics can change due to variations in playing surface (Potthast et al., 2010). Therefore, a deeper understanding of player-surface interaction on NGPs of contrasting hardness may provide an insight into the extent to which it impacts on soccer performance and game characteristics in terms of game-related activity, movement (Andersson et al., 2008), and the physiological, biomechanical and psychological responses (figure 1.1.).

Environmental and practical challenges exist when quantifying a player's response to contrasting NGSH which may explain the lack of research in this area (Low and Dixon, 2014). In soccer, studies have attempted to compare the influence of surface type and characteristics on the physical and psychological responses of players during various laboratory and field-based tests but research involving the sole use of NG is rare but certainly needed (Stiles et al., 2009; Brito et al., 2012).

2.1.2. Soccer based research on natural grass

Soccer-based research has used NGPs but comparisons between different NGPs (i.e., soft vs. hard pitches) seem sparse. Stiles et al. (2011) highlighted the importance of NG as a common playing surface for soccer but emphasised the lack of studies that compare solely NG surfaces. Stiles et al. (2011) investigated human responses to changes in NG while focusing on biomechanical variables during running and turning. Eight participants performed two sport-specific movements; running and turning on separate occasions on three surface soils which comprised of clay, sandy, and rootzone (clay – typical clay soccer pitch; sandy – intermediate sand condition; rootzone – high sand modern elite grass surface) and all were turfed with ryegrass which was placed over a force platform (AMTI, Massachusetts, 960 Hz). During running, the peak loading rate (Peak LR - the speed in which force is applied to the human body) was significantly higher on the softer surface ($P<0.05$). During turning, the peak impact force (Peak IF – the force associated with the foot striking the ground prior to the centre of gravity traveling downwards, resulting in larger ground reaction forces (GRF)) was higher on the softer surface ($P<0.05$) and the Peak LR was highest on the hardest surface ($P<0.05$). These findings suggest that as SH decreases, Peak LR and Peak IF both increase during running, and as SH increases Peak IF increases during turning movements. The small difference in SH between the three surfaces combined with the laboratory-based procedure limit the ability to generalise the findings of the study.

The practical and environmental issues of testing in the field were highlighted by Low and Dixon, (2014) as they investigated the biomechanical responses of soccer players when SH and cushioning changed due to temperature and precipitation variation during different seasonal conditions. One NG surface was tested on two different occasions with approximately 8 weeks apart which corresponded to periods of the year which represented contrasting weather conditions (March and May). A 0.5kg CIH measured the mean SH (SH_{MEAN}) value in March (80.0 ± 4.0 Gmax) and (102 ± 3.0 Gmax) in May. Four soccer players performed running trials at 3.0 $m \cdot s^{-1}$ and 180° turning movements while wearing two boot types (six screw-in studs/15 rubber molded studs). A Footscan pressure insole (500 Hz; RSscan, Belgium) was inserted into each footwear type to collect pressure data

and in-shoe forces for the different surface-footwear combinations. Results showed that pressure measurements were significantly greater on the harder NG surfaces ($P<0.05$). During the 180° turning movement, greater loading was seen on the harder surface ($P<0.05$). This suggests a harder playing surface with greater density reduces the cushioning of loads experienced by an athlete which concurs with previous findings from Dixon et al. (2008). In contrast, during both running and turning, several pressure measurements did not differ between surface and this observation may have been due to the marginal difference in SH between surfaces. From a technical perspective, despite practical limitations, this study proves the feasibility of measuring biomechanical data on NG surfaces on field-based pitches. Limiting factors included using repeated trials without changing the grass areas, a small sample size, and targeting a marked area to obtain pressure measurements may have influenced the impact data measured. These findings concur with other research investigating a variety of different surfaces with different cushioning properties. Stiles et al. (2011) found that as NGSH decreased the Peak LR and Peak IF both increased when running and when NGSH increased Peak IF increased during turning movements. Also, Ford et al. (2006) found peak pressure was significantly higher in the central forefoot and lesser toes areas during cutting movements on AT compared to NG. Despite these similarities, it remains difficult making comparisons as no standard practice has been used to objectively quantify the SH of each surface used and different testing procedures have been utilised.

Over the past four decades, numerous methods (manual tracking, video recording, audio recording, and computerized tracking systems) have been used to examine the physical aspects and the activity pattern of soccer players during match-play (Bangsbo et al., 1991; Rienzi et al., 2000). Early work on soccer used hand notation to analyse player movements (Reilly and Thomas, 1976) which is a highly subjective estimation method and now due to advances in technology has been replaced with semi-automatic computerized player tracking systems (Barros et al., 2007; Bradley et al., 2009: Di Salvo et al., 2009). Such advancements in semi-automatic systems allow the collection of a larger range of soccer performance data more accurately and efficiently compared to visual estimation methods (Drust et al., 2007). Analysis of movement patterns, physical

efforts, and technical actions of players are now simultaneous allowing comparison of performance both with and without the ball (Carling, 2008).

An array of time-motion research exists involving a variety of players, levels, competitions, and playing positions (Carling et al., 2008). The demands of soccer are susceptible to both between-players, within-players and between-match variations (Stølen et al., 2005; Gregson et al., 2010; Rollo et al., 2014) often making it difficult to compare research from this field due to the large variability associated with soccer match-play (Gregson et al., 2010). Research has examined both amateur players (O'Donoghue et al., 2001; Hodgson et al., 2014) and professional players (Bangsbo et al., 1991; Bangsbo, 1994b; Mohr et al., 2003, Carling et al., 2012).

Time-motion analysis has been used to evaluate the physical demands and activity profiles between different standards of soccer (Carling et al., 2008). The amount of HIR varies between different standards in soccer and a good indicator of match intensity is the amount of HIR completed (Mohr et al., 2003; Krustrup et al., 2005). The percentage of match-time spent performing HIA ranges from 10.1-12.8% (Bangsbo et al., 1991; O'Donoghue et al., 2001 and O'Donoghue et al., 2004). Mohr et al. (2003) showed that top-class players performed 58% and 28% more ($P<0.05$) sprinting and HIR, respectively, compared to moderate-level players. Akenhead et al. (2013) reported that 18% of TD is covered during either decelerating or accelerating >1 $m \cdot s^{-1}$.

Table 2.1. The activity profile of professional soccer players (adapted from Mohr et al., 2003).

Locomotion Category (average speed)	Percentage of time (%)	Frequency (no.)	Mean distance (m)	Total distance (m)	Mean duration (s)
Standing (0 $km \cdot hr^{-1}$)	19.5	163	0	0	7
Walking (4 $km \cdot hr^{-1}$)	41.8	379	10.7	4050.8	6.4
Jogging (8 $km \cdot hr^{-1}$)	16.7	316	6.7	2104.6	3
Low Speed Running (12 $km \cdot hr^{-1}$)	9.5	198	8.7	1714.3	2.6
Backwards Running (16 $km \cdot hr^{-1}$)	3.7	73	7.5	547.9	2.7
Moderate Speed Running (16 $km \cdot hr^{-1}$)	4.5	109	9.2	1000.0	2.2
High Speed Running (21 $km \cdot hr^{-1}$)	2.8	69	10.5	724.5	2
Sprinting (30 $km \cdot hr^{-1}$)	1.4	39	16.7	649.7	3.5

Mohr et al. (2003) observed the movements of elite soccer players and reported percentage values presented in table 2.1. (adopted from Mohr et al., 2003). Bloomfield et al. (2007) measured 55 players and found that they spent 40.6 ± 10.0 % of the match performing purposeful movements (planned motor activity requiring the conscious involvement of the player movements (table 2.2. depicts the percentage of total time spent in each category)). Players spent 48.7 ± 9.2% of the match moving directly forwards, 20.6 ± 6.8% not moving in any direction and the remainder of the time was a combination of moving backwards, diagonal, lateral, and in arced directions (table 2.3.). Interestingly, 80% of the movements were completed at low intensity. On average, players run 191 m with the ball in each game which equates to 1.7% of the TD covered and translates into approximately 53 s of match-time spent in possession (<1% of match-time) (Carling et al., 2010).

Table 2.2. Highlights the percentage of total time spent in each locomotion category (adapted from Bloomfield et al. 2007).

Locomotion Category	% of total time
Standing	4.6
Walking	14.2
Jogging	28.1
Running	11.1
Sprinting	4.8
Shuffling	9.3
Skipping	9.9
Other movements	18.1

Table 2.3. Summary of the direction in which the movements were performed (adapted from Bloomfield et al., 2007).

Direction percentage of total movements	
Directly Backwards	48.7
Lateral Left	7
Lateral Right	4.5
Forward Diagonal Left	3.9
Forward Diagonal Right	4.6
No direction (stationary)	5
Directly Forwards	20.6

The positional role in soccer seems to influence the total energy expenditure during match-play suggesting the physical requirements vary when comparing players of different positions. Midfield players appear to cover greater TD when compared to other playing positions as Bangsbo (1994) reported that midfielders covered 11.5 km compared to 10-10.5 km covered by defenders and strikers. Bangsbo (1994) showed that midfield players engaged more frequently in low-moderate intensity activity (LMIA) and O'Donoghue (1998) reported midfielders were stationary for significantly less time compared to all other outfield players. Mohr et al. (2003) found the TD covered and the distance covered at HIR was higher for midfielders, attackers, and full-back players compared to defenders ($P<0.05$). O'Donoghue et al. (2004) found midfield players spent a significantly greater proportion of match-time performing HIA (10.9 ± 2.4%) compared to defenders (9.6 ± 1.9%; $p < 0.05$) and forwards (9.6 ± 2.5%; $p< 0.05$). O'Donoghue, (1998) found that FA Premier League midfielders performed HIA for 13.7% of match time which was greater than that of forwards (11.3%) and defenders (12.0%) although the difference between the positional groups was not significant. In contrast, O'Donoghue et al. (2004) previously found the difference to be significant. Despite the equivocal findings reported on playing position in soccer between defenders, strikers, and midfield players in terms of activity profile, work rate, and movements, the differences seem marginal compared to other sports such as rugby. Rugby forwards tend to spend significantly more total time performing HIA compared to the backs, due to greater involvement in mauling, rucking, and scrummaging (Deutsch et al., 2006). Research found that Rugby centres sprinted for 3% of a match compared to less than 1% by props,

and centres spent 3.3% of the time competing for the ball compared to 16% by forwards. Inside (scrumhalf, fly-half, and inside-centre) and outside backs (outside-centre, both wingers and full-back) spent significantly less total match time (4.5%) performing HIA compared to 12-13% for forwards (Docherty et al., 1988).

In soccer, high intensity movements such as shuffling on-the-spot, tracking, running, and sprinting are classified as "work" (O'Donoghue et al., 2004). Competing for the ball while the ball is in play and all contacts with the ball are also classified as "work" (O'Donoghue et al., 2004). Any other activity is classified as "Rest" and typically includes lying in a prone position, sitting, standing, walking, and jogging (O'Donoghue et al., 2004). O'Donoghue et al. (2004) found that soccer players spent the equivalent time performing work to a work-to-rest ratio of 1:8.9 which was similar to a 1:7 ratio found by Reilly, (2003). A work-to-rest ratio of this magnitude can be partly explained firstly by the fact that soccer is a team game where the work is distributed amongst the team members and secondly that the ball remains in play for 55.3% of match time (O'Donoghue and Parker, 2001). In addition, approximately 35 minutes of stoppages are recorded per game where players are not required to perform any physical work (O'Donoghue et al., 2004). O'Donoghue et al. (2004) reported that players performed 49 repeated work bout periods lasting on average for 2.9 s with short recoveries of <20 s. Players performed 37 isolated work bouts with a mean time of 2.9 s and range from 2 s to over 10 s. The recovery periods that separated the isolated and repeated work periods had a mean duration of 47.8 s.

Robinson and O'Donoghue (2008) emphasised the importance of turning, path changes, and direction of travel in soccer performance. Bloomfield et al., (2007) stressed that only a small number of directional changes occurred during a match and that the majority of soccer match-play is performed in a relatively linear manner. Players performed 111 ± 77 on the ball movement activities and ~8 turns and swerves per minute (726 ± 203 per match) during match-play with ~84% (609 ± 193 per match) of these being 0° to 90° to the left or right. Robinson et al. (2011) quantified path changes and recorded 39.9 ± 13.2 sharp path changes to the side of the non-dominant leg compared to 35.4 ± 12.7 sharp path changes made to the dominant leg ($p<0.01$).

A soccer player performs numerous technical performances during match-play including headers, tackles, jumps, passing the ball, trapping the ball, throwing the ball, shooting, dribbling, and intercepting the ball. On average, elite soccer players execute between 9-15 headers (Rico & Bangsbo, 1992) and 11-20 tackles (Withers et al., 1982; Ekblom, 1986; Mohr et al., 2003) and 18-30 dribbling movements with the ball per match for an average of 2.9 s per dribble (Rico & Bangsbo, 1992; Bloomfield et al., 2007). Per match, a player completed 33 passes and 16 jumps (Burgess et al., 2006) and 5 instances where a player gets up from the ground (Reilly & Thomas, 1976). When considering the influence of surface type on the technical frequencies performed in soccer match-play, Andersson et al. (2008) reported little difference in the technical frequencies between AT vs. NG surfaces however, fewer sliding tackles and more short passes were performed on AT compared to NG ($P<0.05$). FIFA (2006) compared the main soccer events performed in matches on AT vs. NG respectively and produced similar results in terms of the total team passes (703 vs. 720), successful passes (80% and 83%), unsuccessful passes (144 vs. 119), headers (144 vs. 117) dribbles (8 vs. 0), touches per possession (2.5 vs. 2.7), tackles (44 vs. 43), fouls (26 vs. 35), interceptions (240 vs. 233), penalty area entries (73 vs. 52) and final third entries (129 vs. 119). Study one of the present project embedded the inclusion of performance analysis to measure physical, technical, and game related events, based on the evidence that they are important in soccer and may detect differences between soft vs hard NGPs.

2.1.3. Soccer – summary

In summary, a multitude of technical and physical data exist covering a diverse range of levels, competitions, players, and playing positions. There are not extensive differences between playing position in terms of the work-rate in soccer. Soccer research has highlighted the importance of quantifying various technical frequencies (Mohr et al., 2003; Bloomfield et al., 2007; Bradley et al., 2013) and similarities have been shown when comparing NG vs. AT surface (FIFA, 2006; Andersson et al., 2008). However, direct comparisons between soft vs. hard NGPs have not been investigated which supports the rationale for study one. Often laboratory-based research has been used where

repeated trials have been carried out on the same surface area and participant behaviour and range of motion is often limited (Kirk et al., 2007). Impractical issues such as using equipment in an outdoor environment and being unable to control certain environmental factors such as precipitation has certainly contributed to the lack of research in this field (Low and Dixon, 2014). Other factors that pose difficulties including the geographical, temporal (seasonal), and spatial (pitch) variability of NGPs. Research is required that incorporates a research design capable of testing soft vs. hard NGPs on separate occasions while recovery and participant behaviour is controlled. A cross-over design (refer to figure 5.1.) embedded into studies two and three would capture data during two testing days interspersed with approximately 72 h. The inclusion of real-time and real-life situations within the participants' environment is required therefore locomotory movements need to be evaluated using competitive soccer matches on NG to strengthen the generalisability of the findings (Shiffman et al., 2008). The importance of turning in soccer has been highlighted (Robinson and O'Donoghue, 2008) with 726 ± 203 turns performed per match (Bloomfield et al., 2007). Study three of the present project embedded the inclusion of an SSP which involved turning movements and that is justified based on the evidence that they are important in soccer and measuring this variable may detect differences between NGPs. Therefore, it would be of value to establish whether the frequencies, durations, and percentages of various modes of motion, game-related activity, and path changes are influenced when soccer match-play is performed on NG of contrasting SH.

2.2. Natural grass

2.2.1. Sports surfaces – general

Sport surfaces can be divided into natural and artificial surfaces. One natural surface such as grass is created by suitable preparation of an area and is common in many outdoor sports. Artificial surfaces like AT or an athletics track are constructed with human prepared materials and can normally be found in indoor sports like basketball or the track events in athletics (Nigg & Yeadon, 1987). Considering the surface type and condition is one thing, but the ergonomic interaction between a soccer player and playing surface is somewhat more complex with more research needed on how variations in NG characteristics influence human movement (Stiles et al., 2009).

Ball speed, ball bounce, and ball roll have been assessed relative to different surface characteristics however, little research has been performed on how NG surface variation affects a player (Stiles et al., 2009). Tennis is played on different surfaces including clay, grass, and hard court, which have been shown to influence the speed of the game, therefore tennis players adjust their game according to the surface type and hardness (Fernandez et al., 2006). Tennis has different demands depending on the surface, with different cushioning and frictional properties influencing the ball rebound, game speed, and player performance and there is a required need for improved scientific understanding of the tribological interactions at the shoe-surface interface in sport (Severn et al., 2010). Tribology relates to the study of lubrication, friction, and wear between two surfaces and provides an opportunity to describe the relationship between two surfaces to explain how traction is generated on sports surfaces (Barry and Milburn, 2013). In cricket, pitch hardness influences performance, because on ball behaviour in terms of pace, bounce, and movement patterns of a player (Baker et al., 2001). The hardness of ice has been shown to be influential in ice hockey performance and maximum player speed due to the coefficient of friction (Poirier et al., 2011). In summary, surface type and hardness appear to influence performance in sports such as tennis (Fernandez et al., 2006) and cricket (Baker et al., 2001) in terms of movement and pattern. This supports the notion to investigate the influence of surface hardness on soccer performance.

2.2.2. Sports surfaces - specific

Soccer players are required to move in a multi-planar and multi-directional manner (Little and Williams, 2005), therefore, the way the foot makes contact with the ground influences a player's physical movement (Breine et al., 2014). In linear running, the strike patterns of the foot may be classified into three groups based on the foot-related initial contact point: initial rear-foot contact, mid-foot contact, or fore-foot contact patterns (Cavanagh and Lafortune, 1980). High quality, uniform surfaces allow improved technique as the movement of the ball becomes more predictable (Zamparo et al., 1992; Stiles et al., 2009), therefore the condition, deformation, and consistency of the SH remain influential (Stiles et al., 2009).

Soccer is played on an array of surfaces including NG, reinforced NG, and AT (Roberts et al., 2014). Traditionally, NG has been the preferred surface to play soccer on, but NG surfaces are often of poor quality (Burillo, 2009). Desirable NGPs should have consistent even grass coverage and density and grass length cut between 15-40 mm. Other desirable NG properties include a surface that is stable and even, free from saturated and loose areas, potholes, and divots (Department of Local Government, Sport and Cultural Industries, 2011). The PQS recommendations for the construction and upgrade of NGPs are presented in table 1.1. (adopted from FA, 2004).

On-going deliberations continue from sporting organisations on which type of playing surface offers the best surface for performance (Gallardo et al., 2009). It remains questionable whether playing sport on variations of the same surface (i.e., grass) compromises some playing characteristics of the game (Stiles et al., 2009). The majority of soccer competitions and training currently remain on NG (Stiles et al., 2009). It remains unclear how a soccer player's loading response during foot contact with the ground is affected when changes in NG cushioning differs with season, temperature, and precipitation (Ford et al., 2006). Evidence suggests a hard playing surface with greater density reduces the cushioning of loads experienced by an athlete (Dixon et al., 2008; Low and Dixon, 2014). Many variations exist when considering all surface types (i.e., NG, reinforced NG, AT), surface properties (i.e., hard and soft), and external variables (i.e., season, precipitation, and temperature). Trying to compare all variations would be

insurmountable so focusing on two types of NG (soft vs. hard) may provide information related to how a soccer player is affected when a player performs various activities on surfaces of this nature.

2.2.3. Surface hardness, mechanical behaviour, mechanical loading, and surface composition

Playing surface has the potential to influence performance and physiological stresses whilst playing soccer (Kerdok, 2002), field hockey (Reilly and Borrie, 1992), and tennis (Murias et al., 2007) and with an increase in surface hardness, player energy expenditure is reduced when running and walking (Zamparo et al., 1992). A feature of a surface that affects athletic performance is the energy stored and returned (Baroud et al., 1999). The energy that an athlete requires for each jump, stride, step, and landing movement is influenced by the returned energy from the surface (Katkat et al., 2009). If a surface permits a greater energy return, an athlete can complete a given physical activity using less energy (Katkat et al., 2009). The coefficient of restitution relates to the ability of a surface to absorb shock and is a measure of how elastic a collision is (Farkas and Ramsier, 2006). The coefficient of friction relates to how grabby or sticky the surface is and how much force it takes for an athlete's foot to slip. A surface with a low coefficient of friction requires less force for sliding to occur than the force required when the coefficient of friction is higher (Drakos, 2008).

Surface hardness has been defined as "the ability of a surface to absorb the impact energy created by any object striking that surface" (Rogers, 1988). The term "SH" in the present project indicated the resistance the surface had towards deformation (James, 2011). Subtle changes in surface characteristics may affect an athlete's kinetic or kinematic pattern, potentially disturbing their technical skills during competition (Dixon et al., 2000). Soft surfaces have been shown to absorb a larger percentage of the energy applied upon impact when compared to hard surfaces (Bell and Holmes, 1988). The tribological interaction between an athlete and the surface is through foot-to-shoe-to-surface interaction (Baker and Canaway, 1993), with the level of traction and the surface's ability to absorb energy being two important properties of any sports surface (Brosnan et al., 2009). Variation in NGSH has been shown to significantly influence biomechanical

parameters during running and turning movements on three different compositions of NG surfaces (sandy, clay, and rootzone), but was measured in a laboratory setting (Stiles et al., 2011). Research is emerging testing players on NGPs in the field which offers the chance to reproduce specific movements to strengthen the validity and generalisability of the findings (Hughes et al., 2013; Stone et al., 2014). The emerging research proves it is possible to detect 'true' changes in performance using highly rigorous methodological procedures (Haugen, and Buchheit, 2016) while overcoming many uncontrollable variables such as weather constraints (Low and Dixon, 2014). Further research is needed that compares different NG conditions and the influence it has on soccer performance. SH and human responses need to be objectively measured to fully understand movement responses and subsequent performance (Stiles et al., 2009; Potthast et al., 2010).

Other factors that affect NGP characteristics include the mechanical properties such as energy losses, energy storage, and friction of the surface (Nigg and Anton, 1995). Energy storage is related to the stiffness of the surface and surface deformation. Higher surface stiffness produces lower deformation and higher energy storage along with higher impact forces (Stefanyshyn and Nigg, 2003). Impact forces are associated with both damping and stiffness (i.e., internal energy loss) (Nigg and Lui, 1999). The damping also determines the time required to extinguish ground vibrations (Zanetti et al., 2013). Traction and friction are two properties that allow a player to make movements required in sport without unnecessary falling or slipping. The terms 'traction' applies to footwear having extra grip (i.e., cleats, spikes, or studs) and 'friction' to footwear having smooth-soled surfaces (Bell et al., 1985). The presence of friction between the two contacting surfaces provides traction which essentially provides GRF for an athlete to produce a manoeuvre.

2.2.4. Mechanical testing of natural turf pitches in the laboratory and field

Surface hardness can depend on which method is used to mechanically measure the surface and is either defined as "the effect an applied force has on the deformation of the surface, or the effect the surface has on impact forces" (McMahon & Greene, 1979; Twomey et al., 2012). Different mechanical devices exist that immediately assess the in-

situ playing surface properties and these devices can be categorised into 1) devices that provide an insight into the surface condition and 2) devices that try to replicate the athlete-surface interaction. The quantification of SH can be measured in many ways and two methods that have been widely used include the CIH and the Artificial Athlete (AA) which has a second model named the Advanced Artificial Athlete (AAA). Devices in this category typically provide objective surface data that are not applicable to the athlete-surface interaction, yet it is comparable across different pitches and over time or used to benchmark surfaces. The CIH is a valid, reliable, and endorsed method (Clegg, 1976; Bell and Holmes, 1988; Saunders et al., 2011; FIFA, 2012) and a common testing instrument due to its portability, relative affordability, reliability, robustness, and the ease of interpreting data (Baker and Canaway, 1993 Al-Amoudi et al., 2002). The weight of a falling mass of 2.25 kg is dropped from a consistent height of 45 cm or 55 cm (figure 2.1.) onto the surface through a guide tube. The hammer is dropped repeatedly up to five times on each testing location of the pitch to measure the peak or mean deceleration of the impact of the hammer. Longer ground contact times due to greater plastic deformation result in lower peak deceleration values (Rogers and Waddington, 1990; Baker et al., 2007).

Figure 2.1: The 2.25 kg Clegg Impact Hammer (Severn, 2010).

The 2.25 kg CIH is more commonly used as it is less sensitive and susceptible to grass leaves compared to the lighter 0.5 kg counterpart (Rogers and Waddington, 1989; Baker et al., 2007). The number of times the missile is dropped has varied in previous research

with the first, third, fourth, and fifth drop measurement being used to measure SH (Gibbs et al. 2000; Chivers and Aldous, 2004). Twomey et al. (2011). The number of drop numbers can affect the hardness of the surface due to the compaction of the soil. This variance makes it difficult to compare similar research projects due to the contrasting drop numbers used and some research has failed to report drop numbers. Future research needs to standardise this procedure. Previous research has shown that the shape of the missile, mass and drop heights all influence peak deceleration data (Nigg and Yeadon, 1987; Nigg, 1990; Shorten, 2003).

Table 2.4: 'Acceptable' and 'preferred' benchmark SH ranges for the mechanical parameter (2.25 kg CIH). Soccer and rugby limits are taken from Bell and Holmes, (1988); McClements and Baker, (1994); Baker et al., (2007); Australian football limits are taken from Chivers and Aldous, 2004).

Sport	Acceptable SH range (Gmax)	Preferred SH range (Gmax)	Drop Height (m)
Soccer	35-120	45-90	0.45
Rugby	30-110	40-70	0.45
Australian Football	30-120	70-89	0.30

Table 2.5: Benchmark ranges for surface hardness of natural grass pitches (Chivers and Aldous, 2004).

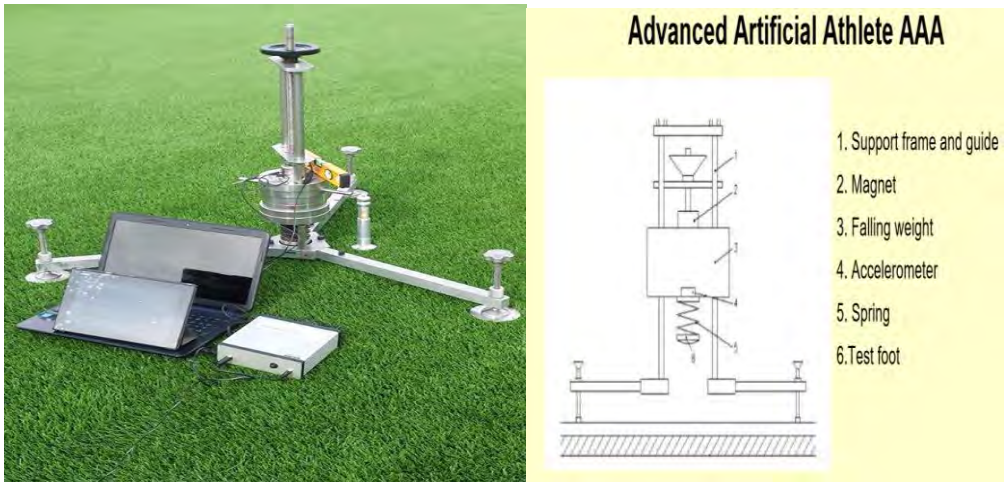
Hardness Class	Unacceptably Low	Low	Normal Preferred Range	High	Unacceptably High
Hardness (Gmax/10)	<30	30 to 69.9	70 to 89.9	90 to 120	>120

Values in gravities (Gmax).

Benchmark limits are not based on tolerances in the human body or related to any injury data so they are not currently used to determine whether a surface is safe for play, but potentially could be used in this way. Research has highlighted concerns with the loading

conditions of the CIH as the magnitude and loading rate of the force and contact time are not consistent with those of an athlete (Nigg and Yeadon, 1987; Nigg, 1990; Young and Fleming, 2007). The duration of the impact of a 2.25 kg CIH is short and typically ranges from 9.7-11.1 ms (Rogers and Vanini, 1988) depending on SH (Rogers and Waddington, 1990) whereas, an athlete's foot-strike is reported to be more than 15 times longer at 120 ms when running on NG at 3.83 $m \cdot s^{-1}$ (Stiles et al., 2011).

The second vertical drop device is the AAA which measures impact force using accelerometer data (FIFA, 2012). The AAA is a field-based mechanical test used to verify sports surfaces in soccer and rugby. Surfaces are expected to meet regulatory standards regarding vertical deformation, shock absorption, and energy restitution (World Rugby, 2008; FIFA, 2012). Standards have been developed for AT based on mechanical data collected from NG (Charalambous et al., 2016) and values are depicted in table 2.4. The AAA measures the impact force and hardness is expressed as the reduction of force (FR) on the tested surface relative to a rigid and stable surface ("no significant deflection under a 5 kg/cm^2 pressure"). The reference force for this is 6760 N, which is the theoretical value calculated for a concrete surface (FIFA, 2012). The AAA is a test used by FIFA whereby a portable device works on the principle that a 20 ± 0.1 kg weight is dropped vertically from a height of 55 ± 0.25 mm above the surface (figure 2.2.). The AAA measures the impact force with either a uni-axial accelerometer (9600 Hz) attached to the top of the weight with a spring attached on the bottom (AAA) (FIFA, 2009; FIFA, 2012). The AAA determines the relative stability and rigidity of the surface after determining the initial impact force.



(a) (b)

Figure 2.2: (a) AAA (b) Schematic overview of the AAA including: 1: support frame and guide 2: electric magnet 3: falling weight 4: accelerometer 5: spring 6: test foot (FIFA, 2009; FIFA, 2012).

Standard Deformation (StD) in [mm] often termed Vertical Deformation (VD) simulates the vertical deformation of the surface under a dynamic applied load of twice that of an average athlete of 1500 N and the surface is regarded as softer the higher the StD. The Force Reduction (FR) measures the surface rigidity relative to a stable surface. The maximum force (Fmax) is measured by testing a rigid concrete surface (6,600 to 6,700 N) and a typical resilient sports surface possesses an Fmax between 500 N and 2,000 N. Energy restitution (%) (ER) is the energy returned by the surface after the applied load. FR on concrete is 0% and for common sports surfaces vary between 25 and 70% and the higher the percentage the softer the surface (Charalambous et al., 2016). The force reduction percentage is calculated as: FR (%) = (Fmax sport surface/Fmax concrete) – (1 x 100). Charalambous et al. (2016) demonstrated that surface temperature significantly altered the mechanical properties of AT (i.e., FR and ER) suggesting different demands are placed on soccer players when the surface temperature changes.

Table 2.6. Fédération Internationale de Football Association (FIFA) One and Two Star and International Rugby Board (IRB) regulations for the mechanical properties tested using the AAA (FIFA, 2012; World Rugby, 2008).

Mechanical Property	FIFA One Star	FIFA Two Star	IRB
Force absorption (%)	55-70	60-70	55-70
Vertical deformation (mm)	4-9	4-8	4-10
Energy Restitution (%)	—	—	20-50

The AAA device is considered the 'gold standard' for surface testing across many sports (Fleming, 2011) measuring several surface properties. However, the CIH and the AAA show similarities as both devices measure SH by dropping a weight onto a surface measuring deceleration and force reduction respectively and previous research reported a good correlation between both methods (Fleming, 2011). The AAA device is approximately five times more expensive than the CIH (up to £20,000) and less portable and can be difficult to set up in the field (McLeod, 2008), therefore the CIH was selected to quantify SH in the present project.

2.2.5. Natural grass – summary

Soccer is played on a number of surfaces including sand, clay, wood, NG, reinforced NG, and AT (Roberts et al., 2014), however, traditionally NG has been the preferred surface to play soccer on (Burillo, 2009). The consistency, deformation, and condition of NG can vary considerably at amateur-level soccer (Stiles et al., 2009), therefore a number of mechanical behaviours and properties have been investigated to see how they impact soccer performance. The mechanical testing of NG has provided knowledge and information towards understanding the complex interaction between a soccer player and NG surfaces, although considerable work is still required to improve the standard of NGPs at amateur-level (Stiles et al., 2009). Quantifying NGSH would allow pitches to be categorised into soft vs. hard clusters. This would allow for specific physical

measurements of players to be made in simulated soccer activity providing valuable data for the amateur soccer community.

2.3. The influence of fatigue, environmental condition, turning, running, and sprinting on soccer

Soccer performance is dependent on an array of interactions between different players within a team (Haugen et al., 2013). Tactical and technical skills are considered important factors as discussed previously, however, the physical abilities are predominant factors required to become a successful soccer player (Haugen et al., 2013).

2.3.1. Fatigue

Fatigue is a multifaceted and complex phenomenon often associated with the inability to continue exercising at a certain intensity and an inability to maintain a required or expected level of force (Gandevia, 2001). A soccer player experiences fatigue during a game which can lead to making mistakes and more goal-scoring opportunities by opposing teams (Yiannakos and Armatas, 2004). Fatigue is a significant factor and influences the physical performance of soccer players and sprint performance deteriorates particularly late in a game (Bangsbo et al., 1992; Mohr et al., 2004). Fatigue affects soccer skills (Russel et al., 2011) and one assumption is that fatigue lowers the pass accuracy therefore possession is lost along with the ability to control the match and performance (Yiannakos and Armatas, 2004). Evidence indicates that muscle fatigue inhibits kicking performance (Nunome et al., 2006). The number of sprints and distance covered is lower in the second half compared to the first half of a match and running speed is slower in the second half of a match (Bangsbo et al., 1992; Mohr et al., 2004). Mohr et al. (2003) found that soccer players perform less HIR in the last 15-minutes of a game. Muscle fatigue has been shown to significantly limit physical performance (Mohr et al., 2007; Mileva et al., 2009) when there is a gradual decline in the capacity to generate maximum force production of a muscle that inhibits the ability to perform motor tasks (Enoka et al., 2008). Activities such as kicking, changing direction, jumping, tackling, accelerating, and decelerating are partly dependable on the muscular strength of a soccer player (Cometti

et al., 2001). In summary, fatigue seems to impair muscular strength, motor control (Enoka et al., 2008) and the execution of physical (Mohr et al., 2007; Mileva et al., 2009) and technical tasks (Nunome et al., 2006; Russel et al., 2011) required in soccer. Assessing fatigue by measuring the movements and frequency of game-related events when environmental conditions change may provide more clarity on the effect of SH on soccer performance.

2.3.2. Environmental conditions

Subtle differences in environmental condition potentially affect the movements made by a soccer player (Flanagan, 2010). Soccer matches, and training are occasionally performed by players in unfavourable environments (Carling et al., 2011). Environmental factors such as the cold, heat, altitude, wind, and rain influence athletic performance however, the effect of rain on performance has received less research attention than other environmental factors (Ito et al., 2013). One investigation by Ito et al. (2013) measured the effect of very heavy rain on seven healthy male candidates while performing a 30-minute treadmill running at an intensity of 70 % VO2 and 82% of HRpeak. A climatic chamber kept the air temperature consistent at 5°C and participants performed the procedure in the absence and presence of heavy rain of 40mm/hr on separate occasions. Results revealed that skin and body temperature were significantly lower in the rainfall condition whereas, BLa levels, noradrenaline, oxygen consumption, and the amount of air breathed per minute were all significantly higher in the rainfall condition. The authors suggested that energy demand increases when performing running based activities in wet conditions.

Carrying out physical activity and exercise when the environmental conditions change result in alterations in the metabolic, thermoregulatory, cardiovascular, and neuromuscular function (Hargreaves, 2008; No and Kwak, 2016). Moderate altitude and high environmental temperature can impair a soccer player's aerobic and anaerobic capacity (Wehrlin and Hallen, 2006; Mohr et al., 2012) and affect the execution of skill (Mohr et al., 2012; Nassis, 2013), the completion of soccer-specific activities and the ability to recover from high-intensity bouts of running (Garvican et al., 2013). Evidence suggests that soccer performance is less affected by cold temperatures (Patton and Cogel,

1984; Carling et al., 2011) although when combined with rainfall, several physical factors seem to be influenced (Ito et al., 2013).

2.3.3. Turning

The importance of turning in soccer has been introduced in section 2.1.3 (match analysis). Soccer players perform ~8 turns and swerves per minute and 726 ± 203 per match (Bloomfield et al., 2007). Several turn types exist in soccer including smooth turns, sharp turns left and right, linear turns, and V-cut path changes (refer to section 4.2.4. variables; Robinson et al., 2011). Cutting manoeuvres are important in soccer and are angle and velocity-dependent where players are required to quickly change direction while running using cross-steps (performed in the direction of the planted foot) and side-steps (performed in the direction opposing the planted foot) (Dos' Santos et al., 2019). Measuring turn frequency and type during real-life soccer matches combined with quantifying the time it takes to turn during a simulated soccer match would provide valuable data, especially if captured on soft and hard NGPs.

Ford et al. (2006) implied that playing surface significantly affected foot motion and loading patterns during soccer-related activities. Hughes et al. (2013) revealed faster peak turning results on the NG surface compared to the AT. In contrast, Gains et al. (2010) reported directional changes were faster on AT during a one-off sprint performance compared to NG. More force is exerted during the directional change resulted in greater and more intense loading from decelerations and accelerations on AT. Unfortunately, SH was not quantified objectively for each surface type used in the Ford et al. (2006), Gains et al. (2010), or Hughes et al. (2013) studies which make it difficult to compare to similar literature of this nature.

Low and Dixon. (2008) showed that during 180º turning movements, the peak rate of loading was higher on hard NG when compared to soft NG. These findings illustrate that changes in mechanical properties of NG may become more apparent during turning movements when using biomechanical methods of assessment. The laboratory setting, subjective monitoring used to control turning speed, and the marginal differences in SH

between the three conditions suggested further work is required to provide more clarity on the equivocal area of research.

Hughes et al. (2013) found the mean L-agility performance test times were faster on AT (5.11 ± 0.17 s) compared to the NG (5.17 ± 0.16 s) surface. Hughes et al., (2013) found that the SA-R (speed-agility run) revealed faster peak turning times (ES = 0.49; $P<0.05$) on the NG (2.55 ± 0.07 s) compared to the AT (2.59 ± 0.09 s) with a mean difference of 0.04 s. The cutting movements during the SA-R were faster on the AT (2.70 ± 0.11 s) compared to the NG (2.74 ± 0.10) surfaces but were not significant.

The importance of turning in soccer has been established in terms of the multiple turn types and the total number of turns performed per match. Equivocal findings exist when assessing the efficiency of turning due to a multitude of different turn types and playing surface being used in both field and laboratory-based research. Therefore, further clarity is required to see if the frequency and speed of turning movements are influenced when performed on soft vs. hard NGPs.

2.3.4. Running and Sprinting

The ability to run and sprint proficiently is vital in soccer performance and during a competitive match, a player performs between 17-81 sprints (Di Salvo et al., 2007; Vigne et al., 2010), each lasting between 2-4 s (Gabbett and Mulvey, 2008; Vigne et al., 2010) and peak sprint velocity ranges from 31-32 $km \cdot h^{-1}$ (Rampinini et al 2007a; Rampinini et al., 2007b). Sprint distances performed in a soccer match range from 5-40 m and 90% of sprints are ≤20 m (Haugen et al., 2013). The activity profile of soccer players has been discussed in section 2.1.3. (match analysis) and the percentage of time, frequency, mean distance, total distance, and mean duration for running and sprinting were summarised in tales 2.3. and 2.4. (Mohr et al., 2003; Bloomfield et al. 2007). The most frequent type of sprinting is in a straight line and this is the most frequent action performed by both the scoring and assisting player prior to a goal being scored (Haugen et al., 2013).

As running speed increases from a jog up to a maximum sprint both stride frequency and stride length increase (Donati, 1996). At a moderate running speed, stride length plateaus, and then stride frequency increases up until maximal speed (Luhtanen and Komi, 1978). An illustration of this can be seen in figure 2.3. (adopted from Dillman, 1975; Beachle and Earle, 2008).

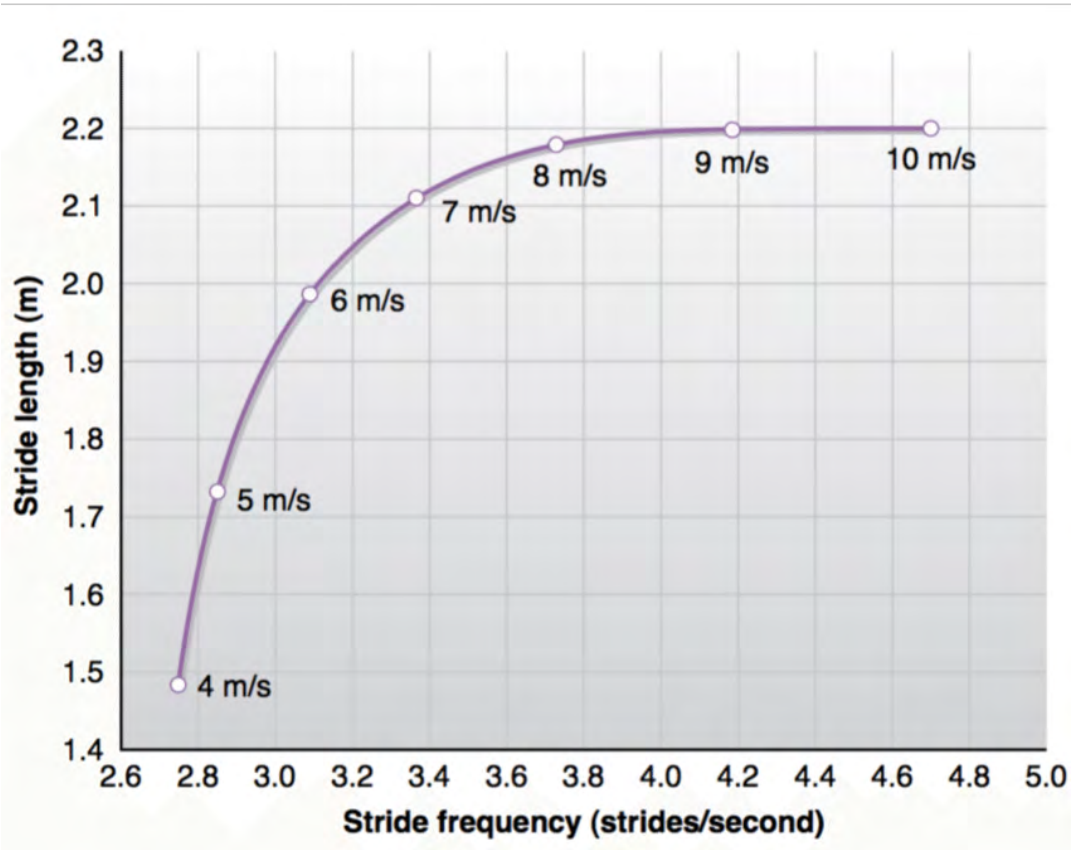


Figure 2.3. stride length-frequency interaction as a function of running speed (adopted from Dillman, 1975).

An increase in stride frequency requires the lower extremities to move faster through the stride cycle, and the skeletal musculature to lengthen and shorten more rapidly (Miller et al., 2012). This finding is linked to a well-known force-velocity relationship of skeletal muscle (Hill, 1938; Katz, 1939) and has been referred to as the potential ‘‘bottleneck’’ that restricts maximum sprinting speed (Weyand et al., 2010). An illustration of the concentric and eccentric force-velocity relationships can be seen in figure 2.4. (adopted from Wilmore et al., 2008). The force-velocity relationship suggests that if the force is greater the rate of movement is less (Wilmore et al., 2008).

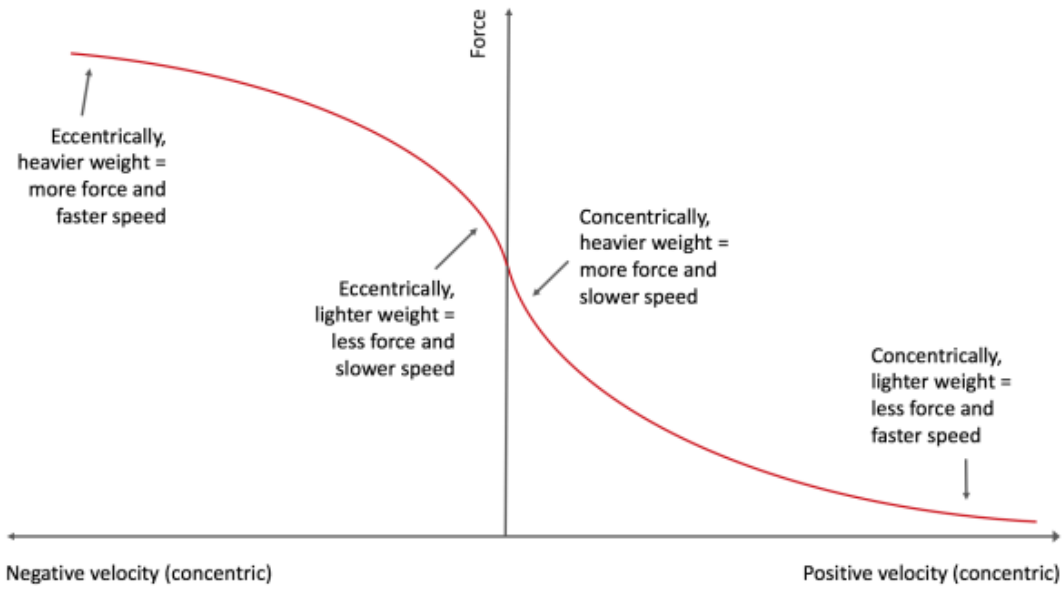


Figure 2.4. The concentric and eccentric force-velocity relationships. (adopted from Wilmore et al., 2008).

Force production is critical for sprint performance and at top speed, both fast and slow sprinters reposition their lower limbs at the same time (~0.350s) (Weyand et al., 2000; Weyand et al., 2010). This suggests that repositioning the lower limb is not considered an important factor associated with sprint performance (Clark and Weyand, 2014). Sprint ability is reliant upon producing large sums of GRF in the appropriate direction, in the shortest contact time feasible (Weyand et al., 2000; Weyand et al., 2010). This implies that slower sprinters require a longer ground contact time to apply the equivalent force of a faster sprinter. By measuring certain kinematic variables during acceleration and maximal speed running during soccer simulated activity on soft vs. hard NGPs may provide information related to force production, stride length-frequency interaction, and the concentric and eccentric force-velocity relationship.

2.3.5. Summary of the influence of fatigue, environmental condition, turning, running, and sprinting on soccer performance

Evidence suggests that fatigue, turning, running, and sprinting are important determinants that influence soccer performance in either a physical or technical way. One example to explain this point is that surface type, footwear, and environmental factors (i.e., rain, wind, and altitude) all affect sprint performance (Dapena and Feltner, 1987; Linthorne,

1994). Therefore, it would be advantageous in the present study to determine the effect of soft vs. hard NGPs on the rate of fatigue and the speed and frequency of turning, running, and sprinting movements in either soccer match-play or real-game simulation.

2.4. Testing procedures

2.4.1. Simulations, SSP and SSA

A multitude of physical tests exist, and this section provides some common SSP protocols used to assess soccer players that closely resemble the sport. It is important to remember that despite the ecological validity, no physical test will replicate soccer match-play exactly due to individual differences and the complex demands of the sport (Svensson and Drust, 2007). Physical tests performed in the field improve the specificity of the evaluation when compared to laboratory-based tests (MacDougall and Wenger, 1991; Balsom, 1994).

Table 2.7: Illustrates some field-based SSPs used for soccer.

Author	Name of test	Description	Duration of test
Nicolas et al. (2000)	Loughborough Intermittent Shuttle Test (LIST)	Running between two lines 20 m apart at various speeds	90-minutes
Fletcher et al. (2009)	Football Simulation	Ten-sets of 2 minutes walking, sprinting, jogging, and running between two lines 20 m apart	20-minutes
Small et al. (2010)	Soccer-specific aerobic field test ($SAFT^{90}$)	Two 45-minutes sessions performing multiple movements over 20 m	90-minutes
Stone et al. (2011)	Soccer-specific protocol	Six-sets of 15 minutes with 3 minutes rest between each set over 20 m apart at various speeds interceded with 15 m sprint-agility run (SA-R) and repeated sprint bouts.	90-minutes

The involvement of soccer simulation protocols (SSPs) to replicate soccer match-play has seen many different protocols employed (table 2.7.), giving the opportunity to assess physical and technical actions.

The Loughborough Intermittent Shuttle Test (LIST) has been used as a field test that simulates the activity pattern of soccer (Nicolas et al., 2000). The 90-minute duration made the test more closely resemble competitive match-play. The test comprised of two parts, part A and part B. Part A consisted of five 15-minute sets, each separated by 3 minutes' recovery (figure 2.5.). The pattern of exercise for Part A was as follows: 3 x 20 m at walking pace; 1 x 20 m at maximal running speed; 4 s recovery; 3 x 20 m at a running speed corresponding to 55% of individual VO_{2max} and 3 x 20 m at a running speed corresponding to 95% of individual VO_{2max}. Part B consisted of an open-ended intermittent running shuttle where participants run at designated speeds (55% and 95% of predicted VO_{2max}) alternating every 20 m until exhaustion in approximately ≤10 minutes. The test is continued until participants are unable to maintain two consecutive shuttles of the higher speed (Nicholas et al., 2000).

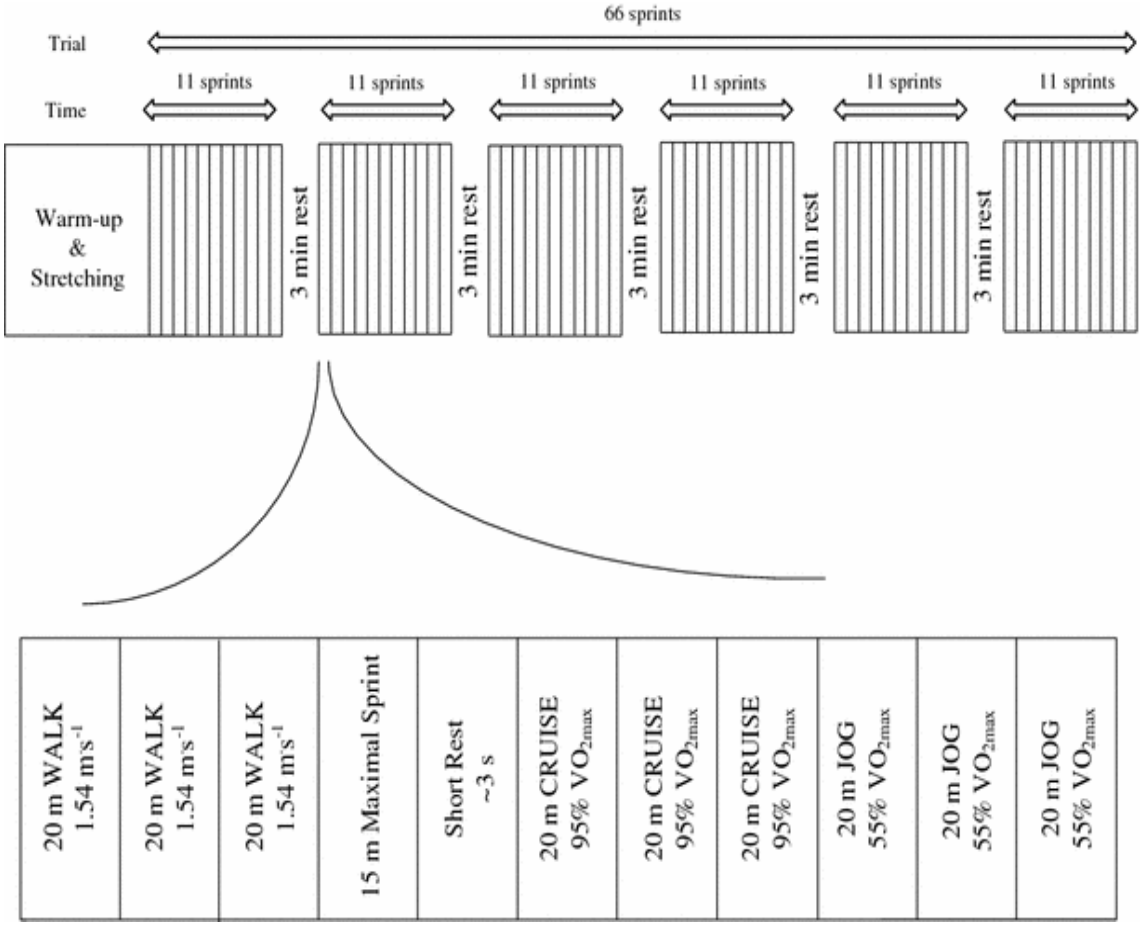


Figure 2.5. Diagram of the LIST (adopted from Nicholas et al., 2000).

Fletcher et al. (2009) conducted research that compared the effect of playing surface (AT vs. NG) involving a 20-minute SSP which consisted of 10 blocks of 2 minutes broken down into four sections of different physical activity (figure 2.6.) over a 20 m long lane. Players performed three 15 m sprints once every two minutes totalling 30 sprints.

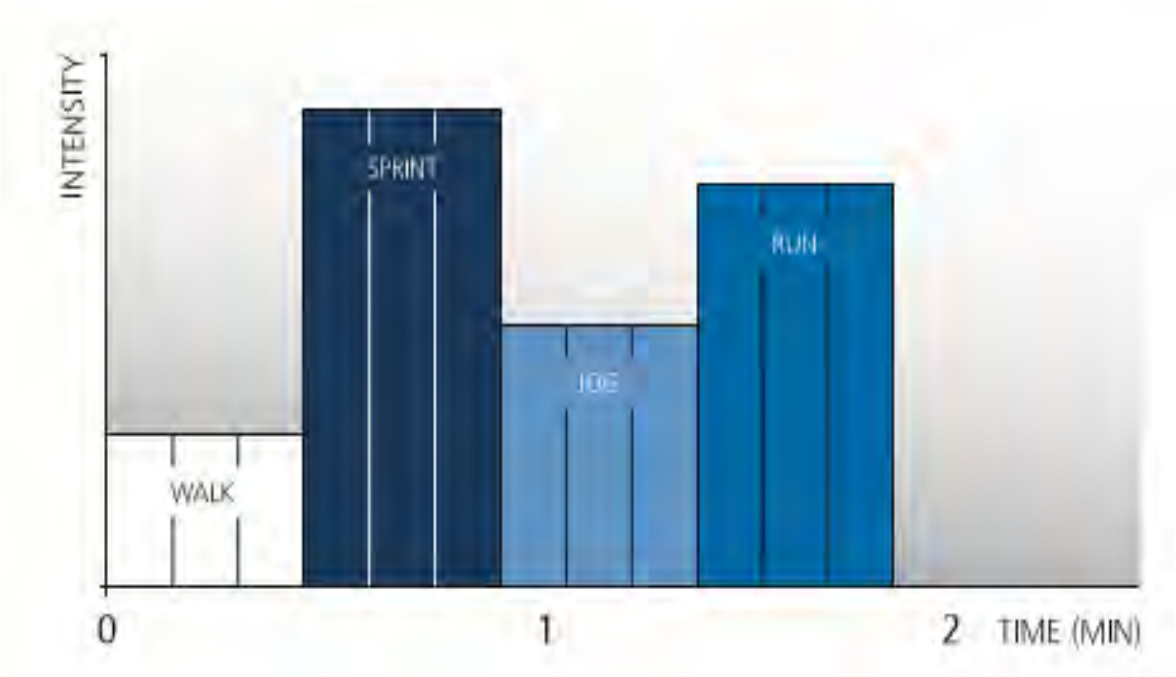


Figure 2.6: Diagram illustrating the modality and time of each exercise type during the SSP (adopted from Fletcher et al., 2009).

Small et al. (2010) devised a similar 90-minute soccer specific aerobic field test protocol ($SAFT^{90}$) that consisted of two 45-minute periods interceded by a 15-minute half-time rest and was performed over a 20-m distance as a shuttle run test designed to replicate soccer match-play (figure 2.7.). Multiple movement types and intensities included 36 shooting actions and multiple sidestepping, acceleration, deceleration actions, running backwards, and directional changes inherent in soccer match-play. The movement intensity was controlled using an audio CD. A 15-minute activity profile was repeated six times and incorporated 1350 COD and 1269 changes of speed (COS).

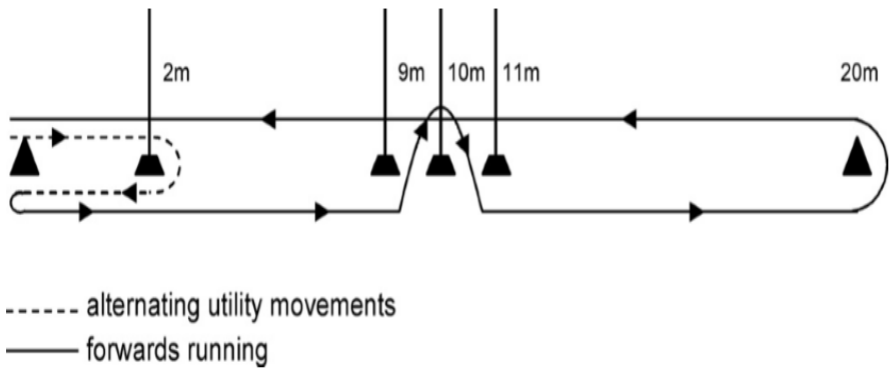


Figure 2.7. Schematic layout of the $SAFT^{90}$ (adopted from Small et al., 2010).

Table 2.8: Distances covered during match-play and each activity during the $SAFT^{90}$ (adopted from Small et al., 2010).

Activity	Distance during $SAFT^{90}$ (km)	Distance from match-play data (km)
Standing (0.0 km^{-1})	0	0.02
Walking (5.0 km^{-1})	3.36	3.60
Jogging (10.3 km^{-1})	5.58	5.81
Striding (15 km^{-1})	1.50	1.46
Sprinting (≥20.4 km^{-1})	0.34	0.27
Total distance (km)	10.78	11.08

Stone et al., (2011) introduced an amended SSP which was a novel adaptation of the LIST and included repeated sprint activity and multidirectional movements which are both regarded as fundamental game characteristics (Reilly, 1977). The SSP devised by Stone et al. (2011) has been used in other soccer simulated research which aimed to measure the influence of playing surface on performance and physiological responses (Hughes et al., 2013; Stone et al., 2014). The SSP consisted of six 16-minute sets of 3 x 20 m at a walking pace of 1.43 $m{\cdot}s^{-1}$, 1 x SA-R at maximal intensity with 20 s for sprint and recovery, 3 x 20 m at a jogging speed of 2.5 $m{\cdot}s^{-1}$, 3 x 20 m at a running speed of 4.0 $m{\cdot}s^{-1}$ and repeated sprint bouts with 3 minutes rest between each set (figure 3.4.). A 15-minute half-time break was administered.

The development of field-based SSPs has been driven by research to improve the ecological validity of the test to replicate soccer match-play as closely as possible. An adapted version of the SSP devised by Stone et al. (2011) will be used in the present project to objectively quantify a range of performance, physiological and biomechanical responses that would otherwise be impractical or difficult to measure during a competitive match.

2.4.2. Biomechanical testing procedure

An array of physical tests exists in soccer that measure fitness and skill-based components including cardiovascular, muscle strength and endurance, agility, speed, RSA, but it seems the biomechanical and kinematic patterns are often neglected (Padulo et al., 2012). Biomechanical techniques are vital tools for numerous sports and in soccer, they are particularly useful for analysing and improving mechanical effectiveness in execution, identifying factors that influence successful performance, and defining the characteristics of skills (Kapidzic et al., 2011). Studies incorporating the ecological validity of human movement are an important research concept often underestimated. The applicability of using real-life situations or at least trying to mimic or replicate such situations strengthen the generalisation of the research findings (Shiffman et al., 2008). Therefore, for scientific research, it is best to measure behaviour in real-time and within the participants' environment (Shiffman et al., 2008).

2.4.2.1. Kinematic analysis

Kinematic analysis is widely used in assessing mechanics that describe the bodies (objects), systems of bodies (groups of objects), and the motion of points without considering the causes of motion (Hay, 1993). Kinematic analysis in the laboratory is performed with instrumentation that provides highly accurate quantifiable data (Atha, 1984; An and Chao, 1984). Disadvantages associated with laboratory-based kinematic assessment include restricted portability, compatibility issues with lighting, highly expensive instrumentation, and often require technical expertise (Padulo et al., 2015). In comparison, recent improvements in instrumentation available for motion capture and analysis have seen such systems and tools widely used although a limiting factor is the significant time required to post-process analysis (Minetti and Ardigò, 2001). Kinematic analysis in soccer is important to provide information related to movements in terms of the gait analysis, therefore using low-cost, time-efficient methods to analyse motion patterns would be highly useful.

Despite the evidence available to support the validity and reliability of two-dimensional kinematic analysis for functional tasks that can shed light on an athlete's efficiency (the work economy for a given physical task), research involving the analysis of running is limited (Maykut et al., 2015). However, two-dimensional kinematic analysis focusing on technical skills in soccer has been carried out (Lees et al., 2010; Shan and Zhang, 2011; Kapidzic et al., 2014; Numone and Ikegami, 2017).

2.4.2.2. Biomechanical variables

Biomechanical parameters and particularly mechanical parameters are especially important in all forms of locomotion (Okuno et al., 2011). Both metabolic factors and kinematics parameters are important aspects related to running performance (Padulo et al., 2012). Metabolic variations generate alterations within the kinematic parameters (Di Prampero, 1986) and research predominantly focuses on the metabolic parameters and often neglects the mechanical parameters (Okuno et al., 2011).

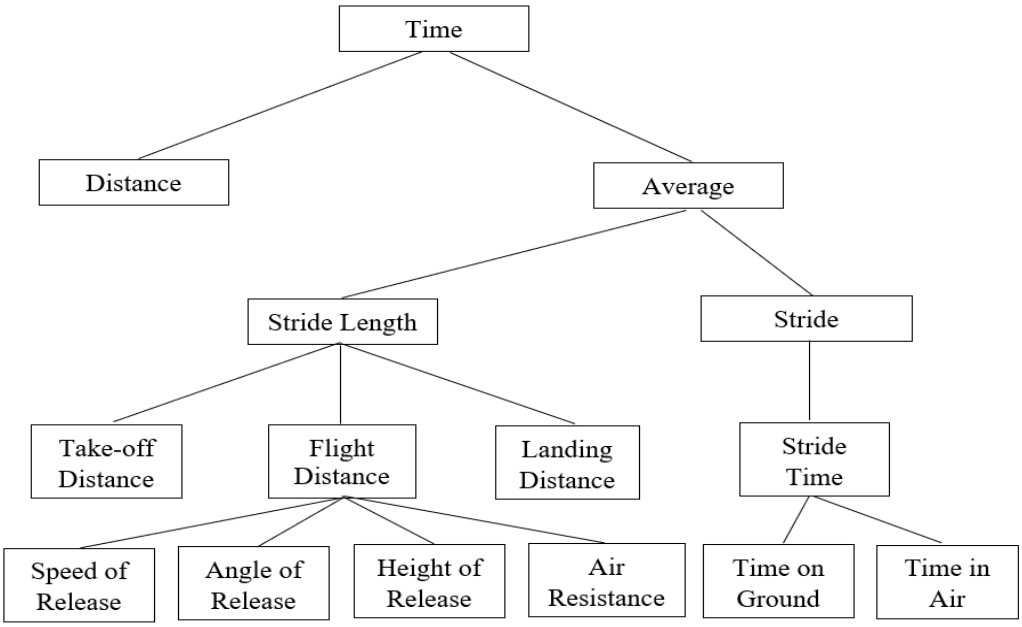


Figure 2.8. Basic factor of sprinting (Hay, 1993).

A reduction in contact time (CT) is associated with an increased ground GRF and stride length (SL) (Swanson and Caldwell, 2000). GRF is defined as "a force of equal magnitude exerted on the opposing direction from the ground up to the foot" (DeLee et al., 2010). Meijer et al. (2007) found that GRF increases in-line with SH during two sub-maximal running speeds. When assessing movement dynamics, humans adjust their lower limbs in response to SH to maintain their centre of mass dynamics (Ferris & Farley, 1997; Ferris et al., 1998). Players land with straighter legs mainly by extending the knee on less stiff surfaces (Farley et al., 1998; Kerdok et al., 2002). To maintain overall stiffness, leg stiffness increases by changing the stiffness at the ankle joint (Farley et al., 1998).

Running at higher speeds potentially changes step strategy and therefore is likely to influence running economy (Hasegawa et al., 2007). Running economy is defined as "the aerobic demands of running, or the relationship between oxygen consumption and running speed" (Daniels and Daniels, 1992). Understanding the kinematics parameters can provide valuable information related to an athlete's efficiency (Padulo et al., 2012).

Stride frequency (SF) and SL play a major part in the mechanics of sprinting and elite sprinters produce higher SF and longer SL when compared to non-elite sprinters (Kunz and Kaufmann, 1981). The relationship between SF and SL interact in a way that the shorter the SL, the higher the SF and vice versa (Donati, 1996). At certain running speeds SF and SL both increase as speed increases linearly (Ito et al., 1983; Cavanagh and Kram, 1989; Brisswalter and Legros, 1995; Yokozawa et al., 2005). As running speed increases both flight time (FT) and CT decrease (Ito et al., 1983; Cavanagh and Kram, 1989; Brisswalter and Legros, 1995; Yokozawa et al., 2005). The combination of FT and CT results in stride time (St) (figure 2.8. Basic factors of sprinting, adopted from Hay, 1993). An experienced athlete running at a constant running speed produces the SF and SL which provides the greatest mechanical efficiency (Williams et al., 1987; Morgan et al., 1994) and energy efficient (Cavagna et al., 1991; Swanson and Caldwell, 2000).

The running gait cycle consists of a flight period when both legs are not in contact with the ground and are moving through the air at different stages of the swing phase (SwT) in preparation to reposition the leg and foot ready for the initial contact (Novacheck,

1998) (figure 2.9; section B). Typically, the swing phase constitutes 64-78% of the gait cycle and is dependent on speed (Mann and Hagy, 1980; Novacheck, 1998). Soccer is a sport that requires speed and players have become faster over time suggesting that sprinting skills are becoming more important in the modern game (Haugen et al., 2014). The importance of the kinematic variables (CT (s), FT (s), SF (Hz), SwT (s) St (ms) and SL (m)) during linear jogging, running, and sprinting (figure 2.10) warranted each to be measured in the present project to determine the effect of SH on such measures.

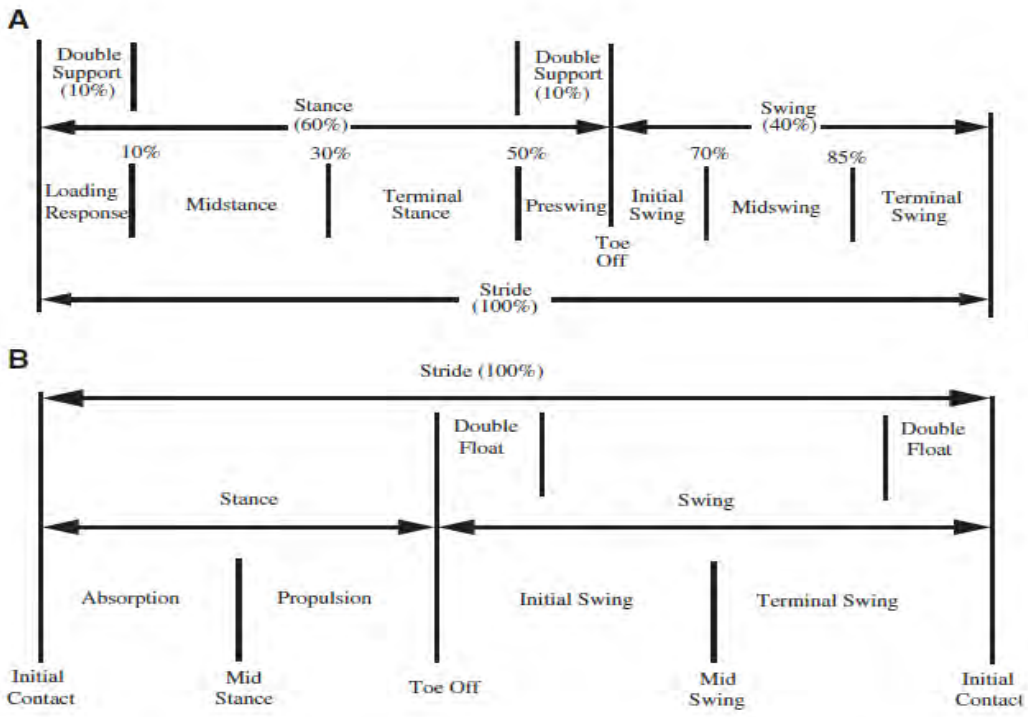


Figure 2.9 Gait cycle with phases of the individual components. (A) walking. (B) running (adopted from Dugan And Bhat, 2005).

2.4.2.3. Running economy and mechanical efficiency

Running economy (RE) refers to the steady state oxygen consumption at a specified running speed (Conley and Krahenbuhl, 1980; Daniels, 1985; Saunders et al., 2004) and is associated with the energy demand required when running at a continuous sub-maximal speed (Barnes and Kilding, 2015). There are several factors that determine and influence

RE including metabolic, cardiorespiratory, environmental, match, neuromuscular, and biomechanical characteristics (Barnes and Kilding, 2015), (figure 2.10).

Metabolic efficiency is the ability to efficiently produce velocity and external power (i.e., mechanical efficiency) by converting metabolic energy to facilitate optimal performance (Daniels, 1985; Saunders et al., 2004; Sandbakk et al., 2012). Cardio-pulmonary efficiency refers to a reduced work output for the processes related to oxygen utilisation and transportation (Barnes and Kilding, 2015).

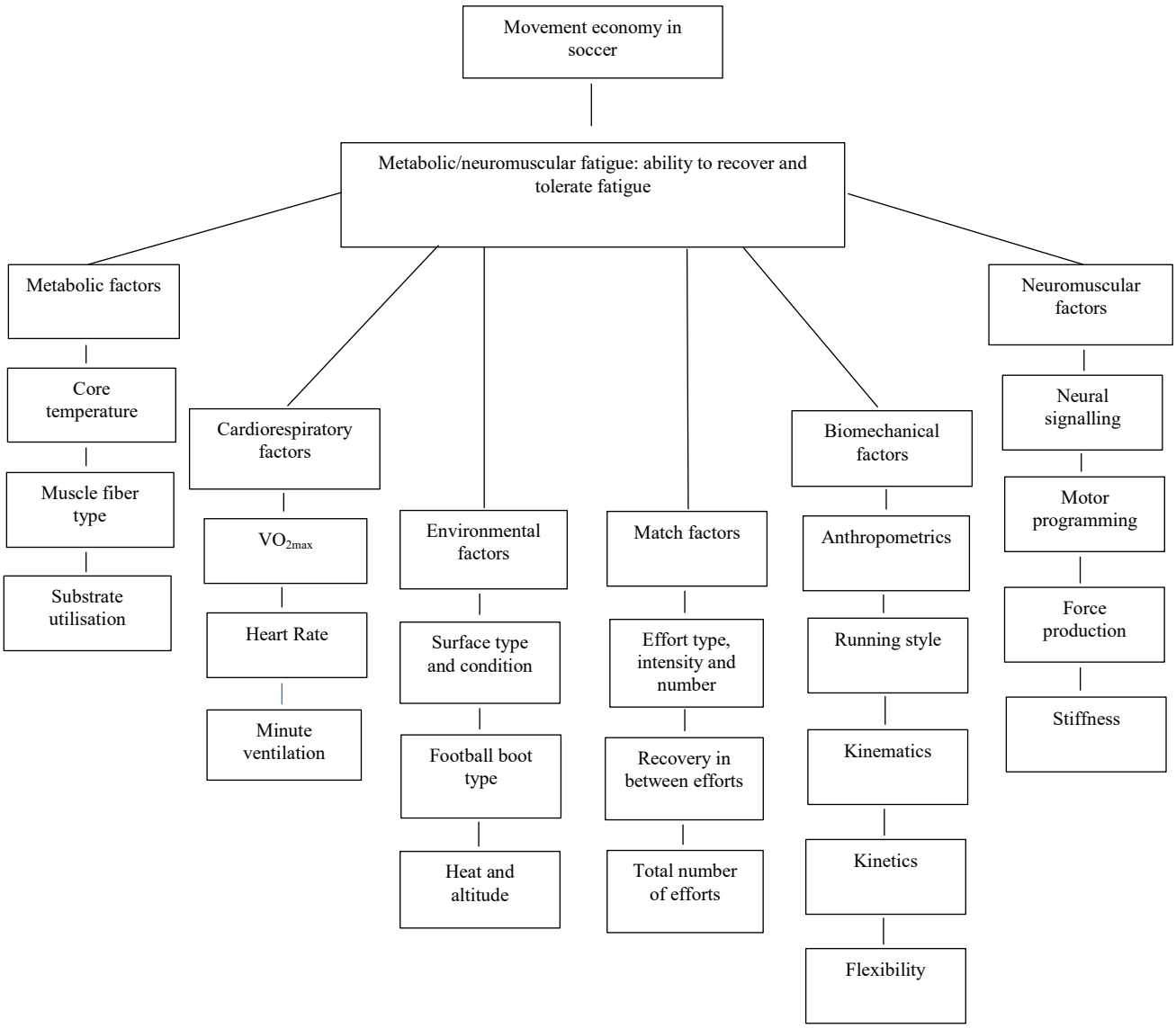


Figure 2.10. Factors affecting movement economy in soccer (adapted form Barnes and Kilding, 2015).

The unconstrained nature of running with many degrees of freedom allows individual athletes to use a diverse range of 'techniques' to produce forward movement. This can generate a large inter-individual variability in lower limb kinematics (Ahn et al., 2014) and stride parameters (Cavanagh and Kram, 1989; Nummela et al., 2007). Despite the large variability and instinctive relationship between running technique, economy, and performance (Anderson, 1996), little research exists concerning the impact that running technique has on economy and performance (Folland et al., 2017). RE is an important factor, given the prolonged demands of a soccer match (Dilci et al., 2018) and is strongly correlated with soccer performance (Castagna et al., 2006). Factors that influence RE include biomechanical efficiency (e.g., kinematics variables such as SL, St, and CT; Barnes and Kilding, 2015). Despite not directly measuring RE in the present project, stride parameters have been shown to influence RE with shorter ground CT resulting in improved RE (Nummela et al., 2007) and horizontal displacement (Folland et al., 2017). Therefore, in the present project, stride parameters will be measured to determine whether they change when performing soccer specific movements (i.e., jogging and sprinting) on soft vs. hard NGPs.

2.4.3. Repeated Sprint Ability, Sprint Speed and Fatigue Index

In court and field-based sports such as hockey, tennis, netball, lacrosse, rugby basketball, and soccer, repeated sprints are defined as "by short maximal sprint efforts, interspersed with longer periods of active recovery or rest, repeated over a prolonged period of time" (Bishop et al., 2001) and this is an important fitness component required for team-sports (Spencer et al., 2004; Glaister, 2007; King et al., 2009). Most team-based sports require a combination of low-to-moderate-intensity (LMIA) with intermittent bouts of high intensity activity (HIA) such as running and sprinting, suggesting reliance on multiple energy systems to complete the physical tasks of the sport (Miltenbergen, 2013). A soccer player's sprint ability has been highlighted as one of the most important physical requirements and it can discriminate players in terms of the different level of ability (Ferro et al., 2014; Haugen et al., 2014; Nikolaidis et al., 2016). The repeated sprint ability (RSA) is considered another important fitness component in competitive soccer players (Stølen et al., 2005; Krustrup et al., 2006; Rampinini et al., 2007a). RSA tests are usually

assessed from a combination of peak performance (typically the first sprint) and the decline in this variable through subsequent efforts (Oliver et al., 2008; Glaister, 2008). Both the percentage decrement (%DS) and fatigue index (FI) have been two indices used to assess RSA. The FI is defined as "the "relative drop-off in performance from the best to the worst sprint" (Glaister, 2008). The %DS attempts to measure fatigue by comparing the actual performance data to an imagined 'optimum performance' (i.e. where the fastest effort would be replicated in each sprint) (Buchheit et al., 2009; Girard et al., 2011). The %DS is calculated as follows: 100 – (mean time/fastest time x 100) (Buchheit et al., 2009).

RSA tests have been used to replicate an intense period of play during a team-game sport (Oliver et al., 2006), and often soccer players are required to perform 10-40 m sprints, over approximately 2–5 s (Spencer et al., 2005), which is said to provide logical validity and relevance to match-play (Krustrup et al., 2002; Mohr et al., 2003; Krustrup et al., 2006; Oliver et al., 2006; Glaister, 2008; Girard et al., 2011). RSA tests have been used widely in a "range of soccer-related research (Oliver et al., 2006; Girard et al., 2011). The duration, distance, number of repeated sprints, and recovery period all have a substantial impact on RSA performance outcomes (Glaister, 2008) by altering the relative energy system contribution and metabolic demand of the exercise (Spencer et al., 2005).

RSA tests are generally over distances of 5-40 m (Huagen et al., 2014), involve 6-7 sprint repetitions, and involve recovery periods lasting 25 s (Bangsbo et al., 1991; Reilly, 2005). Despite the widespread use of RSA tests in soccer, protocols involving straight-line activity only assess linear movement. More information could be gathered if linear and non-linear (i.e., change of direction) movements are assessed during a testing protocol (Little and Williams, 2005). Stone et al. (2011) introduced a repeated sprint-agility run (SA-R) as a more extensive method of assessing the capabilities of team sport athletes which is discussed in the SSP (Chapter: 2.4.1.).

Sprint and RSA tests have been carried out on different sports surfaces involving soccer players. Fletcher et al. (2009) conducted research that compared the effect of playing surface (AT vs. NG) involving a 20-minute SSP which included 15 m sprint and SA-R

performances. The 15-m sprints were slightly slower on the NG (2.63 s) compared to the AT (2.59 s) which revealed a significant difference of 0.04 s in time and 1.4% in percentage terms. Gaudino et al. (2013) selected 29 soccer players to perform a 12-m maximal sprint and measured the average and maximum sprinting speed on NG (6.05 ± 0.2 ms^{-1}; 7.04 ± 0.47 ms^{-1}), AT (6.01 ± 0.29 ms^{-1}; 7.12 ± 0.35 ms^{-1}) and soft, dry sand (5.27 ± 0.23 ms^{-1}; 6.22 ± 0.41 ms^{-1}) ($p<0.001$). The authors suggested the lower average and maximum speed on sand may have been due to the instability of the surface (Gaudino et al., 2013). An unstable sandy surface can produce the foot to slip backwards during the push off phase of the stride (Zamparo et al., 1992).

Sprints times (SA-R 15 m) and repeated sprint performances were faster (ES = 0.39 and 0.35; $P<0.05$) during the SSP over 15 m on AT (2.45 ± 0.13 s and 2.51 ± 0.12 s) compared to NG (2.49 ± 0.08 s and 2.55 ± 0.10 s) respectively (Hughes et al., 2013). A decline in both the repeated sprint and SA-R performances occurred throughout each set with the mean times in the first set being faster than sets 3, 4, 5, and 6 with set 2 being faster than set 6 ($P<0.05$). The fatigue index for repeated sprints did not differ between surface with 7.4 ± 2.4% and 6.9 ± 2.1% for AT and NG respectively (Hughes et al.,2013). Nedelec et al. (2013) measured three 6 s sprint performances (average speed and maximum speed) separated by 3 minutes of passive recovery on a treadmill following the completion of a 90 minutes soccer-specific aerobic field test protocol on two separate occasions on AT and NG. The results revealed only small (ES = 0.01-0.17) differences suggesting surface type did not influence sprint performance. Ford et al. (2006) found no significant differences when performing slalom and sprint performances on NG and AT conditions whereas, Hughes et al. (2013) found faster cutting and sprint times on AT when compared to NG, although both studies used different testing protocols and neither study quantified SH. In summary, the equivocal findings related to sprinting on contrasting surface types, make it a valid question to try and determine whether sprint performance is influenced by soft vs. hard NGPs.

Binnie et al. (2013) found slower 20 m mean sprints on sand when compared to NG in all 3 tests ($P<0.05$) (Binnie et al., 2013). Exercising on sand can result in change in kinematics and muscle activation patterns, and a diminished energy return to the body

(Pinnington et al., 2005). Pinnington et al. (2005) suggested these kinematic changes on sand include an increased SF, plantar flexion, forward trunk lean, and hip range of motion when compared on NG. Similarly, Binnie et al. (2014) found repeated sprints were significantly faster over 5, 10, and 20 m performed on NG compared to sand which coincides with previous work (Binnie et al., 2013).

Previous research remains equivocal in terms of sprint performance on surfaces with different hardness. Binnie et al. (2013) reported faster sprints on NG compared to sand whereas, other research has reported faster sprints on AT when compared to NG (Fletcher et al., 2009; Hughes et al., 2013). Possible reasons why sprint performance varies when comparing different studies may be attributable to different surfaces being used without the hardness being measured. Testing procedures also varied between the research as Hughes et al. (2013) measured 20-m repeated sprint performance during a 90-minute simulation comparing AT vs. NG, Fletcher et al. (2009) used a 20-minute simulation involving a repeated protocol of 30 x 20-m sprints comparing AT vs. NG and Binnie et al. (2013) used a 20-m single sprint performance comparing NG vs. sand. Therefore, the present study needs to assess the impact of SH on sprint performance using soft vs. hard NG while adopting an endorsed protocol that resembles soccer match-play.

2.4.4. Summary: Repeated Sprint Ability, Sprint Speed and Fatigue Index

Before scoring a goal, sprinting is a frequent action performed (Haugen et al., 2014) and players perform on average 17 sprints per match (Schimpchen et al., 2015). In the English Premier League, there has been an increase of 35% in the total sprint distance, an 85% increase in the number of sprints, and an increase in maximal running speed (Barnes et al., 2014). The ability to perform sprinting and repeated bouts of sprinting over a prolonged period are considered a crucial physiological requirement for success in soccer (Reilly, 1997; Svensson and Drust, 2005). These bouts of activity often contribute to the more important moments of the game such as shooting, tackling, chasing a player, or winning possession (Mohr et al., 2003). Therefore, it would be of value to establish whether sprint and repeated sprint performances differ on soft vs. hard pitches where only lower-quality NG surfaces and amateur competitors are involved. RSA tests ranging from

10-40 m provide logical validity and relevance to match-play (Krustrup et al., 2002; Mohr et al., 2003; Krustrup et al., 2006; Oliver et al., 2006; Glaister, 2008; Girard et al., 2011) therefore supports the RSA test selection incorporated in study two of the present project.

2.5. The impact of playing surface on soccer performance

It is widely accepted that physical (Rebelo et al., 2013), physiological (Rampinini et al., 2007), biomechanical (Ford et al., 2006), and psychological (Greig et al., 2007) parameters are considered important factors that influence a soccer player's performance. The direct impact of playing surface and SH on these parameters is less clear therefore warrants such discussion in section 2.5.

2.5.1. Physiology

Comparisons have been made between the physiological performances on NG vs. AT (Andersson et al., 2008; Di Michele et al., 2009; Hughes et al., 2013; Nedelec et al., 2013) and NG vs. sand (Binnie et al., 2013), all of which have shown differences in performance between surface. Higher blood lactate (BLa) and heart rate (HR) responses have been found whilst performing interval training on a sand surface when compared to NG (Binnie et al., 2013). Running on sand has been reported to raise the energy cost of running by 20 - 60 % compared with the use of a firmer surface (Zamparo et al., 1992; Lejeune et al., 1998; Pinnington and Dawson, 2001). Hughes et al. (2013) showed no differences between playing surface with mean values for three physiological variables including BLa (AT: 4.8 ± 1.6 mmol/l and NT: 5.3 ± 1.8mmol/l) average heart rate (HRav) (AT: 171 ± 9 and beats·min^{-1} NG: 171 ± 9 beats·min^{-1}) and peak heart rate (HRpeak) (AT: 182 ± 9 beats·min^{-1} and NG: 182 ± 9 beats·min^{-1}). Nedelec et al. (2013) observed no significant differences between HR average on AT (151 ± 15 beats·min^{-1}) and NG (145 ± 14 beats·min^{-1}) suggesting the physiological load was similar on both surfaces. During small-sided games Brito et al. (2012) found a lower HRav on AT when compared to NG and BLa was lower on asphalt than on NG (Brito et al., 2012). Di Michele et al., (2009) used elite male soccer players and compared the physiological effect of performing a multistage running test on a treadmill, NG, and AT. The AT produced higher HR and BLa concentration values at all speeds. The authors suggested the cushioning properties

of the AT infill was responsible for the higher effort. There seems to be a range of different physiological responses when performing soccer-related activity on different surface types. This may be due to the lack of assessing the mechanical properties of each surface. No research has attempted to assess the physiological responses when performing soccer simulated activity on soft vs. hard NG therefore warranted the approach in the present project.

2.5.2. Biomechanics

Biomechanical parameters are important in all forms of movement (Okuno et al., 2011), especially contact time (CT), flight time (FT), stride frequency (SF), swing time (SwT), stride time (St), and stride length (SL) for linear jogging and sprinting (Lockie et al., 2011; Lockie et al., 2012) involved in soccer. Gaudino et al. (2013) comparing the mean FT and CT during sprints and revealed significant differences between the sand surface when compared to both AT and NG surfaces ($p<0.01$) with a significantly lower FT and greater CT on the sand surface, however, no differences were found when comparing SF across the three surfaces. Ford et al. (2006) examined in-shoe loading patterns in soccer players whilst performing cutting movements on NG and AT. Seventeen soccer players were tested on a slalom course while peak pressure and relative load were calculated by an in-shoe pressure distribution measurement insole in the right shoe. Findings revealed that turning movements produced different biomechanical responses on AT compared to NT. The AT had significantly higher peak pressures compared to NG within the lesser toes (turf: 429.3 ± 200.9 kPa, grass: 348.1 ± 119.0 kPa, P=0.043) and central forefoot (turf: 646.6 ± 172.6 kPa, grass: 533.3 ± 143.4 kPa, P=0.017). Conversely, the relative load within the lateral midfoot (turf: 3.4 ± 1.8%, grass: 4.1 ± 2.3%, P=0.029) and medial forefoot (turf: 27.2 ± 5.3%, grass: 30.2 ± 6.6%, P=0.031) were higher during the NG trials. Greater cushioning properties of the AT may have decreased the loading magnitude under the highest loaded part of the foot along with a more rigid support base in the NG condition. No research has attempted to assess the biomechanical responses when performing soccer simulated activity on soft vs. hard NG therefore warranted the approach in the present project.

2.5.3. Psychology

One area that is often neglected from surface type comparison studies is the players' perceptions making it difficult to make assumptions and determining which factors are important for the player (Roberts et al., 2014). The players' perception when comparing AT and NG surface properties has been investigated and strong opinions exist. Roberts et al. (2014) revealed that a higher proportion of players mentioned that AT was "more abrasive" and "more level" and had "less grip" and was "too hard or harder" and "too fast". Unfortunately, it was unknown whether the responses were regarded as favourable or unfavourable traits of AT and that further analysis would be required to determine this.

Research by Andersson et al. (2008) investigated players' perceptions of movement patterns and technical standards while performing on AT versus NG. On a scale of 0-10, where 10 = "worse than", 5 = "equal to", and 0 = "better than", the male players reported a negative overall impression (8.3 score), greater physical effort (7.2), and poorer ball control (7.3 score) when playing on AT compare to NG. Players found it more difficult to run with the ball, take a shot and make a precise pass on AT compared to NT. Interestingly, 47 of the 72 male players reported subjectively that it was physically and technically more demanding to play on AT compared to NG. Only two players reported that it was less physically demanding. In contrast, the study found only small differences in running activities between surfaces. The discrepancy between the running activities and subjective impressions suggested that further research is required to include blood lactate concentration and heart rate responses during games on contrasting surfaces (Andersson et al., 2008).

The perceived effort was measured following 16 recreational soccer players performing small sided 5-a-side soccer matches on AT, asphalt, and sand surfaces sand (Brito et al., 2012). Results showed that players found playing 5-a-side soccer matches less demanding on asphalt as their perceived effort rating was lower on asphalt than on AT and sand (Brito et al., 2012). No associations were found between the physiological responses during the small-sided games and the visual analogue scale (VAS) questionnaires (a self-report measure consisting of a 10 cm line with a statement at each end representing one extreme

of the dimension being measured). The authors suggested that recreational players perceived the demands of a soccer match were related to external loads (ability/difficulty to run) rather than internal loads (physiological responses). The authors suggested that further research is required to understand the differences in perceived exertion during recreational soccer matches played on different surfaces.

Zanetti (2009) investigated amateur soccer player's preferences and opinions of playing on AT. Results revealed favourable feelings towards AT compared to NG. The reasons for this included NGPs being dry and hard during the summer months and frozen and muddy in the winter months. Sanchez-Sanchez et al., (2014) measured player perceptions performing physical tests (RSA) on AT systems with different mechanical properties. No physiological differences were found between the AT surfaces, but players felt more comfortable on the more rigid and harder AT surface.

Poulos et al., (2014) studied soccer player's perceptions towards the effect of surface-related factors and physical recovery resulting from playing soccer on AT and NG. Findings demonstrated the majority of players found playing on AT resulted in greater joint and muscle soreness and it took more time to recover when compared to NGPs. Three surface mechanical properties were identified by the players (hardness, friction, and the metabolic cost) as important factors in surface related research and key phrases were produced (table 2.9.).

Table 2.9: Key phrases for mechanical group comments (adapted from Poulos et al., 2014).

Group	Key phrases
Hardness	The following are "key phrases" in the responses that corresponded with this surface property:
	"Too hard", "hard impact", "unforgiving surface", "pounds on joints", "no give in ground", "tougher surface", "firm surface", "poor shock absorption"
Friction	The following are "key phrases" in the responses that corresponded with this surface property:
	"studs/foot get stuck", "no give", "feet stick", "cleats do not slide", "cleats get caught"
Metabolic cost	The following are "key phrases" in the responses that corresponded with this surface property:
	"requires more physical effort", "running in sand", "work harder", "heavy surface", "body gets tired faster", "fatigues body"

Equivocal findings exist when trying to ascertain the perceptions of players when playing soccer on different playing surfaces in terms of SH, friction, metabolic cost, and perceived exertion (Poulos et al., 2014). Player perceptions need to be studied further to determine which factors are important for the player when it comes to playing surface (Roberts et al., 2014). Therefore, a focus group (FG) will be used to capture players and coaches perceptions of playing soccer on soft vs. hard NG in the present project.

2.6. Focus groups

When focussing on the same research question or phenomenon, the combined application of multiple research methodologies is a form of triangulation that allows the researcher to gain numerous perspectives on the conclusions made from the data collected (Patton, 2002). Qualitative research should provide a comprehensive and precise description of the research allowing the reader to draw upon comparable conclusions following the systematic research process that led to findings of the analysis without any influence from their personal feelings concerning the subject matter (Dale, 1996).

Focus groups (FGs) involve the interaction between participants where they highlight and express their views, beliefs and values about a topic and the language they use (Kitzinger, 1994; Kitzinger, 1995). Interaction allows participants to question one-another, to reconsider and re-evaluate their own understanding of their experiences related to the subject and should not be undervalued (Gibbs, 1997). Giving the opportunity to work collaboratively with participants and researchers from similar backgrounds can make the participants feel empowered and valued as experts (Goss & Leinbach, 1996). The recommended number of participants per FG is typically between 4-15 (MacIntosh, 1981; Kitzinger 1995; Goss & Leinbach 1996) and usually last from 1-2 hours, and it is often good practice to run a session in a neutral location to avoid either positive or negative associations with a building or institution (Powell and Single, 1996).

It has been argued that FGs may provide quality controls on those taking part, as participants tend to provide balances and checks on one another to curb extreme or false views (Patton, 2002). It is deemed 'good practice' to record notes to help in determining the meaning of the observed activities and events to support and assist answering the research questions during data analysis stages (Bogdan & Biklen, 2007; Pitney & Parker, 2009). Krueger and Casey, (2000) suggest the environment needs to be comfortable for the participant and the principal investigator (PI) needs to show respect and unconditional positive regard through being non-judgemental, genuine, and understanding. Due to the PI being involved during qualitative inquiry, biases could hinder gaining accurate information, therefore, the PI must "bracket out" any biased opinions and beliefs about the research topic (Patton, 2002). Patton (2002) used probing questions to clarify information and attain further expansions on experiences. A methodological approach devised by Patton (2002) was adopted for the qualitative data analysis section in the present project. The procedure consists of four stages including:

(1) approaching the FG: (a) transcribing the script and (b) grasping an understanding of the FG.
(2) focusing and bracketing the data.
(3) reducing any phenomenological findings by eliminating overlapping, repetitive, and irrelevant data and verifying the data elimination.
(4) release meanings by forming categories, identifying, and describing themes.

During the research design and implementation stage of qualitative research, it is imperative to incorporate strategies to improve the credibility of a study. There seem to be no universally accepted criteria and terminology used to evaluate qualitative research to enhance the credibility of a study, although criteria do exist demonstrating scientific rigour (Noble and Smith, 2015). Lincoln and Guba (1985) proposed criteria and alternative terminology to establish the credibility of qualitative research. The criteria included the reliability (ensuring the trustworthiness by which the methods have been carried out making transparent, and clear decisions where a PI should be able to arrive at comparable findings. Validity has been defined by many researchers and Hammersley (1990; 57) insists 'by validity I mean …the extent to which an account accurately represents the social phenomena to which it refers' and similarly Bryman (2008; 31) defines validity as 'integrity of the conclusions that are generated from a piece of research.'

Reliability relates to the consistency within the employed analytical procedure, whilst validity refers to the precision in which the findings accurately reflect the data and the application and integrity of the methods undertaken (Long and Johnson, 2000). Patton (2002) highlighted that for a study to be reliable, all participants must be considered trustworthy. Reliability refers to the ability to produce consistent results and findings across time and people. Considering trustworthiness is vital to ensure that qualitative research is reliable. The extent to which a transcript and theme truly reflect the participant's experiences provides a measure of reliability (Yancey et al., 2011). To determine the reliability during the data collection and analysis in the present project, the following questions were used: (a) did the descriptions capture the participants' experience?; (b) did the structure match the participants' experience?; (c) did the structure emerge from the data?; and (d) did others see the description? Guba (1981) proposed that qualitative research should consider four criteria including a) credibility (internal validity); b) transferability (external validity and the generalisability); c) dependability (reliability) and d) confirmability (objectivity) (refer to table 2.10.).

In summary, the FG used in the present project was carefully devised to ensure the methodological procedures highlighted by Guba (1981) and Patton (2002) were adopted

to enhance the quality and generalisability of the findings. Also, by assessing the relationship between the key themes of the FG with the findings from the quantitative studies in the project could provide a more comprehensive answer to the research question.

Quality criterion (credibility: 11 points met but Transferability: point 1; dependability: points 1 and 2; confirmability: points 1-to-4)

Table 2.10: Illustrates the four criteria essential for qualitative research (adapted from Guba, 1981).

Quality Criterion	Possible provision made by researcher
Credibility	1 - Adoption of appropriate, well recognised research methods 2 - Development of early familiarity with culture of participating organisations 3 - Random sampling of individuals serving as informants 4 - Triangulation via use of different methods, different types of informants and different sites 5 - Tactics to help ensure honesty in informants 6 - Iterative questioning in data collection dialogues 7 - Negative case analysis 8 - Debriefing sessions between researcher and superiors 9 - Peer scrutiny of project 10 - Use of "reflective commentary" 11 - Description of background, qualifications and experience of the researcher 12 - Member checks of data collected, and interpretations/theories formed 13 - Thick description of phenomenon under scrutiny 14 - Examination of previous research to frame findings
Transferability	1 - Provision of background data to establish context of study and detailed description of phenomenon in question to allow comparisons to be made
Dependability	1 - Employment of "overlapping methods" 2 - In-depth methodological description to allow study to be repeated
Confirmability	1 - Triangulation to reduce effect of investigator bias 2 - Admission of researcher's beliefs and assumptions 3 - Recognition of shortcomings in study's methods and their potential effects 4 - In-depth methodological description to allow integrity of research results to be scrutinised 5 - Use of diagrams to demonstrate "audit trail"

2.7. Summary of Literature

The broad nature of the literature review highlights a number of concepts and factors that need to be considered when investigating the influence of SH on soccer performance and game characteristics. A multitude of physical and technical data exists covering a range of levels, players, competitions, and playing positions related to soccer. The magnitude of soccer as a sport and the importance of NG surfaces used for soccer performance has been highlighted, yet the variability, consistency, deformation, and condition of NG can vary considerably at amateur-level soccer (Stiles et al., 2009). The meteorological and environmental variables seem to either directly or indirectly influence soccer performance. Many endorsed testing procedures are available to measure a number of different physical or psychological variables to provide an objective assessment of how NGSH influences soccer performance. Therefore, a research project combining both physical and psychological investigation through the medium of a mixed-method, multidiscipline design will help yield information applicable to understanding how SH influences soccer performance and game characteristics at amateur-level.

CHAPTER 3. GENERIC METHODS

3.1. Introduction

The present chapter initially details the generic procedures employed in terms of handling data securely and ensuring participant safety (section 3.2.). Section 3.2.1. details the procedures completed prior to testing and including permission to gain access to the required facilities, participant selection process, informed consent (Appendices 11.1), informed assent (Appendices 11.1), physical activity readiness questionnaires (PAR-Q), and ethical approval. The procedure to select each NGP used in studies two and three is covered in section 3.2.2. All procedures related to the objective measurement of SH in relation to studies one, two, and three are discussed in section 3.2.3.

3.2. Generic method section

Due to the nature of the project, child protection considerations were required due to some participants being under-eighteen, therefore the principle investigator (PI) provided a current Disclosure and Barring Service (DBS) due to current work commitments in the educational and coaching field. The management of data obtained throughout the project was kept securely using password protected information technology (IT) and sensitively treated maintaining anonymity and only the PI had access to such data. All four studies (one-to-four) were approved by the Cardiff School of Sport, Research Ethics Committee (CSSREC) prior to any testing taking place (Appendices 11.3).

3.2.1. Procedures prior to testing

Studies one-to-three were quantitative in nature and fully supported by the soccer academy-level (amateur) and associated educational institution (College) and permission was granted to use its grounds and NGPs. Access and permission were also granted from a second educational institution (School) for the use of its NGPs. All participants were fully informed of the requirements of any involvement in each of the investigations

verbally and participation information sheets were provided (Appendices 11.2). Prior to any testing, mandatory pre-requisite tasks included obtaining informed consent, informed assent, physical activity readiness questionnaires (PARQ). Participants were required to perform maximal sprinting activity during studies one-to-three therefore it was imperative all were free from injury.

The participants were recruited based on the following criteria: that they were between 16-19 years of age, currently playing soccer competitively at College academy-level (amateur) level, outfield players, and available for the duration of testing for any involvement in any of the three physical studies. Initial contact was between the PI and the Director of Football of the College academy-level (amateur) team. Purposive sampling was used to recruit the participants and communication was direct between the PI and the players. Environmental risks included unsafe pitch conditions due to severe weather conditions (i.e., precipitation, frost, and strong wind), therefore, to minimise such risk, testing was only carried out with fair weather conditions.

3.2.2. Pitch selection

Initially, an array of NGPs were sourced in the local region (5-mile radius of Cardiff Met University) and pre-screening took place to classify "soft" and "hard" pitches potentially suitable for either study two or three. At this stage, the SH of each NGP was objectively measured to determine the mean SH (SH_{MEAN}). In this project, SH of each NGP was classified as either "Low", "Normal / Preferred" or "High" (table 2.5. benchmark ranges; Chivers and Aldous, 2004). For studies two and three, each pitch selected was monitored over a period of two months prior to any experimental procedures taking place to determine the circadian, seasonal, and weather influences on NGPs ensuring the surface behaviour, sensitivity, and SH remained consistent enough to run an 8 h experimental procedure. Prior to testing, each NGP selected for study two and three was assessed at various times of the day (morning, afternoon, and evening) to quantify and ensure SH remained consistent throughout the day.

For study one, pitch selection was not possible due to the nature of the experimental procedure analysing a soccer player during a competitive season where the league fixtures would determine the NGP played on. It was, therefore, decided to measure the SH of each pitch both pre-and-post-match and arrange the SH values of the 11 NGP into two clusters following completion of all matches, with five and six matches in each of the two clusters. The two clusters were termed "hard" (77.3 ± 10 Gmax) and "soft" (49.3 ± 6.0 Gmax) surfaces within the sample with SH ranging from 68-93 Gmax and 41-57 Gmax in the hard and soft surface clusters respectively. In studies two and three, NGSH was measured before and after the RSA, SSA, and SSP procedures. The mean SH in study two was 44.9 ± 10.8 Gmax on the soft pitch and 63.4 ± 18.5 Gmax on the hard pitch. The mean SH in study three was 51.6 ± 2.7 Gmax on the soft pitch and 89.2 ± 5.0 Gmax on the hard pitch.

3.2.3. Surface hardness measurements

Immediately prior to and following any competitive matches or any experimental procedures, a 2.25 kg Clegg Impact Hammer (CIH) (S.D. Instrumentation, Bath, United Kingdom) was used to objectively quantify playing surface hardness. CIH tests were performed five times on six individual sites on 11 v 11 size soccer pitches: (1) corner, (2) goalmouth, (3) area between halfway line and 18-yard box, (4) centre circle (5) wing, and (6) penalty area (figure 3.1: FIFA, 2012).

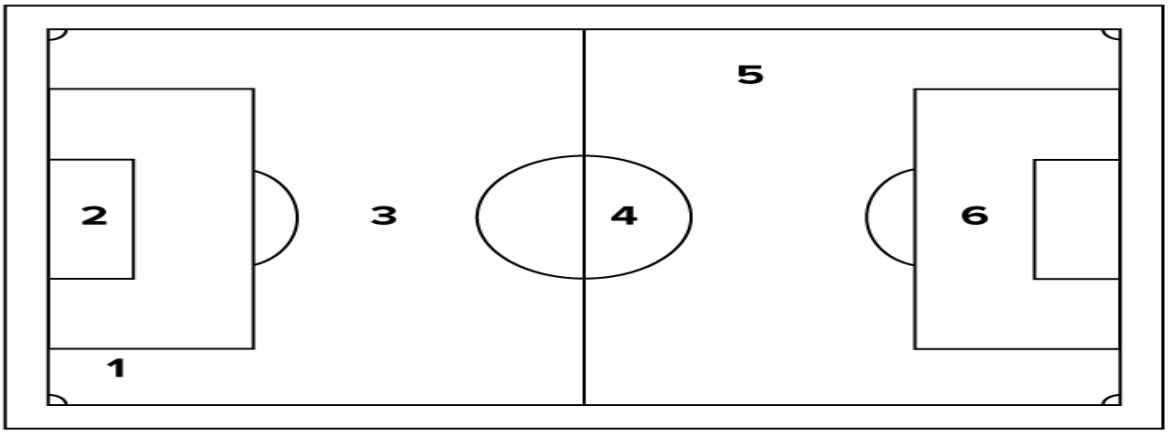


Figure 3.1: Six field test positions for quantifying SH with the CIH (adapted from FIFA, 2012).

CIH tests were not made on joints or inlaid lines. Within each designated CIH testing site each measurement was located on an untested area of grass where no surface deformation existed (within a 0.15 m^2 area) and the drop height of the hammer was 0.457 m which is a standard drop height for the 2.25kg CIH model (Clegg, 1992). The means ± sd. were taken to represent SH of five separate drops on each site and SH_{MEAN} of each pitch was calculated as a mean of the six sites (30 drops) both pre and post-match (60 drops in total). The CIH is a valid and reliable tool for discriminating between different levels of SH and endorsed by the Institute of Groundsmanship (IOG) and the Football Association (FA) (Clegg, 1976; Bell and Holmes, 1988; Saunders et al., 2011; FIFA, 2012). SH is defined as "the gravitational deceleration force of the impact measured in gravities (Gmax), with low numbers indicating less hardness and high numbers showing high hardness" (table 2.5.).

CHAPTER 4. STUDY 1 – MATCH PERFORMANCE CHARACTERISTICS

Study one explored the influence of NGSH on match performance characteristics through analysing performance measures during competitive soccer matches. The case study approach was incorporated to obtain valuable data on path changes, movements, and game events which aimed to inform the direction of subsequent empirical research studies in the project. The preliminary data from study one justified the use of a more controlled research design in study two. The majority of chapter four is an exact copy of the peer-reviewed publication related to study one (Appendix 11.4) apart from only a few minor amendments.

Abbreviation:	Nomenclature:
RSA	Repeated Sprint Ability
SSP	Soccer simulation protocol
SSA	Steady State Activity
S-AR	Speed-Agility Run
HR	Heart Rate
NGPs	Natural Grass Pitches
AT	Artificial Turf
ES	Effect Size

Abstract – Study One

Natural grass surface characteristics can vary considerably at amateur-level sport which can influence technical skills and movements. Surface hardness and human responses need to be objectively measured simultaneously to fully understand movement responses and subsequent physical performance on different playing surfaces. One academy-level (amateur) u-19 soccer player played in eleven matches (five soft pitches and six hard pitches), recorded over 6-months. All matches were competitive and officiated. Data were only included if the participant had played for > 60 minutes. All matches were recorded using a two-dimensional video camera and analysed using Sports Code Elite software. Three analyses were carried out for each match (movements, on-the-ball game-related skills, and turns). Surface hardness was measured using a Clegg Impact Hammer and

pitches were categorised into either hard or soft groups (67.7 to 93.0 Gmax and 41.4 to 58.3 Gmax respectively). There was a greater frequency per minute of each type of turn performed on the soft pitch vs. hard pitch except for linear turns. The frequency per minute of high intensity shuffling was greater (d = 1.2) on the soft pitches (0.12±0.02) when compared to hard pitches (0.07±0.04). The similar duration of high intensity shuffling events on each surface combined with the higher frequency per minute on the soft pitches meant that the percentage of time spent performing high intensity shuffling movements was also greater (d = 1.2) on the soft pitches (0.4±0.1 s) when compared to hard pitches (0.2±0.1 s). The frequency per minute of running was greater (d = 1.1) on the soft pitches (0.65±0.15) when compared to the hard pitches (0.49±0.15). The frequency per minute of low and high intensity activities was 0.23 and 0.24 greater (d = 1.1 and 1.2 respectively) on soft pitches when compared to the hard pitches and both intensities. A greater frequency per minute of sharp right turns (d = 1.4) was performed on soft pitches (0.66±0.03) compared to hard pitches (0.52±0.08). This consequently led to a greater frequency per minute of turns in general performed on the soft pitches (1.97±0.32) than hard pitches (1.65±0.30) (refer to figure 4.1.). There were no significant differences for any of these variables when compared on the two surfaces, but more aerial challenges (d =1.5) and more headed clearances (d =1.1) were made on the soft compared to hard pitches (0.09±0.04 and 0.02±0.02 vs. 0.04±0.03 and 0.01±0.01, respectively) (table 4.8). A greater frequency per minute of dribbling movements (d = 0.8) was performed on hard pitches (0.12±0.06) compared to soft pitches (0.07±0.05). To conclude, certain movements and game events were influenced by natural grass surface hardness during competitive soccer match-play.

Key words: soccer performance, academy-level (amateur) soccer, movements, game-related activity, path changes.

4.1. Introduction

Sporting performance and outcomes are affected by surface (Baker et al., 2001; Fernandez et al., 2006; Andersson et al., 2008; Stiles et al., 2009; Potthast et al., 2010; Poirier et al., 2011) and subtle changes in surface characteristics may affect a player's movement pattern, potentially disturbing their technical skills during competition (Dixon

et al., 2000). Soccer performance and movements can change due to changes in the turf (Potthast et al., 2010) with the majority of soccer competition being played on NG (Stiles et al., 2009). Previously, NG alone has not attracted much research attention therefore, a case study approach was introduced for study one based on a cost-benefit analysis of alternative approaches, and to develop new testable, and empirically valid practical and theoretical insights (Gummesson, 2005; Eisenhardt and Graeber., 2007). In addition, the case study aimed to inform the direction of subsequent research within this study (Halinen and Tornroos., 2005; Vissak, 2010).

4.2. Experimental methods – experimental set-up, procedure, and data analysis – study 1

4.2.1. Participants

One male (aged 18.1 years at the start of the study; stature 1.77 m; and body mass 75.5 kg), central-midfield soccer player from an under-nineteen College academy-level (amateur) team participated in study one. The participant's regular activities included one academy-level College league match and two one-hour training sessions per week. The player was informed of the procedure and purpose of the study and gave written informed consent to participate. The study gained approval prior to starting through the Research Ethics Committee of Cardiff School of Sport at Cardiff Metropolitan University (CSSREC). The player's performance was video recorded in 11 matches for the present study.

4.2.2. Recording player performance

Eleven matches were recorded over a 6-month period. All matches were competitive and officiated. Data were only included if the participant had played for > 60 minutes. The participant was asked to perform naturally, with no alterations to performance due to the observation. A two-dimensional video camera (Sony HDR-XR155E digital video camera, Japan) was used to record video footage of the player's performance in all 11 matches, set up on the halfway line. All matches were recorded and analysed by the same experienced observer.

4.2.3. Surface hardness

The total mean SH of the hard pitches (77.3 ± 10.0 Gmax) was greater when compared to the soft pitches (49.3 ± 6.0 Gmax) which confirmed conditions fell within the 'normal' and 'low' soccer categories of SH respectively (Chivers and Aldous, 2004). Pitch area one (corner) was the hardest area of the soft pitches (50.7 Gmax) and area five (wing) was the softest area of the hard pitches (60.8 Gmax) which confirmed a 10.1 Gmax difference.

Table 4.1. Surface hardness of the six areas (figure 3.1.) of the soft and hard pitches used in study one (means±sd.).

Pitch Area	Hard Pitch (Gmax)	Soft Pitch (Gmax)	Surface Hardness Diff. (Gmax)
1 – corner	64.9 ± 3.7	50.7 ± 1.3	14.2*
2 – goalmouth	94.3 ± 2.8	48.9 ± 2.4	45.4*
3 - halfway line and 18-yard box	67.2 ± 1.9	50.2 ± 0.5	17.0*
4 - centre circle	88.0 ± 3.2	48.4 ± 2.0	39.6*
5 – wing	60.8 ± 1.9	50.0 ± 0.7	10.8*
6 - penalty area	88.5 ± 3.8	47.7 ± 2.0	40.8*
Total Pitch	77.3 ± 10.0	49.3 ± 6.0	28.0*

*Difference between surface hardness ($P<0.05$).

4.2.4. Variables

The study included three sets of dependent variables; movements, on-the-ball game-related skills, and turns. The movements were based on the definitions of the categories used by Huey et al. (2001). However, a limitation of Huey et al.'s (2001) approach is that all shuffling / skipping movement was included in a single movement category that was counted as high intensity activity. This led to an over-estimation of the amount of high intensity activity performed by players. Therefore, separate low intensity and high intensity shuffling movement classes are included in the system used in the current investigation. Huey et al. (2001) also merged the running and sprinting movements into

a single movement category. This prevents analysis of the two movements separately which is problematic because recent research into soccer work-rate has separated sprinting from high speed running (Di Salvo et al., 2009; Gregson et al., 2010). Most key incidents of a match happen during high-intensity activity, therefore separating running and sprinting in the current investigation may provide valuable information on how both movements compare when playing on soft and hard pitches. There is a separate set of variables for on-the-ball events used in the current investigation. However, the frequency of these events was counted rather than the short durations of such events being timed. Dribbling can be performed over much longer periods than some of the more "instantaneous" events and, therefore, dribbling with the ball is distinguished from movement without the ball and other on-the-ball activity within the movements recorded in the current investigation. The guidelines for recognising the different movements are as follows (Huey et al., 2001; Bloomfield et al., 2004):

- Stationary – this included standing, sitting, stretching, or lying in a prone position.
- Walking – walking forwards.
- Backing – walking in a backwards or sideways direction.
- Jogging – slow running movement without obvious effort or acceleration.
- Running – running with obvious effort excluding sprinting.
- Sprinting – running with all-out sprinting effort.
- Low Intensity Shuffling – shuffling backwards or sideways or on-the-spot shuffling movement with the feet performed at low or moderate intensity.
- High Intensity Shuffling – shuffling backwards or sideways or on-the-spot shuffling movement with the feet performed at high intensity.
- Game-related activity – ball contact or challenging for the ball during ball-in-play time (excluding dribbling).
- Dribbling – moving in possession of the ball during ball-in play time.

On-the-ball game-related skill variables were collected separately from movement data. Therefore, dribbling was not included. The game-related events included are listed below:

- Pass – playing the ball with feet with the intention of the ball being received by a team-mate, including crosses.
- Headed pass – playing the ball with the head with the intention of the ball being received by a team-mate.
- Clearance – playing the ball with feet with the primary intention of the ball exiting the defensive third.
- Headed clearance – playing the ball with the head with the primary objective of the ball exiting the defensive third.
- Shot – playing the ball with feet with the intention of scoring a goal.
- Headed shot – playing the ball with the head with the intention of scoring a goal.
- Tackle – an attempt to dispossess an opponent with the ball using the feet.
- Aerial challenge – an attempt to play the ball with the head while an opponent is also competing for the ball in the air.

Turns and path changes were recorded if they were performed at moderate or high intensity. Turns and path changes were then categorised into five types including sharp right, sharp left, V-cuts (Robinson et al., 2011), smooth turns, and linear turns (Robinson et al., 2008) and classified as either moderate or high intensity. Turn definitions were characterised as follows:

- Smooth turn – where the player slightly changed the path travelled while turning, similar to an arced run except the radius was less than 1m.
- The sharp path changes counted in the present study used the definitions made by Robinson et al. (2011) and included some movement at moderate intensity or higher during each path change. Unlike smooth turns, sharp path changes involved straight-line movement prior to and after the path change. Movement was considered to be sufficiently straight-line movement if the direction of movement deviated from the average direction during the period of interest by 15°

or less. Sharp path changes to the left (right) were recorded when the average direction of movement after the path change was 45° to 135° to the left (right) of the average direction of movement before the path change.

- Linear turn – where the player made a turn while continuing to move in the same path of movement, possibly with a slight change of path of less than 45° to the left or right. The player's body may have been facing forward, backwards, left, or right with respect to the path of movement before the linear turn and facing a different aspect afterwards.
- V–cut path changes –where the player moved in a straight line before and after the path change, where the player changed path to travel back in the direction from where they were travelling. Thus, the angle of path change was greater than 135° degrees to the left or right (Robinson et al., 2011).

4.2.5. Recording Systems

Three analyses were carried out for each match. Firstly, path changes and turns were manually recorded using Microsoft Excel noting the time, type, intensity, and movement before and after each path change and turn. Match analysis software was used to separately register the movements and then game events performed in each match (Sports Code Elite, version 5.1.9, Sportstec International, Warriewood, New South Wales, Australia) according to the definitions and guidelines described earlier.

4.2.6. Reliability

Two researchers independently used the computerised system for movement timing and game events and the manual data collection process for identifying path changes performed by the player. The timed version of the Cohen's kappa coefficient statistic was calculated after merging the timelines of movements entered in studio-code. The kappa statistic was used to test inter-rater reliability ensuring the data collected correctly represented the variables measured. Inter-rater reliability refers to the measurement of the extent to which data collectors assign the same score to the same variable (McHugh, 2012). Table 4.2. shows the proportion of time recorded for each movement by each of the observers. The proportion of time where the observers agreed on the movement being

performed, P_0, was 0.714. When the proportion of time the observers are expected to agree by chance, P_C, of 0.405 was considered, the kappa value was 0.519 which represents a moderate strength of inter-observer agreement (Viera and Garrett, 2005).

For the reliability study, the two observers did not merely tally game events, turn and path change types, but also recorded the video times at which these occurred. This allowed the kappa statistic to be calculated for the variables involved. There were occasions where one or other of the two observers recorded a game-related event while the other did not. This required a "None" event to be included, meaning that the kappa statistic here was particularly stringent because "None" could be included in disagreements but not within agreements. Table 4.3. shows that there were 58 occasions where the two observers agreed that some event was performed by the player. There were 7 additional events being recorded by Observer 1 and 10 additional events being recorded by Observer 2. Of the 58 occasions where the observers agreed that some event was performed, there were only three occasions where they disagreed on the type of event. The overall proportion of agreement, P_0, was 0.733 with an expected agreement by guessing, P_C, of 0.230. Therefore, the kappa value was 0.654 which represents a good strength of inter-observer agreement between the two observers.

Table 4.2. Time [s] recorded for different movements by two independent operators.

Observer 1	Observer 2										
	Stationary	Walking	Backing	Jogging	Running	Sprinting	Low Int Shuffling	High Int Shuffling	Game-related activity	Dribbling	Total
Stationary	272.8	250.6	30.3	10.4	6.7	0.0	3.4	0.1	2.9	0.0	577.3
Walking	60.5	2343.4	16.5	125.8	35.2	3.1	7.8	1.1	2.4	0.0	2595.7
Backing	20.1	58.7	58.7	6.5	6.7	1.0	0.7	0.1	2.1	0.0	154.5
Jogging	0.1	156.1	5.7	455.0	16.9	1.1	31.5	2.3	10.3	2.0	681.1
Running	1.1	31.1	3.4	6.2	13.9	0.0	1.3	1.0	3.5	0.0	61.5
Sprinting	5.0	24.7	2.1	9.4	11.0	3.4	6.3	0.9	9.5	0.0	72.2
Low Int shuffling	0.1	26.2	0.0	87.2	9.4	2.0	71.2	19.7	8.3	0.8	224.9
High Int shuffling	0.0	1.8	0.0	1.0	0.0	0.0	1.3	1.4	1.1	0.0	6.5
Game-related activity	7.0	41.3	1.3	21.4	7.1	0.1	15.8	6.7	28.0	0.3	128.9
Dribbling	0.0	4.7	0.0	6.5	1.1	0.0	4.0	0.5	30.0	4.7	51.6
Total	366.6	2938.6	117.9	729.4	108.0	10.6	143.3	33.7	98.1	7.9	4554.0

Table 4.3. Game-related events recorded by the two independent observers.

Observer 1	Observer 2									
	Pass	Clearance	Headed Pass	Headed Clearance	Shot	Headed Shot	Tackle	Aerial Challenge	None	Total
Pass	25	1							6	32
Clearance		1								1
Headed Pass			6						1	7
Headed Clearance										0
Shot					2					2
Headed Shot										0
Tackle		1					14			15
Aerial Challenge			1					7		8
None	1	2		1			3	3		10
Total	26	5	7	1	2	0	17	10	7	75

Table 4.4. shows that there were 127 occasions where the two observers agreed that some turn or path change was performed by the player. There were 17 occasions where such events were only recorded by Observer 1 and 40 occasions where such events were only recorded by Observer 2. Observer 1 recorded almost twice as many linear path changes as Observer 2 while Observer 2 recorded a greater frequency of the remaining turn and path change events. These disagreements limited P_0 to 0.538. The expected agreement by chance, P_C, was 0.173 meaning that the kappa value was 0.442 which represents a moderate strength of inter-observer agreement.

Table 4.4. Turns and path changes recorded by the two independent observers.

Observer 1	Observer 2						
	Left Sharp	Linear	Right Sharp	Smooth	V-cut	None	Total
Left Sharp	29		1	1	3	3	37
Linear	4	16	2	2	2	9	35
Right Sharp		1	25	1	1	3	31
Smooth	7		1	20			28
V-cut	1			1	9	2	13
None	12	1	13	13	1		40
Total	53	18	42	38	16	17	184

Most disagreements were occasions where only one of the two observers recorded a turn or path change. These errors have been accounted for in the calculation of the kappa value for the type of turn or path change. Therefore, the kappa values for the direction of movement before, the direction of movement after, and the intensity with which the turn or path change was performed were calculated using 127 occasions where both observers agreed that some turn or path change had been performed. Table 4.5. and Table 4.6. show the number of times different directions were recorded for the movement before and after events respectively. The kappa values for the direction of movement performed before and after events were 0.754 and 0.668 respectively which represent good strengths of inter-observer agreement. Table 4.7. shows the intensity recorded for the 127-agreed turn and path change events by the two

independent observers. The kappa value of 0.493 represented a moderate strength of inter-operator agreement.

Table 4.5. Movement performed before turns and path changes recorded by the two independent observers.

Observer 1	Observer 2				
	Backwards	Forwards	Left	Right	Total
Backwards	2	1	2		5
Forwards		106	3		109
Left		2	5		7
Right				6	6
Total	2	109	10	6	127

Table 4.6. Movement performed after turns and path changes recorded by the two independent observers.

Observer 1	Observer 2				
	Backwards	Forwards	Left	Right	Total
Backwards	2	1	2		5
Forwards		106	3		109
Left		2	5		7
Right				6	6
Total	2	109	10	6	127

Table 4.7. Intensity of turns and path changes recorded by the two independent observers.

Observer 1	Observer 2		
	High	Moderate	Total
High	29	14	43
Moderate	15	69	84
Total	44	83	127

4.2.7. Data Analysis

The matches had various durations with all being over 60 minutes, therefore all frequency variables (frequency: the total number of instances a particular mode was coded over the duration of a match) were converted to frequencies per 90 minutes (variable frequency x 90 x 60 / total match time (minutes)). Means ± sd. were calculated for the frequency per minute of all game-related events, turns, and the times and frequencies of movements in soft and hard pitches. Data analyses were completed using SPSS (version 17, SPSS, Chicago, USA), with the level of significance calculated using a series of independent samples t-tests ($P<0.05$). Effect sizes (ES; Cohen's d) were calculated (trivial 0.2, medium 0.5, and large ≥ 0.8) (Thomas et al., 1991; Coe, 2002) when interpreting the practical meaningfulness of the surface effect as only one set of five and one set of six values were collected for each variable making statistical significance difficult to obtain.

4.3. Results– study one

4.3.1. Introduction

The quantitative results generated from study one have been presented using text, graphs, and tables to highlight any meaningful and significant differences in section 4.3. The inclusion that the player needed to play for ≥60-minutes per match meant not all matches were the same duration. All frequencies per 90-minutes were converted to frequencies per minute. This was done by dividing the frequency by the match duration (mins). This meant that in tables 4.8., 4.9. and 4.10. two-decimal places were used due to the very low frequencies per minute of some of these events.

4.3.2. Movements

The frequency per minute, mean duration, and the percentage of match time spent performing each movement are shown in table 4.8. The majority of match time (>67%) was spent walking both on soft and hard surfaces. The frequency per minute of high intensity shuffling was greater (d = 1.2) on the soft pitches (0.12±0.02) when compared to hard pitches (0.07±0.04). The similar duration of high intensity shuffling events on each surface combined with the higher frequency per minute on the soft pitches meant that the percentage of time spent performing high intensity shuffling movements was also greater (d = 1.2) on the soft pitches (0.4±0.1 s) when compared to hard pitches (0.2±0.1 s). The frequency per minute of running was greater (d = 1.1) on the soft pitches (0.65±0.15) when compared to the hard pitches (0.49±0.15). The frequency per minute of low and high intensity activities was 0.23 and 0.24 greater (d = 1.1 and 1.2 respectively) on soft pitches when compared to the hard pitches and both intensities.

Table 4.8: Frequency per minute, mean duration and percentage time spent performing different movements (mean±sd.).

Movement	Frequency per minute				Mean duration (s)				%Time			
	Hard	Soft	Cohen's d	P	Hard	Soft	Cohen's d	P	Hard	Soft	Cohen's d	P
Stationary	0.88±0.27	0.88±0.35	0.1 (TRIVIAL)	0.97	5.3±0.9	5.3±1.1	0.0 (TRIVIAL)	0.99	8.0±3.1	7.0±1.7	0.4 (TRIV/MED)	0.70
Walking	2.83±0.50	3.26±0.85	0.5 (MEDIUM)	0.40	14.9±3.3	13.3±2.2	0.6 (MEDIUM)	0.35	67.9±3.8	67.3±3.2	0.2 (TRIVIAL)	0.87
Backing	0.56±0.10	0.57±0.18	0.1 (TRIVIAL)	0.90	3.3±0.6	3.0±0.6	0.5 (MEDIUM)	0.49	3.1±0.9	2.7±0.8	0.5 (MEDIUM)	0.60
Jogging	1.46±0.73	1.74±0.41	0.5 (MEDIUM)	0.52	8.5±6.6	5.1±0.6	0.9 (LARGE)	0.32	13.9±2.1	15.2±4.1	0.4 (TRIV/MED)	0.72
Sprinting	0.23±0.08	0.22±0.06	0.1 (TRIVIAL)	0.91	3.1±0.4	2.3±1.1	1.1 (LARGE)	0.25	1.2±0.5	1.0±0.5	0.5 (MEDIUM)	0.49
Running	0.49±0.15	0.65±0.15	1.1 (LARGE)	0.09	3.1±0.2	3.0±0.4	0.3 (TRIV/MED)	0.08	2.5±0.7	2.9±0.5	0.5 (MEDIUM)	0.49
Low Int shuf	0.48±0.10	0.59±0.43	0.5 (MEDIUM)	0.09	1.7±0.3	2.4±2.0	0.6 (MED/LAR)	0.17	1.4±0.4	1.6±0.6	0.5 (MEDIUM)	0.49
High Int shuf	0.07±0.04	0.12±0.02	1.7 (LARGE)	0.16	1.8±0.3	1.7±0.3	0.3 (TRIV/MED)	0.79	0.2±0.1	0.4±0.1	1.2 (LARGE)	0.13
Dribbling	0.12±0.06	0.07±0.05	0.8 (LARGE)	0.61	3.2±0.8	2.5±0.7	0.9 (LARGE)	0.46	0.6±0.3	0.4±0.3	0.8 (LARGE)	0.66
Game-related	0.45±0.14	0.56±0.19	0.5 (MEDIUM)	0.06	1.8±0.4	1.8±0.4	0.1 (TRIVIAL)	0.60	1.4±0.6	1.6±0.6	0.4 (SM/MED)	0.21
Low Intensity	1.02±0.15	1.25±0.19	1.1 (LARGE)	0.26	56.9±10.7	47.5±6.5	1.2 (LARGE)	0.23	94.3±1.1	94.0±0.6	0.5 (MEDIUM)	0.26
High Intensity	1.00±0.15	1.24±0.19	1.2 (LARGE)	0.37	3.5±0.4	3.0±0.3	1.1 (LARGE)	0.56	5.7±1.1	6.0±0.7	0.3 (TRIV/MED)	0.63

4.3.3. Game skills

The frequencies of game skills performed per minute on softer and harder grass are shown in table 4.9. There were no significant differences for any of these variables when compared on the two surfaces, but more aerial challenges (d =1.5) and more headed clearances (d =1.1) were made on the soft compared to hard pitches (0.09±0.04 and 0.02±0.02 vs. 0.04±0.03 and 0.01±0.01, respectively). A greater frequency per minute of dribbling movements (d = 0.8) was performed on hard pitches (0.12±0.06) compared to soft pitches (0.07±0.05). The ball remained in play, on average, for 48 min on the hard surface compared to 52 min on the soft surface ($P<0.05$).

Table 4.9: Frequencies of game skills performed per minute (mean±sd.).

Skill	Harder	Softer	Cohen's d	P
pass	0.50±0.21	0.41±0.13	0.5 (TRIV/MED)	0.49
headed pass	0.10±0.06	0.11±0.04	0.0 (TRIVIAL)	0.86
headed clearance	0.01±0.01	0.02±0.02	1.1 (LARGE)	0.35
clearance	0.02±0.02	0.03±0.01	0.6 (MEDIUM)	0.36
shot	0.04±0.01	0.04±0.05	0.1 (TRIVIAL)	0.98
headed shot	0.01±0.01	0.00±0.00	0.7 (MED/LARGE)	0.43
tackle	0.27±0.10	0.25±0.06	0.4 (TRIV/MED)	0.74
aerial challenge	0.04±0.03	0.09±0.04	1.5 (LARGE)	0.09

4.3.4. Path changes

There was a greater frequency per minute of each type of turn performed on the soft pitch vs. hard pitch except for linear turns. A greater frequency per minute of sharp right turns (d = 1.4) were performed on soft pitches (0.66±0.03) compared to hard pitches (0.52±0.08). This consequently led to a greater frequency per minute of turns in general performed on the soft pitches (1.97±0.32) than hard pitches (1.65±0.30) (figure 4.1.). The player was right footed and made more sharp path changes to the left which would involve pushing off with the dominant right leg. This was the case on both surfaces, but the difference was much more pronounced on the hard pitches (table 4.10.).

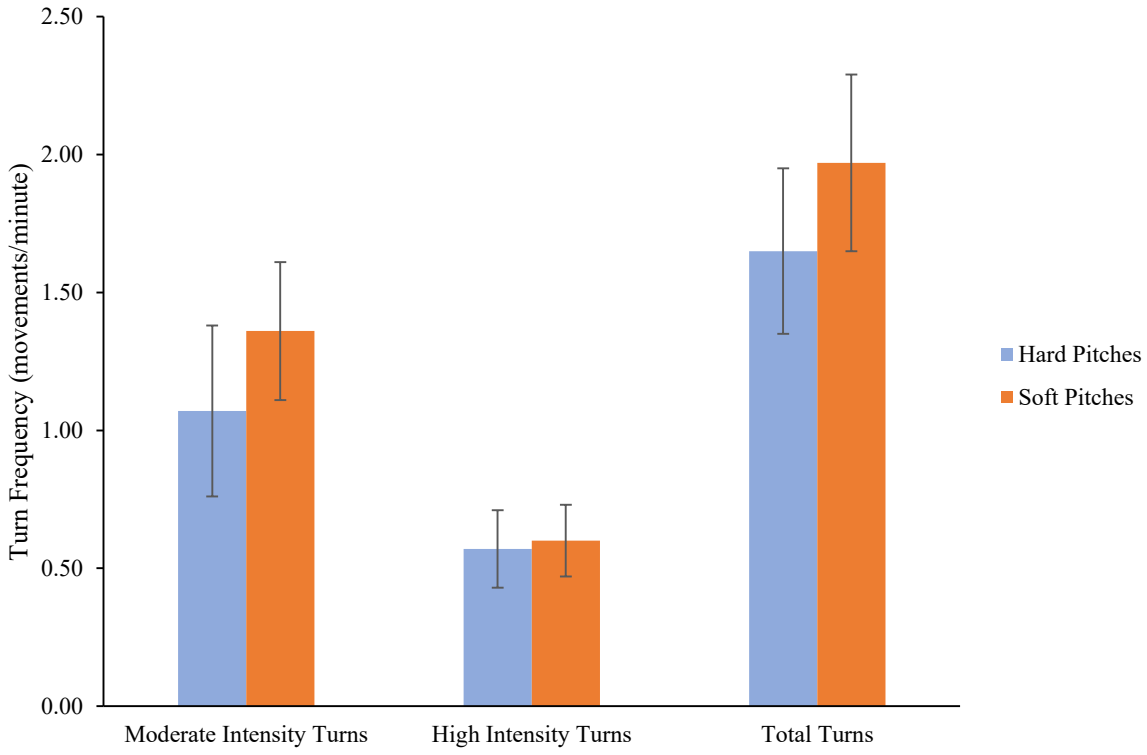


Figure 4.1: Illustrates the moderate, high, and total turn frequency per minute on the hard (blue line) and soft pitches (orange line) (means ± sd.).

Table 4.10: Frequency of path changes performed per minute (mean±sd.).

Type	Hard Pitch	Soft Pitch	Cohen's d	P
Moderate intensity turns	1.07±0.31	1.36±0.25	0.8 (LARGE)	0.18
High intensity turns	0.57±0.14	0.60±0.13	0.1 (TRIVIAL)	0.70
Total turns	1.65±0.30	1.97±0.32	0.7 (MED/LARGE)	0.18
Right sharp	0.52±0.08	0.66±0.03	1.4 (LARGE)	0.01
Left sharp	0.62±0.12	0.67±0.14	0.2 (TRIVIAL)	0.60
Smooth	0.28±0.11	0.38±0.13	0.5 (MEDIUM)	0.28
Linear	0.15±0.04	0.14±0.07	0.1 (TRIVIAL)	0.88
V-cut	0.08±0.02	0.12±0.06	0.7 (MED/LARGE)	0.33

There was a greater frequency per minute of moderate intensity turns (d = 0.8) performed on the soft pitches (1.36±0.25) compared to the hard pitches (1.07±0.31) (figure 4.2.). There was a greater frequency per minute of smooth turns (d = 0.5) performed on the soft pitches (0.38±0.13) compared to the hard pitches (0.28±0.11) (figure 4.2.). There was a greater

frequency per minute of V-cut turns (d = 0.7) performed on the soft pitches (0.12±0.06) compared to the hard pitches (0.08±0.02) (figure 4.2.).

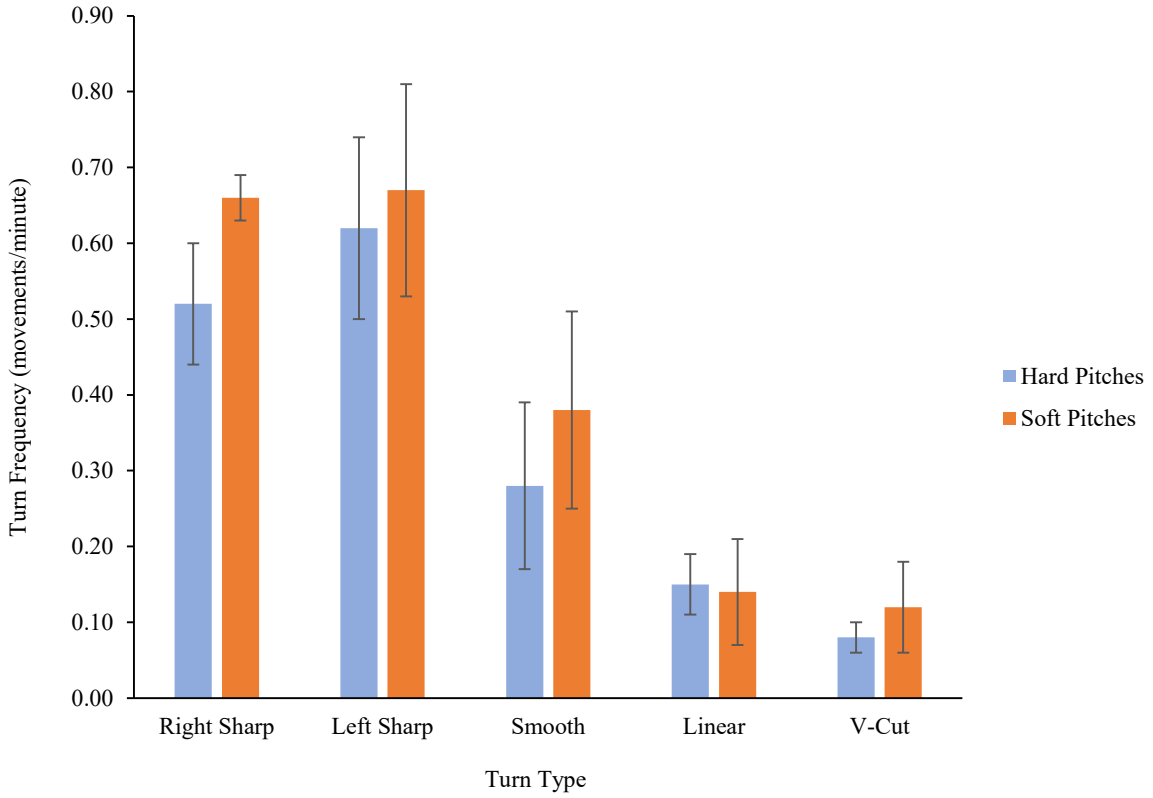


Figure 4.2: Frequency per minute of all turn types on hard (blue line) and soft pitches (orange line) (means ± sd.).

4.4. Discussion

Study one aimed to compare soccer performances on surfaces of contrasting hardness and concurs with previous findings (Andersson et al., 2008; Potthast et al., 2010) suggesting that SH influences game activity and movements in soccer. The frequency of high intensity shuffling was significantly greater on the soft pitches when compared to hard pitches ($P<0.05$). More turns were performed on the soft pitches with medium to large effects for the differences in three (moderate intensity, right sharp, and V-cuts showing $d = 0.8$; 1.4; 0.7 respectively) of the turn types. It is debatable why these findings occurred. Perhaps the player had to work harder on the soft pitches with less traction, more absorption of impact forces, with more muscular force and energy expenditure needed (Zamparo et al., 1992). Maybe the player felt freer to move on so carried out more turns. The frequency of running instances was greater on the soft pitches which also led to the percentage of time spent running being greater on the soft pitches due to the duration of running instances being similar between the two types of surface. This combined with the knowledge that soft pitches increase energy demands from players (Zamparo et al., 1992) suggests that playing soccer on soft pitches could certainly be more physically demanding than on hard pitches. Potentially a higher energy restitution associated with a greater firmness of a surface may have caused a higher workload (defined as "the physical stress to which players are exposed" (Bangsbo, 2014) on the soft pitches (Kerdok et al., 2002; Katkat et al., 2009). A lower impact peak on the soft pitches may be attributable to the inability to produce force rapidly (McGhie and Ettema, 2013) which may have altered joint movement patterns (Hamill et al., 1992), influencing the vertical deformation (Sánchez-Sánchez et al., 2014) and increasing the eccentric muscle activity (Richie et al., 1993). There were also greater frequencies of low and high intensity periods on the soft pitches meaning high intensity activity was more intermittent on the soft pitches. Intermittent activity can elevate workload through short recoveries (Hughes et al., 2005). A laboratory study by Hughes et al. (2005) revealed that repeated 6 s bursts lead to higher heart rate response, lactate accumulation, and reduced power output when performed every 25 s rather than every 45 s or 55 s. The current investigation revealed that the mean duration of bursts of high intensity activity was 3.0 s with average recovery periods of 47.5 s on soft pitches, while the corresponding figures on hard pitches were 3.5 and 56.9 s. These recovery durations are comparable with the two longest recovery durations studied by Hughes et al. (2005) where

there was no significant difference in heart rate response or blood lactate accumulation, but performance declined. However, in soccer performance, not all recoveries are of the average duration. Therefore, the shortest recovery periods experienced on the soft pitches could lead to fatigue more than the shortest recovery periods experienced on the hard pitches.

More than double the number of aerial challenges (0.09±0.04 compared 0.04±0.03 per minute; d = 1.5) and a greater number of headed clearances (0.02 compared to 0.01 per minute; ES = 1.1) were performed on the soft pitches. However, a greater number of passes were performed per minute on the hard pitches (0.50 ± 0.21; d = 0.5). An explanation may be that the hard pitches, with less precipitation and deformation, attracted a shorter passing game on the surface compared to tactics with more long aerial and lofted passes on the soft pitches. The frequency per minute, mean duration, and the percentage of match time spent dribbling were all greater on the hard pitches. Thus, suggesting the hard pitches assisted with a smoother ball roll and subsequent control or perhaps that more time had to be spent using these controlling movements and that control was difficult with hard pitches.

Study one compared soft and hard pitches that were more similar than the low and high hardness surfaces classified by (Chivers and Aldous, 2004); low being 30 to 70 Gmax and high being between 90-120 Gmax. Despite the restricted range of hardness of the surfaces, the difference was significant in all six areas of the pitch. Thus, more pronounced differences may be found in future research comparing performances on surfaces with greater differences in terms of hardness. In summary, SH has been found to influence a soccer player's performance in terms of their technical and turn frequencies and time spent performing movements which concurs with the findings from Andersson et al. (2008) and Potthast et al. (2010). Further research is needed to investigate the physiological and biomechanical responses when NGSH changes.

4.5. Conclusion

Contrasting playing surface in terms of SH appears to influence player performance. Differences occurred between soft vs. hard NG in study one for path changes, movements, and game activity. Complementary future research should endeavour to explore differences in the physical work-rate in terms of the performance, biomechanical, and physiological demands when performing soccer simulated activity on NGPs with contrasting SH.

CHAPTER 5. STUDY 2 - REPEATED SPRINT PERFORMANCE

Study two aimed to characterise the physiological and performance responses of soccer players while performing repeated sprint activity on soft and hard NGPs. Competitive matches were used in study one therefore, study two aimed to gain greater control by included RSA tests to obtain sprint performance and a measurable degree of fatigue on two pitches of contrasting surface hardness. The preliminary data from study two justified the use of a longer, more soccer specific test in study three.

Abbreviation:	Nomenclature:
RSA	Repeated Sprint Ability
NGSH	Natural Grass Surface Hardness
NGP	Natural Grass Pitch
NG	Natural Grass
CIH	Clegg Impact Hammer
SH	Surface Hardness
FI	Fatigue Index
AT	Artificial Turf
%DS	Percentage Decrement
HRpeak	Heart Rate Peak
HRav	Heart Rate Average
CT	Contact Time
FT	Flight Time
ES	Effect Size
Gmax	Gravitational Maximum

Abstract – Study Two:

Surface type and hardness can influence soccer performance with the weather, grass coverage, and seasonal variation potentially impacting various physiological, biomechanical and performance responses. Soccer is characterised as a multi-sprint sport and repeated sprint ability is an important fitness component for a soccer player. This was a preliminary study to investigate the impact of natural grass surface hardness on the aspects of soccer performance (i.e., repeated sprint ability). Ten academy-level (amateur) College soccer players completed a repeated sprint ability protocol consisting of 10 sprint distances of 40 m performing one repetition every 40 s. Participants performed the repeated sprint test on a soft (44.8 ± 10.8 Gmax) and hard (64.7 ± 17.6 Gmax) pitch using a cross over design. Peak and average heart rate were not different between playing surface during the repeated sprint tests. There was a trend for the fastest sprints (peak sprint time within the series of ten) (effect size; d = 0.6; P>0.05) to be faster on the hard vs. soft pitch and a greater percentage decrement (d = 0.8; P>0.05) on the hard pitch vs. soft pitch over the repeated sprint test. Mean sprints (average sprint time within the series of ten) (d = 0.1; P>0.05) were only marginally faster on the hard vs. soft pitch. Performance in a repeated sprint test appears to be influenced by different pitches with contrasting surface hardness.

5.1. Introduction

Field-based sports such as hockey, lacrosse, rugby, soccer, and court-based sports such as netball and tennis require a combination of low-to-moderate-activity bouts with intermittent bouts of high-intensity-activity such as sprinting and running (Miltenbergen, 2013). Time motion research has demonstrated that the team sports' player sprints for 1-10% of the total distance covered during a match, equating to 1-3% of match-play time (Buchheit et al., 2010). Soccer performance requires repeated sprints at high intensity (Oliver et al., 2006), which are very important when considering the outcome of a match (Reilly, 1997). These bouts of activity often contribute to the more important moments of the game such as shooting, tackling, chasing a player, or winning possession (Mohr et al., 2003). Running speed and sprinting performance significantly decrease during the latter periods of matches (Mohr et al., 2003; Krustrup et al., 2005). The ability to reproduce maximal speed over a series of sprints is known as repeated sprint ability (RSA) (Spencer et al., 2004; Glaister, 2007; King et al., 2009; Bishop et al., 2011).

RSA tests have been used in soccer research as a logically valid, reliable, and relevant procedure to replicate an intense period of match-play (Krustrup et al., 2002; Mohr et al., 2003; Krustrup et al., 2006; Oliver et al., 2006; Glaister, 2008; Girard et al., 2011). RSA tests range from approximately 2-5 s and over 10-40 m (Spencer et al., 2005) with recovery durations ranging from 20-60 s between sprints (Serpiello et al., 2011). RSA tests typically measure a combination of peak performance (typically the first sprint) and the decline in this variable through subsequent efforts (Glaister, 2008; Oliver et al., 2008) with the latter being evaluated using either percentage decrement (%DS) and fatigue index (FI). The FI is defined as "the relative drop-off in performance from the best to the worst sprint" (Glaister, 2008). The %DS attempts to measure fatigue by comparing the actual performance data to an imagined 'optimum performance' (i.e. where the fastest effort would be replicated in each sprint) (Buchheit et al., 2009; Girard et al., 2011).

Fletcher et al. (2009) compared the effect of artificial turf (AT) vs. natural grass (NG) on 15 m sprints and found significantly slower sprints on NG when compared to AT. Similarly, using a prolonged soccer match simulation, significantly faster 15-m sprint time was produced on AT compared to NG, although FI did not differ between surface (Hughes et al., 2013). Performance times did not differ when soccer players performed maximal effort trials on a slalom course on AT compared to NG (Ford et al., 2006), whereas Binnie et al. (2013) reported faster RSA over 5, 10, and 20 m on NG compared to sand. The equivocal findings related to RSA on contrasting surface types make it a valid question to determine whether RSA is influenced by contrasting NG surfaces and the importance of RSA in soccer means that this is relevant to the study overall. The nature of this type of research makes it difficult to compare such findings across different studies due to different surface types, surface hardness, and testing procedures.

A key strength in study one (match performance characteristics) was the ecological validity, but it had a lack of control due to the real-life context of the research design. Therefore, study two aimed to investigate the effect of natural grass surface hardness (NGSH) on RSA on soft and hard natural grass pitches (NGPs). RSA tests were used to achieve a measurable degree of fatigue (because this is a standardised test of performance measuring the ability to maintain sprint speed during 10 trials) and sprint performance (high sprint speed) on two pitches of contrasting hardness.

5.2. Experimental methods – experimental set-up, procedure, and data analysis – study 2

5.2.1. Participants

Ten academy-level (amateur) College soccer players participated in the study (18.7 ± 1.4 years, stature 1.76 ± 0.06 m and body mass 70.7 ± 16.1 kg). The participants were from a range of outfield playing positions and were actively involved in training and match-play.

5.2.2. Prior to testing

Participants were prepared for the physical test involved by attending practice sessions in which they were habituated to the testing procedures. Two separate NGPs (hard and soft) were selected for the RSA tests. Initially, two preliminary sessions were performed to (a) familiarise participants with the protocol and (b) collect reference values. Prior to the RSA tests, all players participated in a warm-up performed on NG. Players wore standard training kit and studded soccer boots, which remained the same for both conditions. The warm-up consisted of 15 min of progressing through a raise, activate, mobilise and potentiate (RAMP) method (Jefferys, 2007) involving the same movement patterns prior to a match (Jogging: 8-11 $km \cdot h^{-1}$), multi-directional dynamic activities (forward, backward running, sidestepping, lunging, high knee and heel kicks), and finally varying sprint distances (10 and 20-m) culminating in familiarisation with the 40-m sprint distance, followed by 5 min recovery prior to testing.

5.2.3. Experimental procedure

A sprint distance of 40m was used (Spencer et al., 2005; Krustrup et al., 2006) performing one repetition every 40 s, aimed in this case to provide a valid assessment of team-sport RSA and soccer. Standardised verbal encouragement and instruction was provided during all the RSA tests by the experimenters. Players were requested not to participate in any training or physical activity between tests. Players were advised not to consume food less than two hours before testing and to standardise dietary intake prior to and following each test. Electronic timing gates (Fusion Sport Smart Speed, Queensland, Australia) were used to measure sprint speed. Participants performed a standing start and were encouraged to sprint through the timing gates, maintaining maximal effort. Ten participants performed the RSA protocol on condition A (soft pitch) and condition B (hard pitch) in a randomised cross-over design prescribed with 72 hours between tests (figure 5.1.). Heart rate was monitored and recorded throughout the ten RSA repetitions (Polar Team System, Kempele, Finland) with values averaged every 5 s.

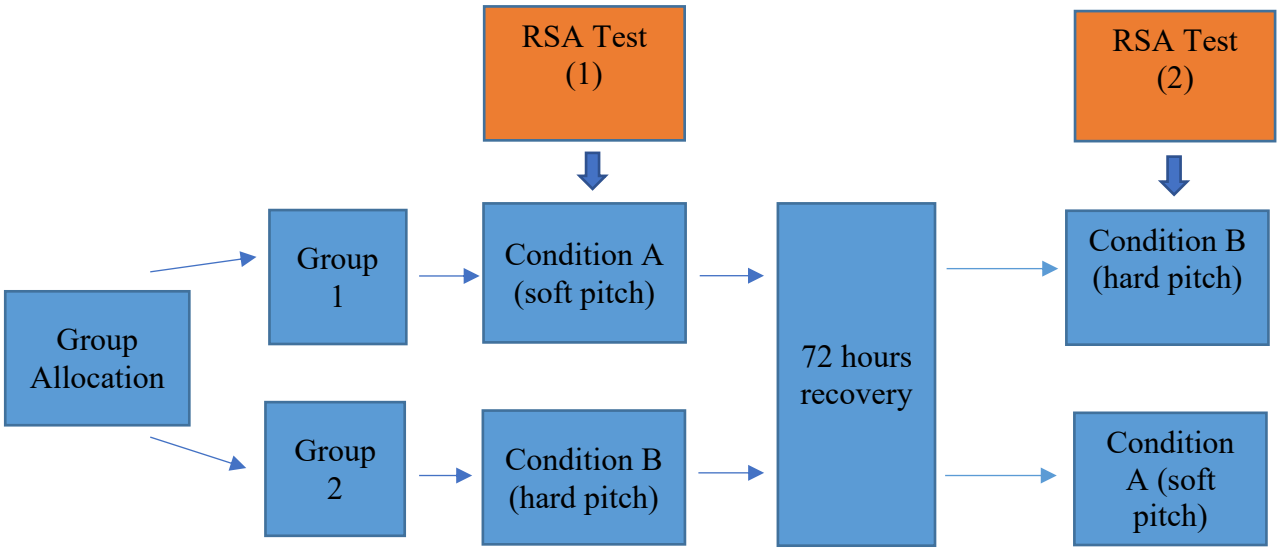


Figure 5.1: Diagrammatic representation of the cross-over design implemented in study 2 (condition A: soft pitch/condition B: hard pitch).

The mean surface hardness (SH) of the hard pitch (64.7 ± 17.6 Gmax) was 19.9 Gmax greater when compared to the soft pitch (44.8 ± 11.5 Gmax) which confirmed that both conditions fell within the 'low' soccer category of SH (Chivers and Aldous, 2004). The RSA test was carried out in area 3 (between the halfway line and 18-yard box) and 4 (centre circle) which showed that the hard pitch was 21.0 Gmax and 24.9 Gmax harder than the soft pitches respectively (table 5.1. highlighted in bold). Pitch area six (penalty area) was the hardest area of the soft pitch (59.4 ± 14.9 Gmax) and area one (corner) was the softest area of the hard pitch (46.4 ± 7.4 Gmax).

Table 5.1. Surface hardness of the six areas (figure 3.1.) of the soft and hard pitches used in study two (means±sd.).

Pitch Area	Hard Pitch (Gmax)	Soft Pitch (Gmax)	Surface Hardness Diff. (Gmax)
1 - corner	46.4 ± 7.4	40.4 ± 2.7	6.0*
2 - goalmouth	90.4 ± 5.1	45.7 ± 2.8	44.7*
3 - halfway line-18-yard box	**56.4 ± 4.7**	**35.4 ± 6.2**	**21.0***
4 - centre circle	**78.0 ± 7.1**	**53.1 ± 6.9**	**24.9***
5 - wing	53.5 ± 11.8	35.3 ± 2.4	18.2*
6 - penalty area	63.4 ± 9.1	59.4 ± 14.9	4.0
Total Pitch	64.7 ± 17.6	44.8 ± 11.5	19.9*

*Difference between surface hardness (P<0.05)

5.2.4. Data analysis

Data analyses were completed using SPSS (version 17, SPSS, Chicago, USA). Simple descriptive statistics are reported as means ± sd. All sprints were recorded, and data processing was used to calculate the mean and fastest to use for data analysis. The %DS method was used to assess repeated sprint test times. The %DS was calculated as follows: 100 – (mean time/fastest time x 100) (Buchheit et al., 2009). The parametric distribution of the data was checked using a Shapiro-Wilks test which confirmed a normal distribution, therefore the level of significance was calculated using a paired samples t-test ($P<0.05$) for the sprint and %DS data and an independent samples t-tests ($P<0.05$) for the SH data. To identify meaningful changes in the performance times, effect sizes were calculated (Hopkins, 2003). Specific threshold values for rating the effect size were 0.2, 0.5, and $\geq$ 0.8 for trivial, moderate, and large effects, respectively (Thomas et al., 1991; Coe, 2002). The p-value was used to show the statistical significance of the differences between the two surface conditions (Thiese et al., 2016) using an alpha level of $P<0.05$.

5.3. Results

Peak heart rate (HRpeak) was not different (d = 0.4; $P>0.05$) between the soft (194 ± 12 beats·min^{-1}) and hard (188 ± 18 beats·min^{-1}) pitch during the repeated sprint test. Heart rate average (HRav) also did not significantly differ (d = 0.3; $P>0.05$) between the soft (176 ± 8 beats·min^{-1}) and hard (173 ± 14 beats·min^{-1}) pitch. There was a trend for the fastest sprints to be faster (d = 0.6; $P>0.05$) on the hard vs. soft pitch. The mean sprints were only marginally faster on the hard vs. soft pitch (d = 0.1; $P>0.05$) whereas, there was a trend for a greater %DS (d = 0.8; $P>0.05$) on the hard pitch vs. soft pitch during the repeated sprint test (table 5.2.). The mean sprint times were faster on the hard vs. soft pitch in eight of the ten repetitions (figure 5.3.) apart from repetitions one and four of the RSA test.

Table 5.2: Illustrates the fastest, average times (s) and %DS (%) for 40 (m) sprint times (s) taken for RSA, performed on soft (44.8 ± 11.5 Gmax) and hard (64.7 ± 17.6 Gmax) NGPs.

	Fastest (s)		Average (s)		Percentage Decrement (%)	
Pitch	(soft)	(hard)	(soft)	(hard)	(Soft)	(hard)
Mean	6.22	6.00	6.54	6.42	5.20	7.12
SD.	0.33	0.42	0.30	0.25	2.43	2.28
P	0.09		0.18		0.12	

Cohen's d	0.6 (LARGE)	0.1 (TRIVIAL)	0.8 (LARGE)

Values are mean ± sd.

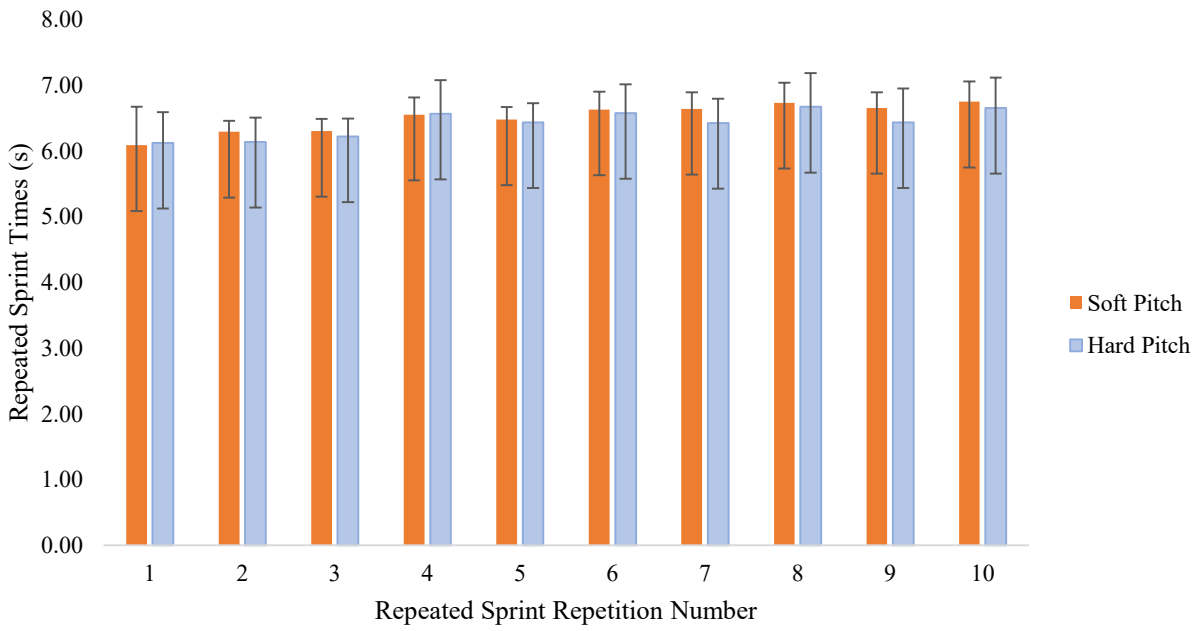


Figure 5.2. Mean 40-m repeated sprint times for each repetition during the RSA test on the hard pitch (blue line) and soft pitch (orange line).

5.4. Discussion

Both surfaces used in the present study both fell within the "low" category range (>30 to 69.9 Gmax) of SH according to Chivers and Aldous's (2004) classification (table 2.5.); despite a significant difference between both surfaces of 19 Gmax with SH values of 44.8 Gmax and 64.7 Gmax for the soft and hard pitches respectively. The RSA test was carried out in pitch area 3 (between the halfway line and 18-yard box) and 4 (centre circle) which was also significantly greater on the hard vs. soft pitch by 21.0 Gmax and 24.9 Gmax respectively (table 5.1.). The results may have been influenced had the difference between the SH been quantified in the low (>30 to 69.9 Gmax) and high categories (90 to 120 Gmax) according to Chivers and Aldous's (2004) classification (table 2.4.).

5.4.1. Performance responses

There was a trend for faster peak sprints (d = 0.6; P>0.05) on the hard vs. soft pitch whereas, mean sprint times were similar across both surfaces (d = 0.1; P>0.05). Fletcher et al. (2009) found 15 m sprints were 0.04 s slower (P<0.05) on NG (2.63 s) compared to the AT (2.59 s). However, it is difficult to compare Fletcher et al.'s (2009) findings to the present study as testing methods differed as they used a protocol consisting of three 15 m sprints performed every 2 minutes for ten sets combined with three other movement intensities (i.e., walking, jogging and running).

The present study demonstrated the high level of fitness and motivation of the players as the calculated 15 m sprints were 2.46 s and 2.49 s for the hard and soft pitches respectively. This was comparable to the Hughes et al. (2013) study, where 15 m sprints were 2.49 s on NG. The participants in the Hughes et al. (2013) study were semi-professional with a mean age of 22.8 ± 2.1 years compared to academy-level (amateur) players used in the present study with a mean age of 18.7 ± 1.4 years. Both Fletcher et al. (2009) and Hughes et al. (2013) did not quantify SH and they compared NG vs. AT instead of soft NG vs. hard NG as in the present study.

The slower sprints on the soft pitch in the present study may have been due to less surface stability and rigidity reducing the ability to apply force concurring with the thoughts of Swanson and Caldwell (2000), Kerdok et al. (2002), and Katkat et al. (2009). Zamparo et al. (1992) suggested a less stable surface can cause the foot to slip backwards during the push off phase of the stride when sprinting, potentially providing a reason why sprints were slower on the soft pitch in the present study. In the present study, greater SH potentially allowed shorter contact times (CT) during sprinting in the RSA test. Higher energy restitution, associated with a harder surface rigidity generally shortens CT (Gaudino et al., 2013) causing leg stiffness to change (Ferris et al., 1998), generating greater use of the stretch-shortening cycle (Kubo et al., 1999) potentially improving running economy (Kerdok et al., 2002; Katkat et al., 2009). Shorter CTs may have allowed for sprints to be faster on the hard pitch in the present study however, CT was not measured on this occasion. The present study did not detect any differences in %DS between the hard and soft pitches suggesting that SH did not affect the rate of fatigue during the RSA test. This finding concurred with Hughes et al. (2013) as they did not detect a change in %DS between playing surface but used a different protocol and surfaces (AT vs. NG) as opposed to the RSA test and soft NG vs. hard NG in the present study. Differences in the kinematic and kinetic parameters possibly allowed for faster sprints on the hard pitch. Biomechanical responses (i.e., contact time, flight time, stride frequency, swing

time, stride time, and stride length) should be investigated using a more soccer specific test on soft vs. hard pitches. Therefore, the biomechanical responses were measured during a soccer simulation protocol in study three (match simulation).

5.4.2. Physiological responses

Despite not being significant, there was a trend for HRpeak and HRav to be marginally higher on the soft pitch vs. hard pitch suggesting that surface differences have the potential to influence HR. Regardless of not taking the same approach to the present study, previous studies by Di Michele et al. (2009) and Binnie et al. (2013), support the observation that HR response may be altered due to playing surface. Di Michele et al. (2009) observed higher heart rate values in a field-based multi-stage running test (adapted from Heck et al., 1985) on AT compared to NG, however, SH was not objectively assessed, and their testing protocol differed to the one used in the present study. Binnie et al. (2013) found a trend for HR to be higher on a softer surface vs. a firmer surface although this was whilst performing interval training on sand vs. NG vs. surfaces. Hughes et al. (2013) and Nedelec et al. (2013) did not detect any differences in HRav and HRpeak between playing surface (AT vs. NG) however, both studies used complex 90-minutes soccer specific simulations and did not quantify SH making it difficult to compare the findings to the present study. Physiological responses (i.e., HRpeak, HRav, and blood lactate concentration) should be investigated using a more soccer specific test on soft vs. hard pitches. Therefore, the physiological responses were measured during a soccer simulation protocol in study three (match simulation).

5.4.3. Summary

The hard and soft pitches used in the study were indeed significantly different in terms of SH ($P<0.05$) and this influenced the performance (i.e., fastest sprint) and physiological (i.e., HRpeak and HRav) responses during an RSA test protocol. The preliminary data from this RSA study justify the use of a longer, more soccer specific test in study three.

5.5. Conclusion

The two main trends (although non-significant differences) were that sprint performance (peak sprint) was better on the hard pitch and HR (average and peak) was a little higher on the soft pitch. Slower sprints coupled with slightly higher physiological demands (i.e., HR) together suggest that it is harder to produce the same effort on the soft vs. hard pitch. If a firmer NG surface elicits faster sprints predominately throughout the 40-m RSA test (faster in eight of the ten repetitions), the potential impact could increase the pace and characteristics of a soccer game. A trend towards SH affecting sprint time was evident but only on a brief protocol that is not fully representative of the demands of a soccer match. A few of the results suggest it is worthwhile exploring this area a little more deeply therefore, study three measured the effect of contrasting NGSH on a range of performance, biomechanical and physiological responses involving solely NG and soccer simulations which closely replicate match intensity and nature.

CHAPTER 6. STUDY 3 – MATCH SIMULATION

A few of the results from the repeated sprint performance in study two suggested it was worthwhile exploring this area a little more deeply. Therefore, a larger empirical study was designed in study three to measure the effect of contrasting NGSH on a range of performance, biomechanical and physiological responses involving steady state activity and soccer simulations. The research outcomes from the preceding empirical studies helped to inform the direction of the subsequent qualitative research design in study four.

Abbreviation:	Nomenclature:
RSA	Repeated Sprint Ability
SSP	Soccer simulation protocol
SSA	Steady State Activity
S-AR	Speed-Agility Run
SH	Surface Hardness
HR	Heart Rate
NGPs	Natural Grass Pitches
NG	Natural Grass
AT	Artificial Turf
CT	Contact Time
FT	Flight Time
SL	Stride Length
SF	Stride Frequency
St	Stride Time
SwT	Swing Time
HRav	Heart Rate Average
HRpeak	Peak Heart Rate
BLa	Blood Lactate
TD	Total Distance
COD	Change of Direction
ES	Effect Size
Gmax	Gravitational Maximum

Abstract

The aim of this study was to examine the effect of natural grass surface hardness on performance, biomechanical, and physiological responses during steady state activity and a soccer simulated protocol. The biomechanical responses were assessed throughout an 8-minute steady state activity along with average heart rate responses. All the variables measured during the steady state activity were again measured during the 84-minute soccer simulation protocol with the inclusion of blood lactate, sprint performance, turning and cutting manoeuvres during the sprint-agility run section of the soccer simulation protocol. Both the steady state activity and soccer simulation protocol were completed on soft (51.6 ± 2.7 Gmax) and hard (89.2 ± 5.0 Gmax) natural grass pitches on separate occasions. Peak time (average time of the fastest three times within the series of forty-eight) and mean time (average time within a series of forty-eight) were used to measure the sprint-agility run performances. The mean sprints (effect sizes; Cohen's d) (d = 0.1; P>0.05), peak sprints (d = 0.2; P>0.05), mean cutting times (d = 0.1; P>0.05) and peak cutting times (d = 0.3; P>0.05) were not different between the two surfaces during the soccer simulation protocol. Mean turn times (d = 1.4; P<0.05) were faster on the soft vs. hard pitch (2.39 ± 0.04 s vs. 2.44 ± 0.09 s) whereas, peak turn times (d = 0.3; P>0.05) were not different between playing surface during the soccer simulation protocol. Contact times were shorter during steady state jogging (d = 1.1; P<0.05) on the hard pitch (0.277 ± 0.018 s) vs. soft pitch (0.294 ± 0.012 s) and shorter during sprinting movements (d = 1.0; P<0.05) on the hard pitch (0.148 ± 0.007 s) vs. soft pitch (0.155 ± 0.007 s) implying that playing surface influenced the mechanics of jogging and sprinting. Participants experienced fatigue indicated by sprint times slowing from set one-to-four on the soft and hard surface. This pattern of fatigue resembles the demands on a soccer player as sprint times slowed especially in the latter periods of a match. It is pertinent to highlight that some differences were observed in the biomechanical and performance responses during the soccer specific activity between pitches. It remains possible that the performance and biomechanical responses may be influenced further if a greater difference exists between pitch hardness.

Key words – natural grass, soccer, surface hardness, steady state activity, soccer simulation protocol, sprinting, turning and cutting manoeuvres

6.1. Introduction

Soccer is an intermittent physical activity involving rapid variations and changes in game-related activity and locomotory movements (Stølen et al., 2005). The repeated sprint ability

(RSA) and multidirectional nature of soccer are fundamental requirements of the game (Stone et al., 2011; Low and Dixon, 2014). Players have become faster over the years, suggesting that sprinting skills are becoming a more important performance parameter in the modern game (Haugen et al., 2014). Biomechanical parameters are especially important in all forms of locomotion (Okuno et al., 2011) and research predominantly focuses on the metabolic parameters and often neglects the mechanical parameters (Okuno et al., 2011). Kinematic variables such as contact time (CT), flight time (FT), stride frequency (SF), swing time (SwT), stride time (St), and stride length (SL) are important biomechanical variables for linear jogging and sprinting (Lockie et al., 2011; Lockie et al., 2012). Decreasing ground CT during running is considered the most important kinematic change for improving sprinting speed (Weyand et al., 2000; Weyand et al., 2010). Kinematic variables interact in a way that the shorter the CT, FT, and SL, the higher the SF and vice versa (Donati, 1996). As running speed increases both flight time (FT) and CT decrease (Ito et al., 1983; Cavanagh and Kram, 1989; Brisswalter and Legros, 1995; Yokozawa et al., 2005). The importance of these kinematic variables (CT, FT, SF, SwT, St, and SL) to jogging and sprinting prompted each to be measured during field-based testing in the present project to determine the effect of SH on such measures.

Field-based tests strengthen the ecological validity and specificity to replicate soccer match-play (Stone et al., 2011). A multitude of soccer-specific protocol (SSP) tests exist (table 2.6.) with a few 90-minute SSPs used that closely resemble soccer match-play including the Loughborough Intermittent Shuttle Test (LIST) (Nicolas et al., 2000) and soccer specific aerobic field test protocol ($SAFT^{90}$) (Small et al., 2010). Stone et al. (2011) introduced an amended SSP which was a novel adaptation of the LIST and included repeated sprint activity and multidirectional movements which are both regarded as fundamental game characteristics (Reilly, 1977). This SSP (Stone et al., 2011) has been used in other research which aimed to measure the influence of playing surface type (AT vs. NGPs) on performance and physiological responses (Hughes et al., 2013; Stone et al., 2014). Therefore, the SSP was selected in the present project to objectively quantify a range of physiological, biomechanical, and performance variables that would otherwise be impractical to measure during a competitive match.

The playing surface (Sanchez-Sanchez et al., 2014) and condition of a playing surface (Hughes et al., 2013) can influence soccer performance and match characteristics. Study one (match performance characteristics) of the project found that more movements (i.e., turns) were performed on a soft vs. hard pitch during competitive soccer (Sleat et al., 2016), and study two

(repeated sprint performance) of the project found that faster sprints were produced on the hard vs. soft pitch over a 40-m RSA protocol. However, despite such findings, neither study one or two considered other different physical and psychological components.

In soccer, time-motion analysis has shown that low to moderate intensity aerobic activity accounts for approximately 80-90% of the total energy expenditure (Bangsbo et al., 1994; Iaia et al., 2009) with activities such as walking and jogging making up large periods of game time (Bangsbo, 1994; Rienzi et al., 2000; Russell et al., 2011). Therefore, a field-based protocol involving steady state activity (SSA) would be beneficial to evaluate the influence of natural grass surface hardness (NGSH) on the physiological and biomechanical responses to low intensity soccer activity as differences in HR can be best judged only using stead exercise.

The field-based SSPs involve various intensities of movement, repeated bouts of sprints combined with turning manoeuvres and cutting manoeuvres (Little and Williams, 2005) thus, strengthening the ecological validity of the test to replicate soccer match-play (Stone et al., 2011). Therefore, the aim of study three was to evaluate the influence of NGSH on the physiological, biomechanical and performance responses to soccer activity.

6.2. Experimental methods – experimental set-up, procedure, and data analysis – study 3

6.2.1. Participants

Ten academy-level (amateur) College soccer players participated in the study (18.0 ± 1.5 years, stature 1.74 ± 0.03 m and body mass 64.8 ± 7.08 kg). The participants were from a range of outfield playing positions and were actively involved in training and match-play.

6.2.2. Prior to testing

Pilot work was carried out prior to any testing to ensure all participants were familiarised with the SSA and SSP procedures. Preliminary visits were carried out leading up to the experimental procedure to ensure the surface hardness (SH) of the two pitches remained within the soft and hard designated hardness classifications (Chivers and Aldous, 2004). The SSA was set up lengthways on the full-sized pitch, predominantly incorporating areas 3 (halfway-line-18-yard box), and 6 (penalty area) of the pitch. The mean SH of the hard pitch (89.2 ± 5.0 Gmax) was 37.6 Gmax greater when compared to the soft pitch (51.6 ± 2.7 Gmax) which confirmed that

conditions fell within the 'normal' and 'low' soccer categories of SH respectively (Chivers and Aldous, 2004)(P<0.05). The SSP was set up widthways on the full-sized pitch in areas 3 (halfway-line-18-yard box) and 4 (centre circle) which showed that the hard pitch was 30.0 Gmax and 35.2 Gmax harder than the soft pitch respectively (table 6.1. highlighted in bold). Pitch area four (centre circle) was the hardest area of the soft pitch (58.9 ± 2.9 Gmax) and area five (wing) was the softest area of the hard pitch (58.3 ± 2.5 Gmax).

Table 6.1. Surface hardness of the six areas (figure 3.1.) of the soft and hard pitches used in study three (means±sd.).

Pitch Area	Hard Pitch (Gmax)	Soft Pitch (Gmax)	Surface Hardness Diff. (Gmax)
1 - corner	85.0 ± 7.2	39.4 ± 3.4	45.6*
2 - goalmouth	107.9 ± 10.1	44.7 ± 4.2	63.2*
3 - halfwayline-18-yard box	**85.3 ± 10.0**	**55.3 ± 3.3**	**30.0***
4 - centre circle	**94.1 ± 5.4**	**58.9 ± 2.9**	**35.2***
5 - wing	58.3 ± 2.5	55.5 ± 2.8	2.8*
6 - penalty area	99.9 ± 6.6	55.6 ± 2.5	44.3*
Total Pitch	89.2 ± 5.0	51.6 ± 2.7	37.6*

*Difference between surface hardness (P<0.05).

6.2.3. Experimental procedure: SSA and SSP

The original 90-minute SSP (Stone et al., 2011) was altered due to the use of 16-18-year-old participants. Two alterations were made to the SSP (refer to the start of section 6.2.3.). The first alteration included reducing the lane distance by 2 m in length where the movements (walking, jogging, and running at controlled intensities) were performed therefore 18 m instead of 20 m. The second alteration included reducing the overall duration by 6-minutes from 90-minutes to 84-minutes and reducing the number of sets from 6 to 4. It was important to reduce the length of the SSP due to the lower fitness levels of the participants compared to the highly trained participants used in the original version used by Stone et al. (2011). The shorter SSP test duration also matched the shorter game duration at this age group. Informed consent was obtained, and PAR-Q forms were completed prior to testing. Ethical clearance was approved by the Cardiff School of Sport, Research Ethics Committee (CSSREC) prior to any testing taking place. The participants were free from injury and were informed they would experience

temporary fatigue following each of the SSP tests however the 84-minute simulation did not differ from the participants' normal sporting activity. The steady-state activity procedure required participants to jog at a controlled speed of 2.5 $m \cdot s^{-1}$ (speed representative of jogging) for 8-minutes in an oval lap on two conditions (hard pitch and soft NG pitch). The SSP required participants to complete an 84-minute soccer simulation on two conditions (hard pitch and soft pitch) on soft and hard NGP. The SSA and SSP experimental procedures were structured in a randomised cross-over design where 10 participants were randomly assigned to one of two groups (soft pitch first - group A; hard pitch first - group B; figure 6.1.). Randomising the surface condition for each group changed the order of surface condition experienced, therefore reduced the period, carryover, or sequence effect (El Kati, 2012). Both groups completed the SSA and SSP tests consecutively with group A in the morning and group B in the afternoon. Previous studies have tried to control fatigue by giving sufficient rest periods between each test (Chappell et al., 2007; Nigg et al., 2009). Therefore, a 72-h recovery period was administered between testing days before repeating the cross-over cycle a second time on the opposite playing surface (figure 6.1.). Kinematic analysis was carried out while soccer players performed in the SSA and SSP to determine the extent that pitch hardness alters the characteristics of step and stride kinematics during steady state running and linear sprinting.

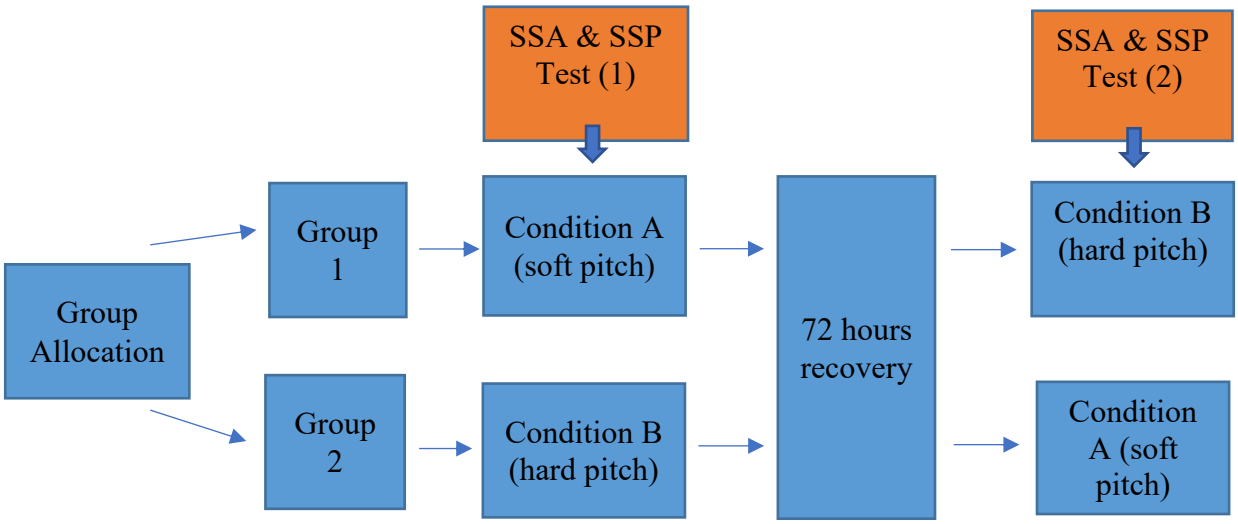


Figure 6.1: Diagrammatic representation of the cross-over design implemented in study 3 (condition A: soft pitch/condition B: hard pitch).

Part A – SSA procedure

The testing procedure for study 3 was conducted in two parts, the SSA (part A) and SSP (part B) procedures. The SSA protocol consisted of participants jogging at a controlled speed of 2.5 $m \cdot s^{-1}$ and completing 8 anti-clockwise laps of 200 m taking 80 s per lap (figure 6.2.). Jogging speed was controlled using a timed audio-recording (sound software; Audacity) with 10 cones located every 20 m. The activity speed was provided throughout the protocol using a pre-recorded audio-track and projected every 8 s using an iDance Cube PA speaker system (iDance Distribution, Kwun Tong, Hong Kong). The average velocity (Vav.) for the SSA protocol was 2.5 $m \cdot s^{-1}$ due to the controlled running speed administered in the SSA procedure. The research team provided verbal instructions throughout the protocol. To consistently measure the 200 m lap on all the pitches used, each corner of the oval was measured by marking in 15 m from both corners in length and width then a semi-circle was marked between the cones. The SSA protocol was used as a steady state warm-up and a staggered start was implemented to allow 4 participants to complete the test at one time with ≥1 cone (40 m) separating each participant to allow for everyone to be filmed jogging through a 10 m section (dashed rectangle 5 m above and below point A in figure 6.2.). A two-dimensional high-speed camera (Sony, HVR-Z5, Japan) was located at the midway-point of the 80 m linear section on one side (point A in figure 6.2.) with a sampling rate of 200 Hz set to capture four stride cycles every lap from minutes 4-8 mins of the SSA protocol, therefore sampling 4 laps per participant.

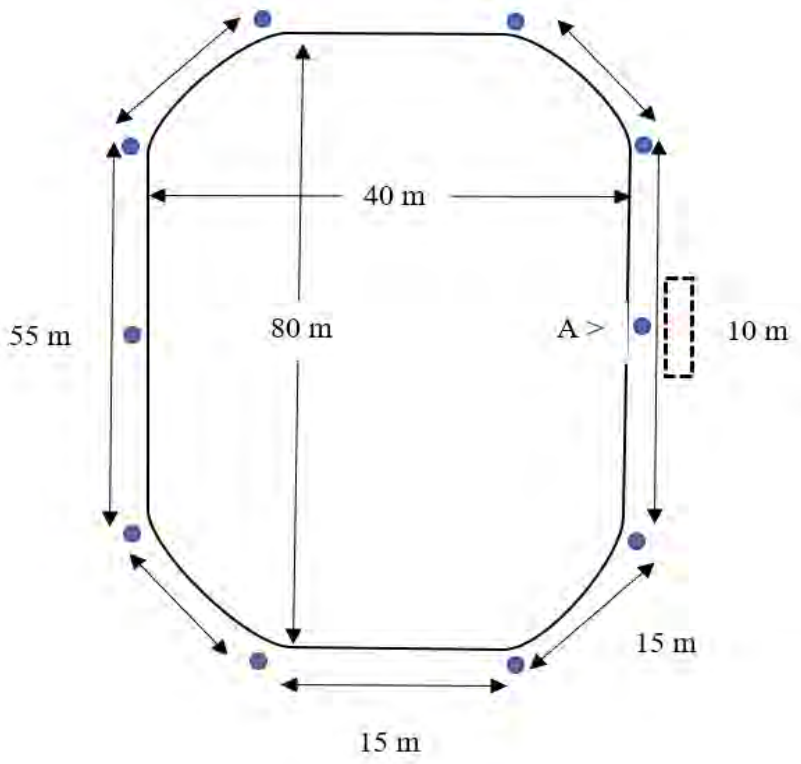


Figure 6.2: Schematic layout of the 200 m lap used for the SSA protocol. The layout was set up along the length of the pitch. Participants performed jogging at a controlled speed of 2.5 $m \cdot s^{-1}$ in an anti-clockwise direction and were controlled using cones (filled circles) and a timed audio-recording. A high-speed camera was positioned at point A to capture up to five stride cycles per lap to determine each kinematic variable identified in section 3.2.5.

Part B - SSP

The SSP was an adapted version of the 90-minute SSP used by Stone et al. (2011) which is a valid simulation of soccer activity (Stone et al., 2011). The altered time (min) and distance (m) reduced the overall workload by 7-10% respectively which was appropriate for the age, level, and physical maturation of the academy-level (amateur) level participants selected for the study compared to the more highly-trained participants used in the original version used by Stone et al. (2011). The SSP required participants to complete four-21-minute sets (84-minute total work duration) with a three-minute 30 s rest between sets 1-2 and 3-4 and a 10-minute 30 s half-time rest period between sets 2-3 to mimic a competitive soccer match. Each set consisted of twelve 105 s cycles and the total distance (TD) covered during the whole SSP simulation was approximately 10.3 km and included the following activities in the order displayed below:

- 3 × 18 m at a walking pace of 1.43 $m \cdot s^{-1}$
- 1 × 15 m sprint-agility run (S-AR) at maximal intensity (20 s for sprint and recovery)

- 3 × 18 m at a jogging speed of 2.5 $m \cdot s^{-1}$
- 3 × 18 m at a running speed of 4.0 $m \cdot s^{-1}$ (adopted from the SSP simulation devised by Stone et al., 2011).

The SSP required participants to complete the intermittent shuttle cycle at speeds representing walking (1.43 $m \cdot s^{-1}$), jogging (2.5 $m \cdot s^{-1}$), and running (4.0 $m \cdot s^{-1}$) in a lane that was 18 m in length and 1.5 m in width (figure 6.3. and 6.4.). The sprint-agility run commenced from a standing start behind the first timing gate twice during each 1-minute 45 s cycle. During the SSP procedure the 15 m linear sprint times, decline in sprint times, 10 m turning manoeuvre (180 degree turn around a cone), and 15 m cutting manoeuvre times (slight change of direction at the half-way point around a cone 2 m away from the midline) were measured using smart speed light-gates (Fusion Sport., UK). Heart rate (HR) was monitored throughout using Polar heart rate monitors (Polar Electro, Finland) recorded every 5 s to calculate the HR peak and HR average for each set not including any rest period between sets. Blood lactate (BLa) concentration was analysed using capillary samples following sets 1, 2, 3, and 4 using a Biosen C-Line lactate analyser (EFK Diagnostics, Barleben, Germany).

Ten participants completed the SSP using staggered starts every 3-minute 30 s to stagger each participant's rest period to permit the collection of blood samples. All defined kinematic variables (CT, FT, SF, SwT, St, and SL) were measured using a two-dimensional high-speed camera (Sony, HVR-Z5, Japan) (figure 6.3.) set up in lane 6 to capture footage during the final lane of each set.

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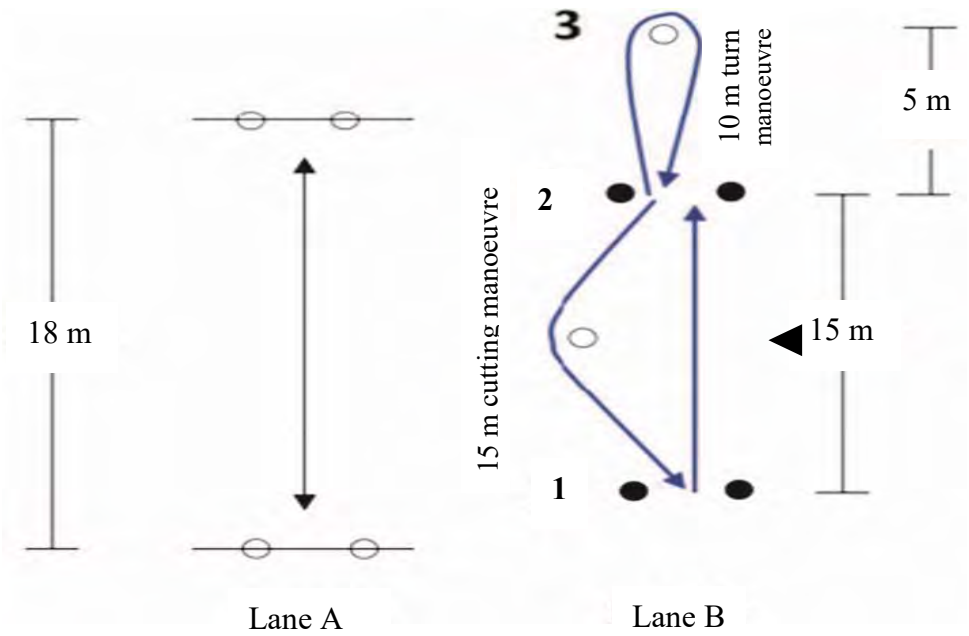

Figure 6.3: Schematic layout of a single lane of the SSP (adapted from Hughes et al., 2013). The 18 m lane A was used for the movements (walking, jogging, and running at controlled intensities). Lane B was used for the sprint-agility run (number order: 1-2-3-2-1). Open circles are marker cones and small filled circles are timing gates. One filled circle (large) at the side of lane B demonstrates where a two-dimensional high-speed camera was positioned with a sampling rate at 200Hz (small filled triangle).

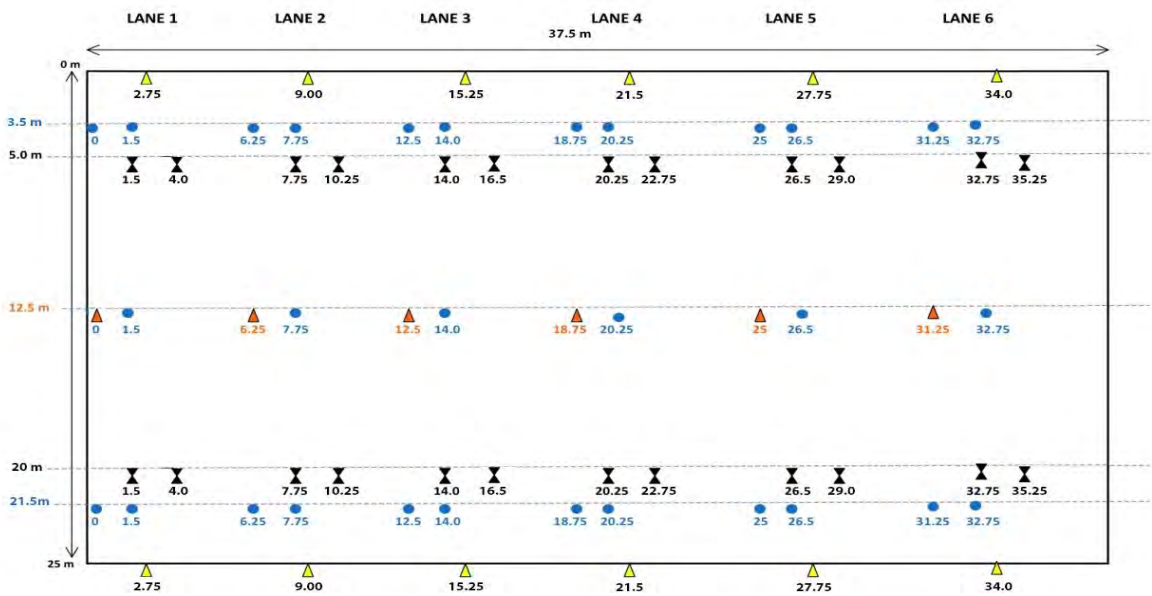

Figure 6.4: Schematic layout of the SSP simulation (adapted from Stone et al., 2011). The schematic layout was set up across the width of the pitch located between the centre circle and

both 18-yard boxes.

6.2.4. Physiological, performance, and biomechanical variables

One physiological variable (HR) was measured during the SSA procedures and two physiological variables were measured during the SSP procedure (HR and BLa). During the SSA protocol, the HR was recorded and used to subsequently establish the HR average. For the SSA, HR was monitored every 5 s and the average was obtained by processing all these data points from the 8-minute test. For the SSP, HR was monitored every 5 s and the average was obtained by processing all the data points for each of the four sets not including any rest periods between sets. Following sets 1, 2, 3, and 4 of the SSP, BLa was recorded. Three performance measurements (15 m linear sprint performance; 15 m cutting manoeuvre and 10 m turning manoeuvre (figure 6.3)) were recorded during the S-AR on both conditions. The Vav. for the SA-R section (15-m linear sprint) of the SSP was measured using video analysis software. The six biomechanics variables were measured during the SSA and SSP procedures on both conditions and are defined below:

Defined Biomechanics Variables:

- Contact time (CT): time between initial foot contact and toe-off of the same foot (units of measurement; s).
- Flight time (FT): time between the toe-off of one foot to the initial contact of the opposite foot (units of measurement; s).
- Stride frequency (SF): number of strides per second (units of measurement; Hz).
- Swing time (SwT): time between the toe-off and initial ground contact of consecutive footfalls of the same foot (units of measurement; s).
- Stride time (St): time between heel strike of one foot to the next heel strike of the same foot (2 steps - constitutes one gait cycle) (units of measurement; s).
- Stride length (SL): distance from heel strike of one foot to the next heel strike of the same foot (2 steps - this constitutes one gait cycle) (unit of measurement; m).

6.2.5. Data analysis

Video footage captured during the SSA and SSP procedures underwent several stages of data processing. Initially, the video files were recorded on cassette using the two-dimensional high-speed camera (Sony, HVR-Z5, Japan) and had to be converted to a digital format by linking

the video camera to a laptop using a firewire/USB digital video cable. The next data processing stage consisted of de-interlacing each video file using video software (VideoLan VLC Media Player, Paris). On completion of the de-interlacing process, each video file was edited using video editing software (NHC Software, Videopad Video Editor, Australia). The editing application allowed for each participant's running trials and laps to be prepared, cropped, edited, and ordered for each condition (condition A and B; figure 5.1 and 6.1.) and test (SSA and SSP). The final stage consisted of using a video analysis software (Kinovea version 0.8.15; Worldwide) to measure the temporal kinematic variables frame by frame using the stopwatch and timeframe functions which were then transferred to Microsoft Excel to undergo analysis. Direct measurements (CT and SwT) were used to determine indirect measurements (FT, St, SF, and SL) using the five calculations below in this chapter:

- Step 1:
  [Swing Time (s) – Contact Time (s)]/2 = Flight Time (s)

- Step 2:
  Contact Time (s) + Swing Time (s) = Stride Time (s)

- Step 3:
  1/Stride Time (s) = Stride Frequency (Hz)

- Step 4:
  Vav. (m/s) = Distance (m)/Time (s)
  (SSA - Vav. was 2.5 m/s; SSP distance was 15m and time was measured using Kinovea Software).

- Step 5:
  Stride Length (m) = Vav. (m/s)/Stride Frequency (Hz)

Data analyses were completed using SPSS (version 17, SPSS, Chicago, USA). Simple descriptive statistics are reported as means ± sd. unless otherwise stated. For the SSA protocol, the means were calculated for all the biomechanical variables from the four jogging laps. From the SSP, mean values for all variables were first calculated on each set on each surface type. The HRav for the SSP (Polar Team System, Kempele, Finland) was calculated for each of the four sets, not including any rest period between sets. During the SSP the mean (average time within a set of forty-eight) and peak (average time of the fastest three times within the series of forty-eight) values were calculated for the performance responses during the SSP on each surface type. The parametric distribution of the data was checked using a Shapiro-Wilks test ($P>0.05$) which confirmed a normal distribution. For the SH data, the level of significance

(P<0.05) was calculated using a series of independent samples t-test. For the biomechanical (CT, FT, SF, SwT, St and SL), performance (15-m linear sprint; 15 m cutting manoeuvre and 10 m turning manoeuvre) and physiological responses (BLa concentration and HR), data were analysed using a separate two-way (surface x time) repeated measure factorial analysis of variance (ANOVA) test. For both the SSP and the SSA the main effect of surface was comprised of the hard vs. soft pitches and the time main effect was from the 4 sets (SSP) or 4 laps (SSA). The interaction effects consisted of pitch hardness x set number (SSP) or lap number (SSA). When assumptions of sphericity were violated, the Huynh-Feldt adjustment was applied. Bonferroni post-hoc tests were employed to determine the level of significance when a significant interaction was found. To identify meaningful changes in the biomechanical and physiological responses and performance times, effect sizes were calculated (Hopkins, 2003). Specific threshold values for rating the effect size were 0.2. 0.5, and ≥ 0.8 for trivial, moderate, and large effects, respectively (Thomas et al., 1991; Coe, 2002)

6.3. Results

6.3.1. Biomechanics results – SSA

The biomechanical variables measured during the SSA protocol are presented in table 6.2. and 6.3. Shorter CTs (ES = 1.1; P<0.05) were produced on the hard (0.277 ± 0.018) vs. soft (0.294 ± 0.012) pitch during the SSA. There were no main effects for lap number and no interactions between playing surface and lap number in the SSA for CT.

FT was shorter (P<0.05) on the hard vs. soft pitch in lap three of the SSA. FT was shorter (P<0.05) in lap three of the SSA compared to laps one and two on the hard vs. soft pitch. SwT was shorter (P<0.05) on the hard pitch in lap three of the SSA compared to soft pitch. SwT was shorter (P<0.05) in lap three compared to all other laps on the hard pitch but neither biomechanical response showed a difference between surface (d = 0.4 and 0.1 respectively). Playing surface did not significantly influence SF, St and SL measured during the SSA protocol (main surface, lap time, and interaction effects: soft pitch vs. hard pitch; P>0.05).

Table 6.2: Biomechanics variables measured during the SSA protocol on soft and hard NGPs (mean±sd).

Variable	Hard Pitch	Soft Pitch	Cohen's d	2-way Repeated Measures ANOVA (P<0.05)		
				Surface Hardness (P)	Lap Number (P)	Surface Hardness * Lap Number (P)
SSA Contact Time (s)	0.277 ± 0.018	0.294 ± 0.012	1.1 (LARGE)	0.006*	0.060	0.807
SSA Flight Time (s)	0.081 ± 0.022	0.073 ± 0.017	0.4 (TRIV/MED)	0.162	0.019*a	0.007*b
SSA Stride Frequency (Hz)	1.39 ± 0.09	1.37 ± 0.09	0.2 (TRIVIAL)	0.241	0.440	0.098
SSA Swing Time (s)	0.438 ± 0.034	0.441 ± 0.030	0.1 (TRIVIAL)	0.715	0.012*a	0.001*b
SSA Stride Time (ms)	0.720 ± 0.041	0.730 ± 0.040	0.2 (TRIVIAL)	0.499	0.484	0.101
SSA Stride Length (m)	1.80 ± 0.10	1.83 ± 0.10	0.5 (MEDIUM)	0.259	0.474	0.118

*Shorter result on the hard pitch vs. soft pitch (P<0.05).
*aDifference between lap number (P<0.05).
*bInteraction (surface x lap number) (P<0.05)

Table 6.3: Biomechanics variables measured during the SSA protocol on soft and hard NGPs (mean±sd).

Variable	Lap 1	Lap 2	Lap 3	Lap 4
SSA Contact Time (s)				
Soft Pitch	0.292 ± 0.012	0.293 ± 0.014	0.294 ± 0.011	0.297 ± 0.011
Hard Pitch	0.272 ± 0.020	0.275 ± 0.022	0.278 ± 0.014	0.282 ± 0.017
SSA Flight Time (s)				
Soft Pitch	0.075 ± 0.016	0.071 ± 0.021	0.072 ± 0.016	0.075 ± 0.017
Hard Pitch[*3]	0.091 ± 0.025	0.087 ± 0.019	0.068 ± 0.018[**1.2]	0.077 ± 0.021
SSA Stride Frequency (Hz)				
Soft Pitch	1.37 ± 0.06	1.37 ± 0.06	1.36 ± 0.05	1.39 ± 0.14
Hard Pitch	1.38 ± 0.05	1.39 ± 0.06	1.37 ± 0.06	1.44 ± 0.15
SSA Swing Time (s)				
Soft Pitch	0.441 ± 0.030	0.436 ± 0.035	0.439 ± 0.030	0.447 ± 0.029
Hard Pitch[*3]	0.454 ± 0.035	0.448 ± 0.027	0.414 ± 0.032[**1,2,4]	0.436 ± 0.032
SSA Stride Time (ms)				
Soft Pitch	0.700 ± 0.083	0.698 ± 0.095	0.704 ± 0.083	0.695 ± 0.094
Hard Pitch	0.723 ± 0.028	0.722 ± 0.032	0.732 ± 0.031	0.702 ± 0.062
SSA Stride Length (m)				
Soft Pitch	1.83 ± 0.08	1.82 ± 0.08	1.83 ± 0.07	1.81 ± 0.16
Hard Pitch	1.81 ± 0.07	1.81 ± 0.08	1.83 ± 0.08	1.76 ± 0.16

[*]Shorter result than in the surface and lap indicated (P<0.05).[**]Shorter result than in the lap number indicated (P<0.05).

6.3.2. Biomechanics results - SSP

The biomechanical variables measured during the SSP are shown in table 6.4. and 6.5. Playing surface did not significantly influence FT, SF, SwT, St and SL measured during the SSP (main surface, set time and interaction effects: hard vs. soft pitch; $P>0.05$). Shorter CTs ($d = 1.0$; $P<0.05$) were produced on the hard (0.148 ± 0.007 s) vs. soft (0.155 ± 0.007 s) pitch (figure 6.5.).

6.3.3. Connection between the biomechanical variables during the SSA and SSP

Shorter CTs were evident in the SSP compared to the SSA which showed that CT decreased as running speed increased. However, FT did not show this pattern and remained similar during the SSA and SSP. SF and SL both increased as speed increased from the jogging performed in the SSA to maximal sprinting performed in the SSP (Ito et al., 1983; Cavanagh and Kram, 1989; Brisswalter and Legros, 1995; Yokozawa et al., 2005).

Table 6.4: Biomechanics variables measured during the SSP protocol on soft and hard NGPs (mean±sd).

Variable	Hard Pitch	Soft Pitch	Cohen's d	2-way Repeated Measures ANOVA (P<0.05)		
				Surface Hardness (P)	Set Number (P)	Surface Hardness * Set Number (P)
SSP Contact Time (s)	0.148 ± 0.007	0.155 ± 0.007	1.0 (LARGE)	0.021*	0.034*a	0.578
SSP Flight Time (s)	0.087 ± 0.022	0.085 ± 0.015	0.11 (TRIVIAL)	0.630	0.718	0.280
SSP Stride Frequency (Hz)	2.14 ± 0.17	2.10 ± 0.16	0.27 (TRIVIAL)	0.152	0.263	0.329
SSP Swing Time (s)	0.322 ± 0.037	0.326 ± 0.033	0.1 (TRIVIAL)	0.530	0.611	0.281
SSP Stride Time (ms)	0.470 ± 0.036	0.479 ± 0.035	0.25 (TRIVIAL)	0.159	0.349	0.303
SSP Stride Length (m)	3.17 ± 0.28	3.22 ± 0.29	0.16 (TRIVIAL)	0.138	0.404	0.182

*Shorter result on the hard pitch vs. soft pitch (P<0.05).
*aDifference between set number (P<0.05).

Table 6.5: Biomechanics variables measured during the SSP on soft and hard NGPs (mean±sd).

Variable	Set 1	Set 2	Set 3	Set 4
SSP Contact Time (s)				
Soft Pitch	0.153 ± 0.007	0.157 ± 0.006	0.155 ± 0.007	0.155 ± 0.010
Hard Pitch	0.145 ± 0.007	0.151 ± 0.007	0.150 ± 0.008	0.147 ± 0.007
SSP Flight Time (s)				
Soft Pitch	0.089 ± 0.016	0.085 ± 0.016	0.085 ± 0.014	0.083 ± 0.016
Hard Pitch	0.086 ± 0.019	0.089 ± 0.018	0.087 ± 0.023	0.086 ± 0.021
SSP Stride Frequency (Hz)				
Soft Pitch	2.09 ± 0.17	2.08 ± 0.15	2.09 ± 0.14	2.13 ± 0.19
Hard Pitch	2.18 ± 0.17	2.09 ± 0.12	2.13 ± 0.20	2.16 ± 0.19
SSP Swing Time (s)				
Soft Pitch	0.330 ± 0.036	0.326 ± 0.033	0.325 ± 0.029	0.312 ± 0.038
Hard Pitch	0.317 ± 0.036	0.329 ± 0.031	0.323 ± 0.044	0.320 ± 0.040
SSP Stride Time (ms)				
Soft Pitch	0.482 ± 0.038	0.482 ± 0.033	0.479 ± 0.032	0.474 ± 0.042
Hard Pitch	0.462 ± 0.034	0.479 ± 0.028	0.473 ± 0.043	0.466 ± 0.039
SSP Stride Length (m)				
Soft Pitch	3.27 ± 0.32	3.20 ± 0.29	3.22 ± 0.35	3.17 ± 0.25
Hard Pitch	3.15 ± 0.24	3.23 ± 0.22	3.16 ± 0.34	3.14 ± 0.32

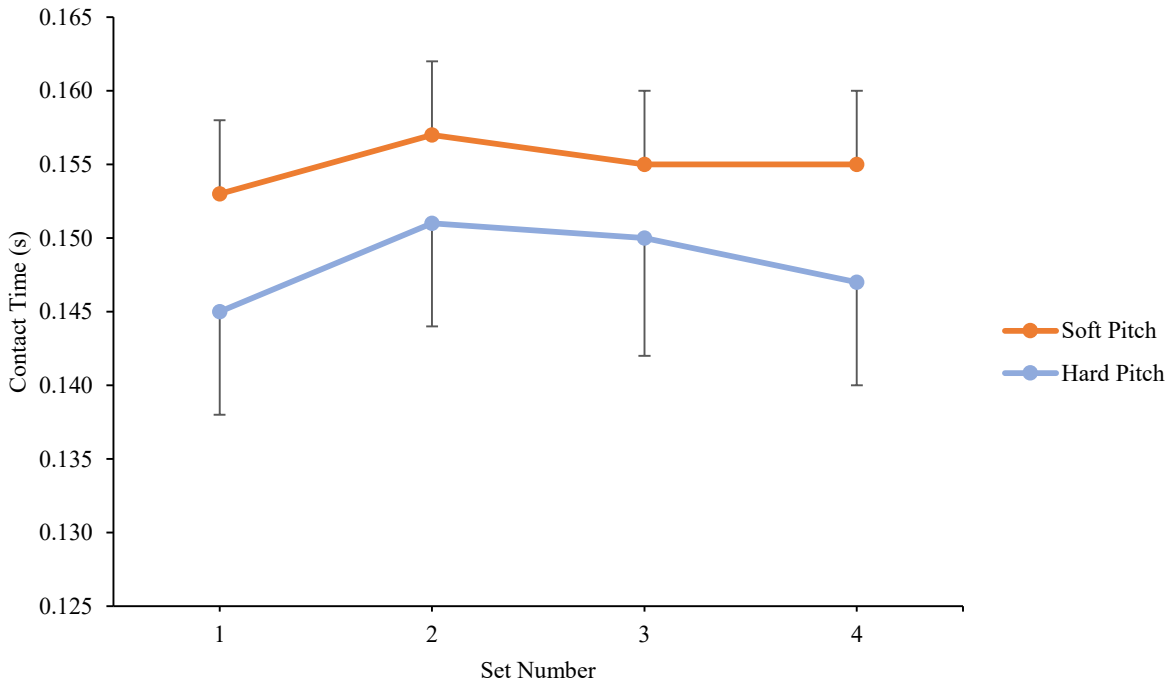

Figure 6.5. Foot CTs for each set during the SSP on hard pitch (blue line) and soft pitch (orange line)

6.3.4. Performance times – SSP

6.3.4.1. 15m linear sprint times

Neither the overall mean (d = 0.1), nor peak (d = 0.2), 15-m linear sprint times were different due to surface (main effect 'surface') (P>0.05). There was a main effect (P<0.05) of 'set number' in the SSP with a trend for faster mean sprints in set one compared to sets two, three, and four on the hard and soft pitches (Fig 6.6). There was a main effect (P<0.05) of 'set number' in the SSP with a trend for faster peak sprints in set one compared to set three on the hard pitch and faster peak sprints in set one compared to set four on the soft pitch. Neither the overall mean, nor peak, 15-m linear sprint times revealed a significant interaction effect (surface x set number).

6.3.4.2. 15 m cutting manoeuvre times

Neither the overall mean (d = 0.1), nor peak (d = 0.3), cutting manoeuvre times were different due to surface (main effect 'surface') (P>0.05). There was a main effect (P<0.05) of 'set number' in the SSP with a trend for faster mean cutting manoeuvre times in set one compared to sets two, three, and four on the hard pitch and faster mean cutting manoeuvre times in set one compared to set four on the soft pitch. The peak cutting manoeuvre times were not different due to the set number (P>0.05). Neither the overall mean, nor peak, cutting manoeuvre times revealed a significant interaction effect (surface x set number).

6.3.4.3. Turning manoeuvre times

The mean turn times were faster (d = 1.4; P<0.05) on the soft pitch (2.39 ± 0.04 s) compared to the hard pitch (2.44 ± 0.09 s) in the SSP. Faster mean turn times were performed on the hard pitch during the SSP in sets three compared to set one and in set four compared to sets one, two, and three (P<0.05) (figure 6.8.). The mean turn times revealed a significant interaction effect (surface x set number) with faster turns in set one of the SSP on the soft pitch (2.38 ± 0.05 s) compared to the hard pitch (2.52 ± 0.05 s). In contrast, for peak turn times in the SSP, there were no main effects (d = 0.3; P>0.05) of playing surface or interaction (surface x set number).

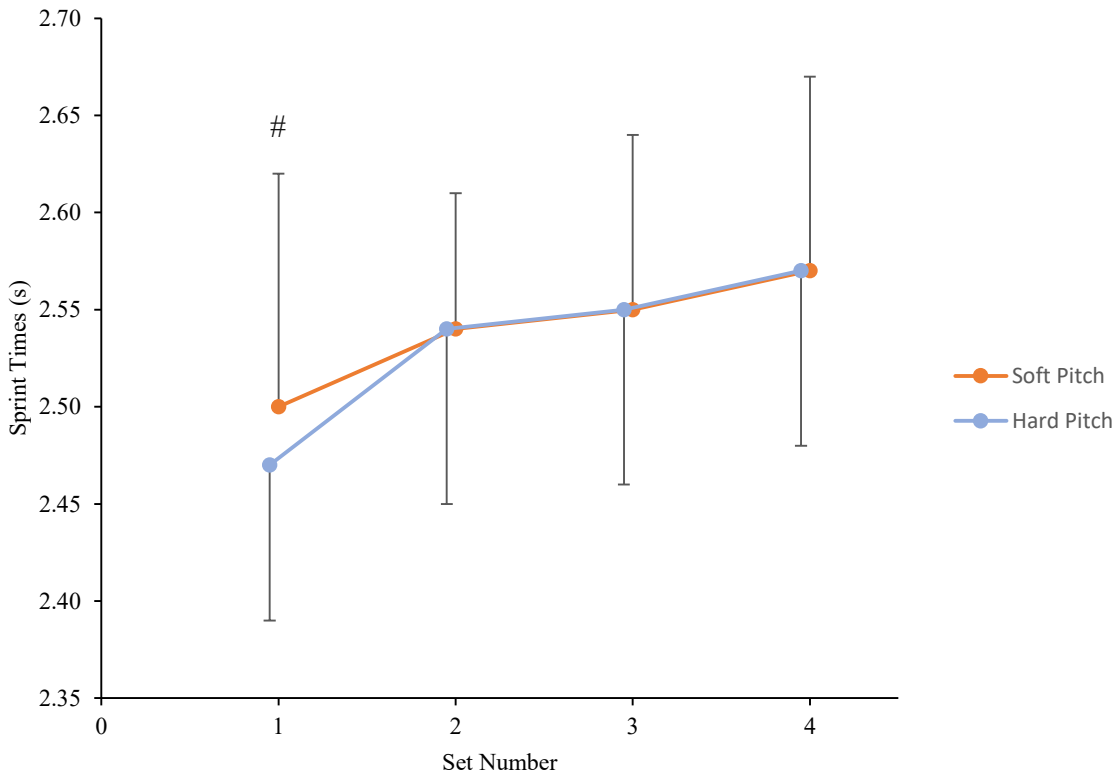

Figure 6.6. Mean 15 m linear sprint times for each set during the SSP on the hard pitch (blue line) and soft pitch (orange line). #Faster mean sprint times on the hard and soft pitches in set one compared to sets two, three, and four ($P<0.05$).

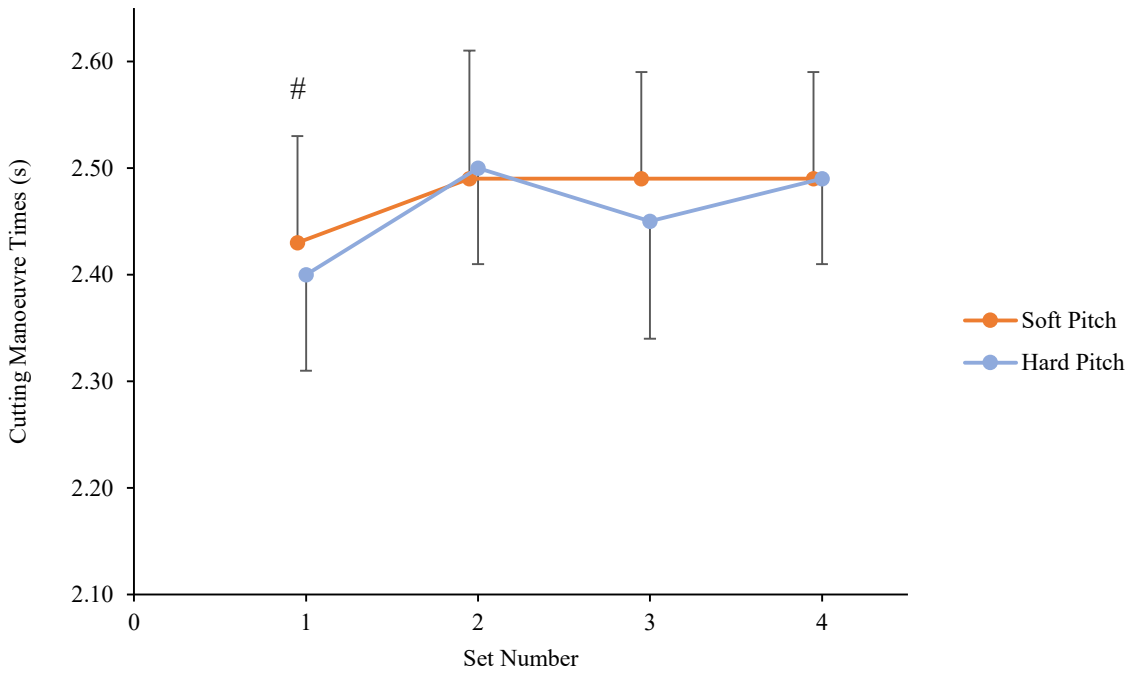

Figure 6.7. Mean 15 m cutting manoeuvre times for each set during the SSP on hard pitch (blue line) and soft pitch (orange line). #Faster mean cutting manoeuvre times in set one compared to sets two, three, and four on the hard pitch and faster in set one compared to set four on the soft pitch ($P<0.05$).

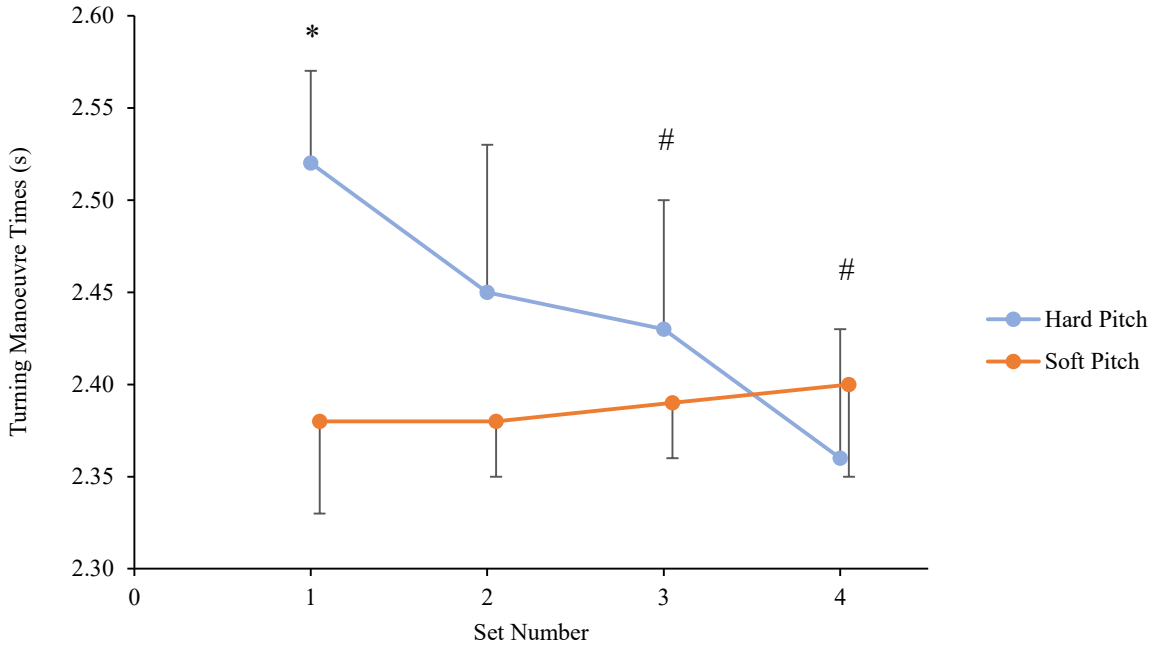

Figure 6.8. Mean 10m turning manoeuvre times for each set during the SSP on hard pitch (blue line) and soft pitch (orange line). *Faster mean turning manoeuvre times in set one on the soft pitch compared to the hard pitch (P<0.05). #Faster mean turning manoeuvre times on the hard pitch in set four compared to sets one, two, and three and in set three compared to set one (P<0.05).

Table 6.6: Overall performance values measured during the SSP on soft and hard NGPs (mean±sd.).

	Performance times	Hard Pitch	Soft Pitch	Cohen's d	2-way Repeated Measures ANOVA (P<0.05)		
					Surface Hardness (P)	Set Number (P)	Surface Hardness * Set Number (P)
15m Sprint (s)	Mean	2.53 ± 0.07	2.54 ± 0.09	0.1 (TRIVIAL)	0.710	0.000*a	0.507
	Peak	2.44 ± 0.04	2.45 ± 0.06	0.2 (TRIVIAL)	0.130	0.002*a	0.701
Cutting Movement (s)	Mean	2.46 ± 0.08	2.47 ± 0.09	0.1 (TRIVIAL)	0.605	0.009*a	0.610
	Peak	2.35 ± 0.07	2.37 ± 0.05	0.3 (TRIV/MED)	0.751	0.232	0.416
Turning Section (s)	Mean	2.44 ± 0.05	2.39 ± 0.02	1.4 (LARGE)	0.019*	0.000*a	0.004*b
	Peak	2.36 ± 0.09	2.34 ± 0.03	0.3 (TRIV/MED)	0.308	0.138	0.063

* Main effect of surface (faster on soft) (P<0.05)
*a Main effect of set number (P<0.05).
*b Interaction effect (surface and set number) (P<0.05).

Table 6.7. Performance times for 15m sprint, turning and cutting movements during four sets of the SSP on soft and hard pitches (mean±sd.).

	Performance times	Set 1	Set 2	Set 3	Set 4
SSP 15m Sprint (s)	Soft Pitch (Mean)	2.50 ± 0.12**2,3,4	2.54 ± 0.07	2.55 ± 0.09	2.57 ± 0.10
	Hard Pitch (Mean)	2.47 ± 0.08**2,3,4	2.54 ± 0.09	2.55 ± 0.09	2.57 ± 0.09
	Soft Pitch (Peak)	2.38 ± 0.07**4	2.47 ± 0.02	2.49 ± 0.01	2.47 ± 0.07
	Hard Pitch (Peak)	2.39 ± 0.02**3	2.45 ± 0.04	2.46 ± 0.04	2.47 ± 0.04
SSP Cutting Movement (s)	Soft Pitch (Mean)	2.43 ± 0.10**4	2.49 ± 0.12	2.49 ± 0.10	2.49 ± 0.10
	Hard Pitch (Mean)	2.40 ± 0.09**2,3,4	2.50 ± 0.09	2.45 ± 0.11	2.49 ± 0.08
	Soft Pitch (Peak)	2.35 ± 0.02	2.35 ± 0.10	2.37 ± 0.05	2.41 ± 0.02
	Hard Pitch (Peak)	2.29 ± 0.03	2.40 ± 0.07	2.33 ± 0.07	2.40 ± 0.06
SSP Turning Section (s)	Soft Pitch (Mean)	2.38 ± 0.05*1	2.38 ± 0.03	2.39 ± 0.03	2.40 ± 0.05
	Hard Pitch (Mean)	2.52 ± 0.05	2.45 ± 0.08	2.43 ± 0.07**1	2.36 ± 0.07**1,2,3
	Soft Pitch (Peak)	2.32 ± 0.05	2.36 ± 0.01	2.36 ± 0.02	2.33 ± 0.04
	Hard Pitch (Peak)	2.47 ± 0.05	2.35 ± 0.06	2.35 ± 0.06	2.27 ± 0.03

*Shorter result than in the surface and set indicated ($P<0.05$).
**Faster result than in the sets indicated ($P<0.05$).

6.3.5. Blood lactate (SSP) and average heart rate (SSA and SSP)

The blood lactate response to the SSP was not significantly different between surfaces but there was a significant main effect ($P<0.05$) of set number such that BLa was higher in set one (7.3 ± 3.6 mmol/l) compared to set two (6.0 ± 2.8 mmol/l), three (5.7 ± 2.2 mmol/l) and four (5.4 ± 1.8mmol/l) (table 6.8.) on the hard pitch.

The HRav response to the SSP was not significantly different between surfaces but there was a significant main effect ($P<0.05$) of set number such that HRav was higher in set one (164 ± 112 beats.min-1) compared to set three (162 ± 11 beats.min-1) and in set two (166 ± 11 beats.min-1) compared to sets three (162 ± 12 beats.min-1) and four (163 ± 11 beats.min-1) on the soft pitch. The HRav was higher in set one (168 ± 12 beats.min-1) compared to sets three (162 ± 13 beats.min-1) and four (163 ± 10 beats.min-1) on the hard pitch (table 6.9.). The HRav response to the SSA was not significantly different between surfaces ($P>0.05$) (table 6.8.)

Table 6.8. Physiological responses during the SSA and SSP on soft and hard pitches (mean±sd.).

Performance times	Hard Pitch	Soft Pitch	Cohen's d	2-way Repeated Measures ANOVA (P<0.05)		
				Surface Hardness (P)	Set Number (P)	Surface Hardness * Set Number (P)
SSP Blood Lactate (mmol/l)	6.1 ± 2.6	5.9 ± 2.1	0.1 (TRIVIAL)	0.741	0.025[*a]	0.360
HRav SSP (beats·min^{-1})	166 ± 11	164 ±11	0.2 (TRIVIAL)	0.703	0.000[*a]	0.075
				Paired-samples t-test (P<0.05)		
HRav SSA (beats·min^{-1})	143 ± 12	145 ± 11	0.2 (TRIVIAL)	0.09		

[*a]Difference between set number (P<0.05).

Table 6.9. Physiological responses during four sets of the SSP on soft and hard pitches (mean±sd.).

Physiological Variable	Set 1	Set 2	Set 3	Set 4
SSP Blood Lactate (mmol/l)				
Soft Pitch	6.3 ± 1.8	6.3 ± 2.3	5.4 ± 1.9	5.6 ± 2.6
Hard Pitch	7.3 ± 3.6**2,3,4	6.0 ± 2.8	5.7 ± 2.2	5.4 ± 1.8
Both Surfaces	6.8 ± 2.7	6.1 ± 2.5	5.5 ± 2.0	5.5 ± 2.2
SSP Heart Rate Average (beats·min^{-1})				
Soft Pitch	164 ± 12**3	166 ± 11**3,4	162 ± 11	163 ± 12
Hard Pitch	168 ± 12**3,4	167 ± 13**3,4	162 ± 13	163 ± 10
Both Surfaces	166 ± 11	166 ± 12	162 ± 12	163 ± 11

**Higher result than in the sets indicated ($P<0.05$).

6.4. Discussion

6.4.1. Introduction

The present study shows that one biomechanical response (CT) to simulated soccer activity and steady state activity was influenced by SH. However, there were no differences in the physiological responses (HRav and BLa) due to SH. The performance tests show that SH has an influence on turning activities but not on sprinting and cutting activities. The pattern of fatigue observed in the present study showed how hard the players worked during the SSP which gave the best possible chance to detect differences between surfaces. The SSP developed fatigue indicated by slower sprints from set one-to-four on the soft and hard surface. This pattern of fatigue resembles the demand of a soccer match as sprint speed slows especially in the latter periods of a match (Millet and Lepers, 2004; Krustrup et al., 2006; Andersson et al., 2008) and HRav (Rodrigues et al., 2007) and BLa (Rohde and Espersen, 1988; Roi et al., 2004) responses were similar to values found during match activity.

6.4.2. Biomechanical responses during steady state activity and the soccer simulation protocol

During the SSA, SF, St, and SL were unaffected, but CT was shorter on the hard vs. soft pitch. During the SSP, FT SF, SwT, St and SL were unaltered, but CT was altered between SH. CTs were shorter on the hard surface during the SSA and SSP which coincides with the findings by Gaudino et al. (2013) as they found longer CTs on softer sand surfaces during maximal sprinting compared to firmer surfaces such as NG and AT. Decreasing CT is an important change required to improve sprinting speed (Weyand et al., 2000; Weyand et al., 2010) but despite this, the mean sprint time was only marginally faster (0.03 s) in set one on the hard pitch and the same on both pitches in set two, three and four of the SSP in the present study. Unfortunately, Gaudino et al. (2013) did not measure SH, making it difficult to compare to the present study. When performing jogging and sprinting, it seems the softer the pitch, the greater the alteration in kinematics and muscle activation patterns (Pinnington et al., 2005). A possible explanation for these changes is that on a softer surface, SF, plantar flexion, forward lean of the trunk, and hip range of motion all increase (Pinnington et al., 2005). The latter three variables (plantar flexion, trunk inclination, and hip range of motion) were not measured in the present study, but SF was. SF was not different across the two surfaces in neither the SSA nor

SSP, which concurs with the findings from Gaudino et al. (2013) as they found no difference in SF between sand, NG and AT surfaces. Soft pitches were similar to hard pitches for many biomechanical responses in this study including SF, St and SL, but CT was different between the two surfaces during jogging and sprinting movements. The relationship between the six biomechanical responses was not explored in the present study, therefore it would be useful to observe how they interact in future research. It would be interesting to consider other joint kinematic and kinetic variables that might help to give a fuller explanation of the response.

6.4.3. Physiological responses during the steady state activity and soccer simulation protocol

6.4.3.1. Heart rate response during the steady state activity

The HRav response did not differ between surfaces during the SSA. Di Michele et al. (2009) observed higher heart rate values when running at 8, 10, 12, and 14 $km \cdot h^{-1}$ during an incremental running test on AT compared to NG. They used an oval circuit consisting of 4-minute running stages separated by a 1-minute rest period although the SH of the AT and NG was not measured. The nature of the oval circuit and running speeds (ranging from 8-14 $km \cdot h^{-1}$) used by Di Michele et al. (2009) was similar to that used in the SSA protocol in terms of the oval structure and jogging speed (9 $km \cdot h^{-1}$). However, the incremental testing procedure and surface comparison used by Di Michele et al. (2009) was not the same as in study three.

6.4.3.2. Heart rate response during the soccer simulation protocol

The HRav response did not differ between surfaces during the SSP which agreed with the finding of Nédélec et al. (2013), Hughes et al. (2013) and Stone et al. (2014) as they all support the notion that playing surface has little influence on physiological responses during SSP. The studies by Nédélec et al. (2013), Hughes et al. (2013) and Stone et al. (2014) did not compare soft NG vs. hard NG and SH was not quantified.

6.4.3.3. Blood lactate response during the soccer simulation protocol

BLa responses did not differ between surfaces during the SSP although there was a general decline from sets one-to-four with a lower concentration towards the end of the SSP on both surfaces, which concurred with similar work by Hughes et al. (2013) and Stone et al. (2014).

The BLa mean values on both surfaces ranged from 5.3 - 7.3 mmol/l during the SSP which was within the typical range (4 - 8 mmol/l) found during soccer match-play (Rohde and Espersen, 1988; Roi et al., 2004). Hughes et al. (2013) and Stone et al. (2011) found similar BLa ranging between 3.9 - 6.0 mmol/l and 3.0 - 4.3 mmol/l respectively, in research involving the SSP. The level of intensity of the SSP used in the present study was considered appropriate to simulate soccer match-play. Similarly, HRav was within the typical range (155 to 172 beats·min^{-1}) found during soccer match-play (Rodrigues et al., 2007). The TD covered during the whole SSP was approximately 10.3 km which was similar to 11.2 km TD covered in the Hughes et al. (2013) study. This showed how hard the participants worked in the current study as the time (i.e., 84-minutes) and distance (18 m lane) was reduced compared to the SSP used by Hughes et al. (2013), giving the best possible chance to detect differences between surfaces. The TD covered in the present study fell within the typical range of 8-11 km covered by amateur players during competitive soccer match-play (Izzo et al., 2018).

Although previous studies have explored the effects of playing surface on physiological responses to soccer specific simulations (Stone et al., 2011; Hughes et al., 2013), no research has investigated these responses on soft vs. hard NG. There was no change detected between surfaces in HRav responses when jogging in the SSA and performing the four movement-intensities in the SSP. There was a general decline in BLa from sets one-to-four with a lower concentration towards the end of the SSP on both surfaces but BLa concentration did not differ between surfaces.

On its own, the physiological data (i.e., HRav and BLa) did not show any difference between surfaces apart from that the players were able to work at a consistent intensity. However, despite the physiological data not being different, the performance data (i.e., turn times) was different which showed a surface effect.

6.4.4. Performance times

6.4.4.1. 15m linear sprint performance (SSP)

The performance responses show that SH influences turning activities but not cutting and sprinting movements. Mean sprint times ($d = 0.1$; $P>0.05$) in the SSP were similar on the hard (2.53 ± 0.07) and soft (2.54 ± 0.09 s) pitches in the present study closely resembling the same

performance measure (2.49 ± 0.08 s) on NG in the Hughes et al. (2013) study. Peak sprint times (d = 0.2; P>0.05) were also similar during the SSP on the hard (2.44 ± 0.04 s) and soft (2.45 ± 0.06 s) pitches in the present study. This demonstrated the high level of fitness and motivation of the players in the present study as the players in the Hughes et al. (2013) study were semi-professional with a mean age of 22.8 ± 2.1 years compared to academy-level (amateur) players used in the present study with a mean age of 18.0 ± 1.5 years. The decline in mean sprint times from set one-to-four seen on both surfaces in the SSP is evidence of the appropriateness of the procedure as similar findings have been detected during a match (Mohr et al., 2003; Bradley et al., 2009) where similar performance measures have been used. Surface type has been shown to influence sprint times in research by Fletcher et al. (2009) as they found sprint times to be faster on AT compared to NG over 15 m. It is difficult to compare the results from other studies when surface type and hardness differ. Higher energy restitution associated with a higher rigidity in surface characteristics has been shown to provide more resistance to the application of force (Kerdok et al., 2002; Katkat et al., 2009) and an increase in traction levels can give advantages in sprint performances (Luo and Stefanyshyn, 2011). However, traction and kinetic values were not measured in the present study. The present study demonstrates no difference in sprint times between surfaces during the SSP.

6.4.4.2. 15 m cutting manoeuvre (SSP)

Mean (d = 0.1; P>0.05) and peak (d = 0.3; P>0.05) cutting manoeuvre (slight change of direction at the half-way point around a cone 2 m away from the midline) times during the SA-R component of the SSP did not differ between surface which concurs with the findings from Hughes et al. (2013) and Stone et al. (2014) as they both found no difference in cutting manoeuvre times during the SSP when comparing AT vs. NG. Despite using a different protocol, Ford et al. (2006) showed no performance time differences in the slalom course during maximal effort laps on AT and NG and the total loading experienced under the entire foot also did not change. There was a trend for the mean and peak cutting manoeuvre times to be faster in the first set compared to set four (figure 6.7.). Earlier work on AT surfaces did provide faster cutting times and sprint times when compared to NG (Stanitski et al., 1974), although the mechanical properties of AT have changed dramatically in more recent times. It remains difficult to directly compare the findings to other research when different surfaces have been used and SH has not been quantified objectively. Traction and friction properties were not considered in the present study despite their importance in terms of providing GRFs for an

athlete to change direction, accelerate, decelerate, push off or stop (Barry, 2004; Luo and Stephanyshyn, 2011). Footwear (studded boots) and surface type (i.e., NG) remained the same on both surfaces to ensure friction and traction properties (i.e., grip) remained consistent. Grass coverage potentially influences physical performance (Steffen et al., 2007; Stiles et al., 2009), however, it was not considered in the present study. In summary, mean and peak cutting manoeuvre times were not significantly different between surface. There was a general trend showing faster cutting manoeuvre times in the first set compared to the last set on both surfaces although the difference was not significant. There was no observation of contrasting wear and tear on either of the soft and hard pitches following testing, suggesting the observed difference in cutting manoeuvre time was a characteristic between the two surfaces and not one that could be attributed to wear and tear on the pitch.

6.4.4.3. Turning manoeuvre (SSP)

Mean ($d = 1.4$; $P<0.05$) turn times (180 degree turn around a cone) were 0.05 s faster on the soft vs. hard pitch during the SA-R section of the SSP. There was a trend for the mean turn times to slow by 0.02 s from set-one-to four on the soft pitch whereas, mean turn times got faster by 0.16 s from set one-to-four on the hard pitch ($P<0.05$). There was a significant interaction (surface x set number) specifically showing faster mean turn times in set one of the SSP on the soft (2.38 ± 0.05 s) vs. hard (2.52 ± 0.05 s) pitch ($P<0.05$). Hughes et al. (2013) measured the SA-R component of the SSP and found slower mean turn times on NG (2.55 ± 0.07 s) compared to 2.44 ± 0.05 s on the hard pitch and 2.39 ± 0.02 s on the soft pitch in the present study. Faster mean turn times were performed on the hard pitch during the SSP in set three compared to set one and in set four compared to sets one, two, and three ($P<0.05$) (figure 6.8.). In contrast, with peak turn times there were no main effects ($d = 0.3$; $P>0.05$) of playing surface, set number, or interaction (surface x set number). Peak turn times (180 degree turn around a cone) were only 0.2 s faster on the soft vs. hard pitch whereas, peak turn times got faster by 0.20 s from set one to four on the soft pitch during the SA-R section of the SSP. The peak turn times got faster by 0.20 s from set one-to-four on the hard pitch ($P>0.05$). One possible explanation could be that the hard pitch remained firm throughout the four sets of the 84-minute SSP, which could potentially have reduced any decline in turn times from set one-to-four on the hard pitch. There was no observation of contrasting wear and tear on either of the soft and hard pitches following testing, suggesting the observed difference in turn time was

a characteristic between the two surfaces and not one that could be attributed to wear and tear on the pitch.

6.4.4.4. Strength and the project

In the present study, SH was measured five times across six sites (FIFA, 2012) on each pitch before and after each testing period. For the SA-R component of the SSP, the timing gates were separated by 2.5 m and the procedure was never carried out on the same area of the pitch twice. With 48 turns performed in the 84-minute protocol, only 24 were performed at each end of the SSP layout therefore, reducing the likelihood of the wear and tear of the pitch potentially impacting on the results.

Several measures were put in place to strengthen the experimental design and included monitoring the environment prior to testing (i.e., weather and SH), implementing a cross-over design, and objectively quantifying SH. The temporal uniformity (seasonal change) of both surface conditions was considered, and testing was carried out during the month of May without the presence of rain or strong wind. The cross-over design was implemented with 72 h prior to completing the SSA and SSP on each surface to ensure recovery was sufficient (Chappell et al., 2007; Nigg et al., 2009). The participants in the cross-over design acted as their own control, minimising the effects of potential confounding factors between participants (i.e., carryover, period, or sequence effects) (Wang et al., 2016). SH was repeatedly measured during the weeks leading up to testing, to monitor the pattern and behaviour of the surface to ensure the hardness was classified as soft or hard using a CIH.

6.5. Conclusion

This study is the first to compare biomechanical, physiological, and performance responses to soccer activity on soft vs. hard NGPs. It is pertinent to highlight that one biomechanical response (i.e., CT) differed between surface during the SSA and SSP. It is also pertinent to highlight that one performance response (i.e., turn times) differed between surface during the SSP. Physiological responses (i.e., HRav and BLa) did not change between surface during the SSA and SSP. The absence of differences due to SH needs to be highlighted as many of the biomechanical (SSA - SF, St, and SL; SSP - SSP, FT SF, SwT, St and SL), physiological (HR and BLa) and performance responses (sprint and cutting manoeuvre times) were similar across

both surfaces. The pitches used in the present study were lower-quality surfaces therefore should not be generalised to higher-quality surfaces. It remains possible to suggest that the biomechanical and performance responses would be influenced further if a greater SH difference exists between the soft vs. hard pitches. Further research should continue to quantify an array of physical responses using situations within the participants' environment via testing protocols that closely resemble competitive soccer match-play using NGPs with contrasting SH. A few of the results suggest it is worthwhile exploring this area a little more deeply therefore, it would also be of value to evaluate the perceptions of players and coaches on the effect of playing soccer on soft and hard soccer pitches.

CHAPTER 7. STUDY 4 – FOCUS GROUP

Study four aimed to evaluate the perceptions of players and coaches on the effect of playing soccer on soft and hard NGPs. The research methodology for study four was qualitative in nature, and the procedure involved using a focus group. Four main topics were investigated including the technical, tactical, physical, and psychological concepts when playing on harder or softer NGPs. Gaining feedback related to opinions and experiences would either affirm that the summaries from the three previous research studies may or may not reflect their feelings, experiences, and views.

Abbreviation:	Nomenclature:
FG	Focus Group
PI	Principle Investigator
NGP	Natural Grass Pitch
NGSH	Natural Grass Surface Hardness
AT	Artificial Turf
NG	Natural Grass
PS	Playing surface

Abstract

The purpose of this study was to evaluate the perceptions of players and coaches on the effect of playing soccer on soft and hard natural grass pitches (NGPs). Purposive sampling was used to select four participants consisting of two coaches and two players. Information was collected through one meeting of a focus group (FG). The format of the FG consisted of nine open-ended questions covering four main areas including the technical, tactical, physical, and psychological concepts of playing and coaching soccer on NGPs with contrasting surface hardness. A thematic and content analysis was subsequently carried out on the data. The consensus drawn from the thematic and content analysis was that playing on a hard pitch elicits greater stress on the body, joints and muscles and this is commonly experienced during the summer months when the surface is too hard and the winter months when the surface is cold and hard. Players and coaches suggested that hard pitches facilitated the execution of technical skills and increased the speed of the game whereas, on soft pitches, the ball is played from front to back more frequently. Findings suggested that on soft pitches it is more difficult to perform movements (i.e., turning and sprinting) and the metabolic cost is higher. In summary, the present study predominantly shows players and coaches would prefer to play soccer on a hard pitch over a soft pitch. More research is required solely focusing on the perceptions of playing on soft and hard NGPs to provide more information on the complex subject.

Key words – natural grass, perceptions, soccer, surface hardness

7.1. Introduction

The style and pace of soccer is thought to be influenced by the performance characteristics of different playing field surfaces (Dragoo and Braun, 2010) however, knowledge is sparse in terms of understanding the effect of different pitch surfaces on the perceived effort and exercise intensity during a soccer match (Brito et al., 2012). Match performance characteristics and outcomes are affected by surface type and hardness (Baker et al., 2001; Fernandez et al., 2006; Andersson et al., 2008; Stiles et al., 2009; Potthast et al., 2010; Poirier et al., 2011) and subtle changes in surface characteristics may affect a player's movements, potentially disturbing their technical skills during competition (Dixon et al., 2000). Certain path changes and locomotory

movements have been influenced by NGSH during competitive soccer match-play in study one of the present project (Sleat et al., 2016). Sprint performance was affected by contrasting NGSH in study two of the present project. Certain performance and biomechanical responses were influenced by NGSH during soccer-specific simulations in study three of the present project. One area that is often neglected from surface type comparison studies is the players' perceptions making it difficult to make assumptions when determining which factors are important for the player (Andersson et al., 2008; Roberts et al., 2014).

Soccer players perceived playing 5-a-side soccer matches less demanding on asphalt as their perceived effort rating was lower on asphalt than on AT and sand (Brito et al., 2012). Andersson et al. (2008) investigated player perceptions of movement patterns and technical standards while performing on AT versus NG and reported that it was physically and technically more demanding to play on AT compared to NG. Roberts et al. (2014) revealed that a higher proportion of players mentioned that AT was "more abrasive" and "more level" and had "less grip" and was "too hard or harder" and "too fast" compared to NG but it was unclear on which surface was favourable. In contrast, Brito et al. (2012), Andersson et al. (2008) and Zanetti et al. (2009) revealed that players preferred playing soccer on AT due to NGPs often being hard and dry in the summer months and muddy and frozen in the winter months. Soccer player perceptions were captured following physical tests (RSA) performed solely on AT but with different mechanical properties and players felt more comfortable on the more rigid and harder AT surface (Sanchez-Sanchez et al., 2014). Poulos et al., (2014) found that playing on AT resulted in greater joint and muscle soreness and it took longer to recover when compared to NGPs. Equivocal findings exist when trying to ascertain the perceptions of players when playing soccer on different playing surfaces in terms of SH, friction, metabolic cost, and perceived exertion (Poulos et al., 2014). Player perceptions need to be studied further to determine which factors are important for the player when it comes to playing surface (Roberts et al., 2014). The previous three studies in the present project focused on the physical demands of playing soccer on NG of contrasting pitch hardness and involved performance analysis, physiology, and biomechanics disciplines. To produce a comprehensive and multidisciplinary research project, it was necessary to investigate the psychological perceptions of players and coaches playing on contrasting NGPs. Therefore, an endorsed four stage FG procedure (Patton, 2002; section 2.6.) was purposely utilised to triangulate the themes from the three quantitative studies in the present project to strengthen the internal validity (Shenton, 2004) and confidence that the research question under scrutiny was accurately analysed (Lincoln, 1995). Member

checking involved each participant reading the transcript to check the content reflected the FG discussion. The inclusion of member checking would ensure the accuracy (Côté, 1993; Shenton, 2004) and trustworthiness (Brewer and Hunter, 1989; Miles and Humberman, 1994; Pitts, 1994) and biases (Côté, 1993; Patton, 2002) of the transcript. Relating the results generated from the study back to the existing body of knowledge would either confirmed the findings as logical and reasonable (Burnard, 1991; Morse and Richards, 2002). Therefore, the purpose of this study was to evaluate the perceptions of soccer players on the effect of playing soccer on soft vs. hard NGPs.

7.2. Experimental methods – experimental set-up, procedure, and data analysis – study 4

The research methodology for study four was qualitative in nature, and the procedure involved using a focus group (FG). One meeting, lasting approximately two hours focused on four main topics including the technical, tactical, physical, and psychological concepts when playing on harder or softer NGPs. Gaining feedback related to opinions and experiences would either affirm that the summaries from the three previous research studies may or may not reflect their feelings, experiences, and views. The FG was the only method used in study four but was embedded to complement the other quantitative methods used in studies one-to-three. Instead of the FG being used at the exploratory or preliminary stages (Kreuger, 1988) of the whole research project, it was used to investigate and evaluate themes linked particularly to the three preceding studies (Race et al., 1994) (performance analysis, biomechanics, and physiology) and the associated psychological concepts.

All participants were fully informed of the investigation (Appendix 11.2.5); testing procedures were approved by the CSSREC (Appendix 11.3.4) and written informed consent was obtained from all participants (Appendix 11.1.6). Informed consent consisted of the following statements: (a) participants may withdraw unconditionally from the study at any point and should not be required to disclose a justification to the PI; (b) participation is voluntary; (c) there are no incentives rewarded for participating; (d) participants are allowed to ask questions at any time; (e) the FG will be digitally recorded and transcribed; (f) transcripts will be evaluated by the PI to analyse and identify any emerging thematic structure; (g) non-disclosure will be obtained from all members participating. The PI worked in the education sector and held a current DBS. Data were stored securely with password protected IT equipment and only the PI and research team had access to such data. The nature of an FG carried no physical risks

to any participants involved due to the FG being set within a boardroom/conference room. Risk was minimal in terms of reputational damage as only one educational establishment was involved in the research project with no other external institutions involved. The FG discussions posed no specific risk to the institution as the topics related to sporting and coaching experiences only. All precautions were implemented to ensure the confidentiality and welfare of the PI and all participants was maintained throughout the FG.

Participants were informed that an audio recorder (Olympus VN-541 PC DNS dictation machine, Japan) and video recorder (Sony HDR-XR155E digital video camera, Japan) would record the FG for analysis purposes (transcript and body language purposes). The PI took precautionary steps to maintain confidentiality of the data. Participants were told that all information shared in the FG should be treated with privacy and should not be shared with anyone outside of the FG. The informed consent document offered all participants an option where they had to agree by ticking the non-disclosure box. If a sensitive issue arose in that the researcher could be a party to 'guilty knowledge' the PI would decide the limits of tolerance, beyond which he will not venture. Given the nature of the FG, it remains highly unlikely any information solicited during the FG would be illegal, illicit and/or had potential for harm. It was agreed by all participants that informed consent and non-disclosure would be violated should illegal, illicit and/or any information with potential to harm occurred.

7.2.1. Participants

Four participants were selected to attend one FG and a purposive sampling procedure (Seaberg, 1985) was used in the recruitment process and expert/homogenous sampling was employed to include only those with expertise and knowledge in the research area of interest (Bernard, 2002; Etikan et al., 2016). The criteria for inclusion required participants to have experienced either previously or currently playing or coaching soccer at amateur or professional level. The sample consisted of the following participants:

- Deputy Head of Department/Football Association Wales Coach (U18s)
- Director of Football (Yeovil Ladies Football Club/Cardiff and Vale College academy-level (amateur))/Ex-professional Football Player
- Welsh Schools Football Association Coach (U18s)

- Ex-professional Football Player/Current Lecturer in Sport and Exercise Sciences

7.2.2. Approaching the FG and the experimental procedure

Only those participants who were genuinely willing to contribute with frankness were offered the chance to take part. The aim was to build rapport from the start of the data gathering stage (Shenton, 2004). The location selected for the FG was secure, private, comfortable, and quiet to not discourage participants from talking and expressing their opinions and experiences. Preparation prior to the FG included familiarity with the leading open-questioning route, and subsequent guidance points to allow the PI to maintain the correct direction. The independent status of the PI was emphasised at the start of the FG and it was stressed that there were no right answers to any of the questions, so the participants could express their thoughts and contribute without losing their credibility. It was imperative to reduce the likelihood of any distractions and to ensure all participants listened with discipline and respect. An open-circle FG was utilised, and the session started with a concise introduction comprising of welcoming the group, providing an overview of the topic, setting ground rules, and starting with an introductory open-question. Probing questions were used such as "would you give an example?" or "would you explain further?" The content of the FG consisted of three main areas including the technical and tactical, physical, and psychological concepts of playing and coaching soccer on NGP of contrasting hardness. Section one aimed to address how the characteristics of NGSH influenced the way soccer is played i.e., the technical and tactical aspects including the style and pattern of play, formation, playing position, locomotion, path changes, game-related activity and preparation. Section two aimed to address the perceptions of how NGSH impacts on the physical aspects including the physical demands and technical demands, specific training prescription, and fatigue. The third section aimed to address the psychological perceptions of players and coaches on their opinions and experiences of playing and coaching on contrasting NGP. The main section of the FG included questions that asked the participants to directly compare soft and hard NGPs. Four participants were asked nine open-ended questions. All questions were answered, and all four candidates contributed equally. The following questions were asked:

1. Do you think that playing on a hard or soft pitch changes the technical application and tactical set-up?

2. With turning and changing direction, how do you think they would change when being performed on soft or hard pitch?
3. If you had a match coming up on a specific condition, how would you prescribe training on certain conditions to suit?
4. How do movements change when you are playing on a hard and soft pitch?
5. With sprinting and repeated sprint ability, how would they change on a hard and soft pitch?
6. Do you think it would be more taxing if a midfielder player performs on a hard pitch or a soft pitch?
7. How do you think running mechanics or running technique changes on a hard and soft pitch?
8. How would psychological concepts like motivation, stress, and anxiety be influenced when playing on contrasting NGPs?
9. If you were going to play a match on a hard or soft pitch, do you think your workload and work-rate would be influenced and which surface do you think would make you feel more tired?

7.2.3. Content analysis

Following the FG, the PI individually transcribed the FG to produce a document for thematic analysis to assure the accuracy of the data (Patton, 2002). The next stage involved the PI understanding a grasp of the experience by listening and reading the FG transcript. Carrying out this process allowed for a complete grasp of the data, a thorough understanding of the experiences obtained to make sense in its entirety. Content analysis was used with some induction to identify themes related to explanations but being framed in a deductive manner based on the findings from the previous studies. A thematic approach was conducted to get a sense of the interview content before breaking it into parts for further analysis. Major themes emerged identifying a thematic framework, writing short phrases, and sorting quotes to compare the findings. On completion of classifying each theme, the PI was debriefed by a supervisor with extensive experience in qualitative research and the project's topic. Questions in the FG aimed to address the general topic of the main research question (refer to section 1.3.4. thesis layout) by triangulating specific questions related to the three disciplines (performance analysis, physiology, and biomechanics) to ascertain the participants' experiences. This ensured the study measured what it intended to measure and enhanced the

internal validity (Shenton, 2004) and confidence that the phenomena under scrutiny was accurately recorded (Lincoln, 1995). The trustworthiness of the analysis was established through researcher familiarity with the research topic, independent checking of the themes identified, and checking with a supervisor familiar with qualitative research. Member checking (where the four participants checked the conclusions and agreed they reflect their views drawn from the data) also ensured the trustworthiness of the data was established.

7.3. Results

Personal perceptions of the players and coaches (professional players, amateur player, and coach) representing strongly agreed on a number of questions; however, on a few occasions, there was disagreement on a few questions. The results have been presented in table 7.1. with key phrases related to key themes relevant to the study (surface hardness, turning, tactical, technical, metabolic cost, movements, sprinting, and biomechanics). Comments captured were categorised in relation to either soft or hard pitches.

Table 7.1. Key themes and phrases in the responses from the FG.

Key theme	Key phrases
Surface hardness	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“autumn where it has a nice drop of rain, it becomes boggy”,
(hard pitch)	“bounce more”, “react more quickly”, “more stress”, “summer months it is too hard”, “winter it becomes cold and hard”
Metabolic cost	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“harder to run on a boggy pitch”, “it takes more out of you”, “it is like running on sand”, “come off and feel exhausted”, “you expend more energy”
(hard pitch)	“more physically demanding”, “lighter across the ground”
Technical	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“foot could be stuck in the ground”, “ball sticking under your feet”, “long passes”, “half the turf moves”
(hard pitch)	“pass it around more”, “run away from you”, “easier to get under the ball”, “little extra and fizz it”, “spring for a header”, “better grounding to take off from” “run out of play”
Turning	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“trying to turn and your footing is going”, “more taxing”, “legs become tired”

(hard pitch)	“harder to change direction on a harder pitch”
Tactical	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“unable to play”, “go back to front a lot quicker”
(hard pitch)	“nice pitch you would have your ball players and if not, you would have your players that work harder”, “high press”, “game is faster”
Movements	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“not the same explosive movements as you can get with a firm pitch”, “press but, it is not going to be in the same intensity”
(hard pitch)	“do not change on softer and harder grass”, “run more”, “move faster because you get a better grip”,
Sprinting	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“harder to sprint on a softer pitch as the ground is not as firm”, “not going to be as fast”
(hard pitch)	“more sprints”, “lighter across the ground”, (linear acceleration and deceleration changes on softer and harder grass and maximal speed running does not change”
Biomechanics	the following are “key phrases” in the responses that corresponded with the surface property or physical performance measure:
(soft pitch)	“change in technique and forces”, “push down further”, “got a little more give and cushioning”, “joint angles change”

(hard pitch)	“will push as hard but move off quicker”

7.4. Discussion

7.4.1. Introduction

The findings indicate that FG members (professional players, amateur player, and coach) representing a sample with broad experience of playing and coaching soccer on contrasting NGPs, believe that SH influences the characteristics of a match. The present study found both positive and negative perceptions of playing soccer on soft and hard pitches with a general preference leaning more towards the latter surface.

7.4.2. Surface hardness

Surface hardness was identified as a key characteristic of NGPs having the potential to impact on soccer performance. Conflicting views were captured in relation to the impact of SH on soccer performance. Positive comments associated with a hard pitch suggested a player can react more quickly and bounce more efficiently implying that it would benefit a player in terms of certain movement types (i.e., change of direction, jogging, running, and sprinting). The negative connotation of playing on a hard pitch was that a player experiences a greater physical load (i.e., greater stress on the body, joints, and muscles). These thoughts may be further explained by the perception that pitches are often harder during the summer and winter periods. Zanetti (2009) discovered that soccer players preferred to play on AT over NGPs due to the latter surface being dry and hard during the summer months and frozen and muddy in the winter months. Similarly, Polous et al. (2014) found that hard pitches were perceived as tougher, harder, and unforgiving surfaces which had poor shock absorption and caused harder impacts. In contract, Sanchez-Sanchez et al. (2014) found that soccer players felt more comfortable when performing physical tests on hard pitches. The findings of Zanetti (2009), Polous et al. (2014) and Sanchez-Sanchez et al. (2014) were perceptions of playing soccer on either AT vs. AT surfaces or AT vs. NG, unlike the present study that compared soft and hard NGPs. A pre-established bias towards a certain playing surface could possibly influence a players' perception. Players' and coaches' satisfaction of playing soccer on NG was greater when compared to AT as 74% stated that NG possesses significantly better shock-absorption qualities (Gallardo et al., 2010) and 72% stated that NG lowers the burden of risk with lower impact forces. In contrast, Ávalos-Guillén et al. (2017) reported that the values for impacts and body loads were significantly greater on NG compared to AT.

The present study did not focus on the demographics of the FG members (i.e., age, years as a player, training surface type, competition surface, percentage of careers on either AT or NT) to determine their influence on perceptions. The focus group members had confusing and conflicting views on the impact of SH on the characteristics of a soccer match. It should be noted that the opinions in the present study and other related research by Zanetti (2009), Gallardo et al. (2010), Polous et al. (2014), Sanchez-Sanchez et al. (2014) and Ávalos-Guillén et al. (2017) are predominantly based on subjective observations and not from scientific data.

7.4.3. Metabolic cost

Five key phrases were observed in relation to the metabolic cost of playing soccer on a soft pitch and included "it takes more out of you", "it is like running on sand" "you come off and feel exhausted", "you expend more energy" and it is "harder to run on a boggy pitch." Research by Andersson et al. (2008) reported a negative impression of playing soccer on AT compared to NG and that it is physically more demanding, although they used professional players and did not measure the hardness of either surface used. Previous work by Brito et al. (2012) suggested that recreational players perceived the demands of playing 5-a-side soccer to be greater on sand and AT compared to asphalt. The authors suggested the greater demands were attributed to external loads (i.e., ability/difficulty to run) rather than internal loads (i.e., physiological responses). Conflicting comments were observed in the present study in relation to the metabolic cost of playing on a hard pitch as one comment stated that it is "more physically demanding" while in contrast, another comment stated that a player is "lighter across the ground" which implies that it is less physically demanding. Playing soccer on NG pitches has produced significantly higher HR (average and maximum) and stress values (Ávalos-Guillén et al., 2017). The authors suggested that the higher HR values may have been attributable to a greater physical burden and effort required when playing on NG compared to AT. Possibly players produce less traction yet more absorption of impact forces when performing on soft pitches resulting in more muscle force and energy expenditure required (Zamparo et al., 1992).

The general trend in the present study supports the notion that players and coaches perceive it to be more physically demanding (i.e., more tiring) playing soccer on a soft pitch compared to a hard pitch. The present study did not clarify whether the perceptions were related to

performance (ability to run and sprint) and or physiological responses (i.e., HR and BLa). However, HRav and HRpeak was not different between hard and soft pitches when performing repeated sprint performance in study two (repeated sprint performance). The HRav was not different between hard and soft pitches when jogging in the SSA protocol and performing different movement intensities during the SSP in study three.

7.4.4. Technical

Four key negative comments were observed in relation to the technical skills of playing soccer on a soft pitch and included the "foot could get stuck in the ground", "ball sticking under your feet", "long passes" and "the turf moves." These comments concur with Dixon et al. (2000) as they suggested that technical skills and movements are disrupted when surface characteristics subtly change although a subtle change is not the same as contrasting hard and soft pitches. A mixture of comments were observed when considering the effect of SH on the technical skills important for soccer performance. Positive comments relating to the influence of a hard pitch on the technical skills were observed and included "pass it around more", "easier to get under the ball", "little extra and fizz it", "spring for a header" and "better grounding to take off from." Jumping ability has been shown to decline with match-related fatigue (Millet and Lepers, 2004; Krustrup et al., 2006; Andersson et al., 2008), therefore linking this back to the previous perceptions that it is more tiring playing on a soft pitch would suggest that jumping ability is further reduced. This coupled with the ability to produce greater forces on a firmer surface (Ekstrand and Nigg, 1989), may explain why the players expressed that a harder surface is better to "take off" and "spring" off for a header. Negative comments relating to the influence of a soft pitch on the technical skills were observed in the context of the ball-to-player interaction and included phrases such as the ball "runs away from you" and "runs out of play."

The general trend in the present study supports the notion that players and coaches perceive it to be easier to execute technical skills on a hard pitch compared to a soft pitch. Previous work by FIFA (2006) and Andersson et al. (2008) concluded that playing patterns and techniques were not influenced by differences between AT and NG surfaces. In study one (match analysis), no differences were found in game skill frequencies between soft vs. hard pitches but clearly, more research is required to detect the perceived influence of soft vs. hard NGPs on the technical execution of soccer skills.

7.4.5. Turning

Performing turning movements was perceived as more difficult on a soft pitch by the players and coaches. Negative comments included “more taxing”, “legs become tired” and “trying to turn and your footing is going.” One possible explanation for the perceptions in the present study is that the soft pitch suffers greater deterioration than the hard pitch resulting in less ability to perform turning movements successfully. Were perceptions on turning movements influenced by the previous perceptions that soccer players generally found it to be more physically demanding and more difficult to execute technical skills when playing soccer on soft pitches. One FG member’s comment strongly disagreed with this notion and stated that it is “harder to change direction on a harder pitch.” Important variables such as the age, playing position, years as a player, training surface type, competition surface) were not investigated in the present study to determine their influence on perceptions.

The findings of the present study provide additional information with the findings of study one (match analysis) as a greater frequency per minute was found on the soft pitches for each turn type (moderate intensity, high intensity, sharp right, sharp left, V-cuts, and smooth turns). However, study one did not examine how difficult the players found it to turn in study one. This is an example of why complementary qualitative analysis is important. The intensity observed by the researcher in study one was an external perception of intensity experienced by the player. The respondents in the FG were discussing things from the player’s point of view which was different.

The general trend in the present study suggests that players and coaches perceive it to be easier to execute turning movements on the hard pitch vs. soft pitch. The opposite was found in study three (match simulation) where turning movements were significantly faster on the soft pitch vs. hard pitch. The findings from study three were objective and produced facts whereas, the subjective findings from study four produced opinions. Future qualitative work should seek to find more information as to why players and coaches perceive it to be more difficult performing turning movements on soft pitches.

7.4.6. Tactical

Different playing styles have been shown to influence the physical demands on the soccer player (Bradley et al., 2011), potentially changing the physiological stress and level of work-rate imposed on a player (Reilly et al., 1991). Two negative comments relating to a soft pitch included "unable to play" and "go back to front a lot quicker" suggested the group of players and coaches thought that playing on soft pitches impacted on the tactics of a game. These comments suggest that when playing on a soft pitch, the 'direct' style of play is the preferred choice characterised by longer passes, a low number of touches per ball involvement, and a low number of passes (Kempe et al., 2014). Two important positive comments relating to playing on a hard pitch included the "game is faster" and a "high-press" tactic is often implemented. A high-pressure method is one defensive style of play (Bangsbo & Peitersen, 2000; Peitersen, 2001), characterised by applying pressure closer to the opponent's goal (Fernandez-Navarro et al., 2016).

The present study supports the notion that players and coaches perceive SH to affect the tactical characteristics of a soccer match. The consensus suggested that it is tactically advantageous playing on a hard pitch making it easier to play a 'passing game' without playing a 'direct' style of play if this is the preferred choice.

7.4.7. Movements

An emerging theme was observed with the comments associated with movements suggestive that it is easier to perform movements on hard pitches. The comments suggested a player moves faster with more explosively intensity with better traction and firmness underfoot resulting in a greater rate of force development (defined as "the speed at which the contractile elements of the muscle can develop force;" Aagaard et al., 2002). The comments favouring the hard pitch to produce movements may simply be explained by the ability to produce greater forces on a firmer surface (McGhie and Ettema, 2013).

The frequency per minute of several movements (high intensity shuffling, running, low, and high intensity activities) was greater on the soft pitches in study one. In study two, the fastest

and average sprint performances were quicker and there was a greater percentage decrement (PD) on the hard pitch vs. soft pitch during repeated sprint performances. Faster turns were produced on the soft pitch in study three when performing soccer simulated activity.

The general trend in the present study supports the notion that players and coaches believe it is easier to perform movements on the hard pitch compared to a soft pitch, as was the case with turning movements previously discussed. A possible explanation for this belief was associated with being able to produce greater force (McGhie and Ettema, 2013) and better traction on a firmer surface which gives advantages in acceleration and linear movements (Luo and Stefanyshyn 2011).

7.4.8. Biomechanics

Comments related to biomechanical aspects when playing on the soft pitch suggested that technique, forces, and joint angles change but it not did reveal in what way they change. Perhaps a lower impact peak on the soft pitch reduced the ability to produce force rapidly (McGhie and Ettema, 2013) which in turn alters joint movement patterns (Hamill et al., 1992), influences vertical deformation (Sánchez-Sánchez et al., 2014) and increases eccentric muscle activity (Richie et al., 1993). The comments suggest that you can push off a hard pitch more quickly than a soft pitch implied that perhaps the lower energy restitution associated with a soft pitch may cause a higher workload (defined as "the physical stress to which players are exposed" (Bangsbo, 2014)) on a soft pitch (Kerdok et al., 2002; Katkat et al., 2009). It would be helpful to consider their familiarisation of a given surface (Nedelec et al., 2013). The candidates in the present study had a broad range in terms of age, playing and coaching experience, however, familiarisation of a given surface was not measured. The general trend in the present study supports the notion that players and coaches perceive it to be easier to execute movements influenced by biomechanical concepts (i.e., force production, technical proficiency, and energy restitution) on a hard pitch compared to a soft pitch.

7.4.9. Limitations

A few limitations exist with this study, which may in future be overcome to strengthen the ability to generalise the findings. Candidates were selected using a purposive sampling method

based on the objective of the study and the characteristics of the population required. A small sample size was used and therefore the findings may not be representative of the opinions of all soccer players. A much more diverse and broad population of players and coaches from the amateur soccer population would enhance the ability to generalise the findings of the study. Further research needs to address the perceptions of these populations solely focusing on NG surfaces with contrasting SH (Andersson et al., 2008). Utilizing more probing questions to determine the 'why' and 'how', following answers may have provided further information on the topic, however, important key phrases and comments were only identified during the content analysis phase and not during the actual FG. Polous et al. (2014) looked at current professional soccer players whereas, the present study included a mix of amateur players and ex-professional players only. The strength of the research design ensured the content analysis procedure was extensive and robust, ensuring accuracy of the information. Cluster categories and similar themes were merged (Patton, 2002) and member checks were implemented to eradicate any biases to increase the validity (Côté, 1993). Four criteria (credibility, transferability, dependability, and confirmability) essential for qualitative research devised by Guba (1981) (table 2.10.) were embedded in study four. Nearly all the points under each of the four quality criterion were met apart from points 3 (random sampling of individuals serving as informants), 6 (iterative questioning in data collection dialogues) and 7 (negative case analysis) under the credibility criterion and point 5 under the confirmability criterion (use of diagrams to demonstrate "audit trail"). Purposive sampling was used instead of random sampling to select a homogenous group of participants with expertise and knowledge in the research area of interest (Bernard, 2002; Patton, 2002; Cresswell and Plano Clark, 2011; Etikan et al., 2016). Nine planned open-ended questions and occasional probing questions were used as a guided replicable structure to ensure all planned themes were covered in the FG.

7.5. Conclusion

The present study is the first to evaluate perceptions associated with playing soccer on soft vs. hard NGPs. The study showed that players and coaches had a general preference for playing on a hard pitch. Players and coaches showed inconsistent views on the impact of SH on soccer performance but showed a preference towards playing soccer on hard pitches in terms of less physical demand and better technical execution (game-related events), tactical options, movements (i.e., linear and turning movements) and improved execution of movements

influenced by biomechanical concepts (i.e., force production, technical proficiency, energy restitution).

Apart from the present study, no research has solely focused on the perceptions of playing on soft vs. hard NGPs to provide more information on the complex subject. There was dissimilarity when comparing the subjective opinions from the present study with the objective facts derived from the previous three quantitative studies from the present project. Future work in this area should seek to find more detailed information as to why players and coaches perceive certain preferences towards either soft or hard pitches. Important variables such as the age, playing position, years as a player, training surface type, competition surface were not investigated in the present study to determine their influence on perceptions.

CHAPTER 8. GENERAL DISCUSSION

8.1. Introduction

The project is innovative and original as it involved only one surface type (NG), two forms of NG with contrasting hardness (soft vs. hard), four sports-science disciplines (performance analysis, physiology, biomechanics, and psychology), and objectively assessed SH as well as several physical, psychological and performance variables in real-time, real-life and game-related situations. Key features that impacted on the strength of the project included the multidisciplinary, mixed-methods, and field-based design. The four independent studies all contributed to providing a comprehensive answer to one research question, therefore generating a more thorough understanding of the influence of NGSH on soccer performance and game characteristics.

8.1.1. Discussion – study one

There was a trend for more soccer movements on the soft vs. hard pitches including high intensity shuffling, running, and low and high intensity activities. Similarly, there was a trend for more turns on the soft vs. hard pitches including moderate intensity, smooth, left sharp, V-cuts and significantly more sharp right turns performed on the soft vs. hard pitch. In contrast, there was a trend for more game activities on the hard vs. soft pitch including passes, tackles, and dribbling whereas, more aerial challenges and headed clearances were performed on the soft vs. hard pitches.

Andersson et al. (2008) showed that only four of twenty game activities analysed were different when comparing NG vs. AT with significantly fewer sliding tackles, and more passes, short passes, passed into the midfield zone and receptions were performed on AT vs. NG. In the present project, more passes and tackles were performed on the hard pitches with moderate effects for the differences (d = 0.5 and 0.4 respectively). More than double the number of aerial challenges (d = 1.5) and a greater number of headed clearances (d = 1.1) were performed on the soft pitches. An explanation may be that the hard pitches, with a firmer surface and less

precipitation and deformation, attracted a shorter passing game on the surface compared to tactics with more long aerial and lofted passes on the soft pitches. The frequency per minute, mean duration, and the percentage of match time spent dribbling were all greater on the hard pitches (d = 0.8; 0.9 and 0.8 respectively). Thus, suggesting the hard pitches assisted with a smoother ball roll and subsequent control or perhaps that more time had to be spent using these controlling movements and that control was difficult with hard pitches. It is difficult to directly compare

It is debatable why more turns (moderate intensity, high intensity, total, sharp right, sharp left smooth, and V-cut turns) were performed on the soft pitches. From one standpoint, perhaps change in SH fundamentally alters the nature of the match being played. The player had to work harder on the soft pitches with less traction, more absorption of impact forces, with more muscular force, and energy expenditure needed (Zamparo et al., 1992). Work by Low and Dixon (2014) showed that pressure measurements were significantly greater on hard NG surfaces ($P<0.05$) compared to a soft NG during the 180º turning movement, therefore greater loading was seen on the harder surface ($P<0.05$). This suggests a harder playing surface with greater density reduces the cushioning of loads experienced by an athlete which concurs with previous findings from Dixon et al. (2008). Although Low and Dixon (2014) used two contrasting NG surfaces, only four participants were assessed in a laboratory setting which reduces the ability to generalise the findings. When assessing movement dynamics, humans adjust their lower limbs in response to SH in order to maintain their centre of mass (Ferris & Farley, 1997; Ferris et al., 1998). The player possibly felt less stable on the soft pitches, therefore altered their lower-limbs with a wider stance which in-turn caused the player to perform more turns compared to more linear movements performed on hard pitches starting from a more upright and stable position. From another standpoint, maybe the player felt freer to move on with more traction so carried out more turns.

The frequency of running instances was greater (d = 1.1) on the soft pitches which also led to the percentage of time spent running being greater (d = 0.5) on the soft pitches due to the duration of running instances being similar (d = 0.3) between the two types of surface. This combined with the knowledge that soft pitches can increase energy demands from players (Zamparo et al., 1992) suggests that playing soccer on soft pitches could be more physically demanding than on hard pitches. Potentially a higher energy restitution associated with a greater firmness of a surface may have caused a higher workload (defined as “the physical

stress to which players are exposed" Bangsbo, 2014) on the soft pitches (Kerdok et al., 2002; Katkat et al., 2009). However, the physiological responses measure in study two (HRav and HRpeak) and study three (HRav and BLa) did not significantly differ between surfaces. Although not measured in the project, perhaps a soft pitch results in a lower impact peak resulting in less ability to produce force rapidly (McGhie and Ettema, 2013) which may alter joint movement patterns (Hamill et al., 1992), influencing the vertical deformation (Sánchez-Sánchez et al., 2014) and increasing the eccentric muscle activity (Richie et al., 1993). There were also greater frequencies of low (d = 1.1) and high (d = 1.2) intensity periods on the soft pitches meaning high intensity activity was more intermittent on the soft pitches. Intermittent activity can elevate workload through short recoveries (Hughes et al., 2005). A laboratory study by Hughes et al. (2005) revealed that repeated 6 s bursts lead to higher heart rate response, lactate accumulation, and reduced power output when performed every 25 s rather than every 40 s or 55 s. The current investigation revealed that the mean duration of bursts of high intensity activity was 3.0 s with average recovery periods of 47.5 s on soft pitches, while the corresponding figures on hard pitches were 3.5 and 56.9 s. These recovery durations are comparable with the two longest recovery durations studied by Hughes et al. (2005) where there was no significant difference in heart rate response or blood lactate accumulation, but performance declined. However, in soccer performance, not all recoveries are of the average duration. Therefore, the shortest recovery periods experienced on the soft pitches could lead to fatigue more than the shortest recovery periods experienced on the hard pitches.

Study one provides evidence that SH has the potential to influence performance responses (i.e., movements and game activity) however, a case-study is not as extensive as testing in a more prolonged and comprehensive situation. The preliminary data from study one justified the use of soccer specific activities in a simulated format to allow for specific performance, biomechanical and physiological responses to be investigated in a controlled experiment in studies two and three.

8.1.2. Discussion – study two

When assessing the impact SH has on soccer performance, study two revealed a trend for faster peak sprints (d = 0.6; P>0.05) on the hard vs. soft pitch whereas, mean sprints (d = 0.1; P>0.05) were similar across both surfaces during a repeated sprint protocol. Study two did not detect

any significant differences but did detect a trend that %DS was greater (d = 0.8; P>0.05) on the hard vs. soft pitch during the RSA test.

The hard pitch used in the present study had a higher rigidity and energy restitution, and therefore, provided more resistance for the players to apply force (Kerdok et al., 2002; Katkat et al., 2009) when sprinting. Perhaps the players experienced greater pressure and loading on the hard pitch, therefore fatigued faster which supports the thoughts of Low and Dixon (2014) and possibly explains the %DS trend. Zampora et al.'s (1992) thoughts contradict this notion as they postulate that players had to work harder on soft pitches as more impact force is absorbed into the floor, elastic energy is reduced causing more muscle fatigue and energy expenditure. Despite Zampora et al.'s thoughts, having to work harder to run and sprint on a soft pitch is not the same as sprint performance but their reasons may partially explain why sprinting was slightly slower on the soft pitch in study two of the current project.

The hard pitch with greater SH possibly allowed shorter CTs during the RSA test. Shorter CTs are usually associated as an essential criterion that is required to improve sprinting speed (Weyand et al., 2000; Weyand et al., 2010). Factors such as higher energy restitution associated with a harder surface rigidity generally shortens CT (Gaudino et al., 2013) causing leg stiffness to change (Ferris et al., 1998), generating greater use of the stretch-shortening cycle (Kubo et al., 19990) potentially affecting running economy (Kerdok et al., 2002; Katkat et al., 2009). The present study did not investigate the stretch-shortening cycle but utilising it more greatly would only enhance muscle contraction (Kubo et al., 19990) and subsequent sprint performance. Perhaps the greater muscle activation on the hard pitch possibly explains the trend that sprints were faster and that %DS was also greater on the hard pitch. Muscle activation was not investigated in the present study nor was the stretch-shortening cycle. Unfortunately, CT was not measured in study two as this may help to partially explain the stretch-shortening cycle, but CT was measured in study three and discussed in section 8.1.3.

Despite not being significant, there was a trend that HRpeak (d = 0.4) and HRav (d = 0.3) was marginally higher on the soft pitch vs. hard pitch suggesting that surface differences have the potential to influence HR during RSA tests. Literature suggests that HR may be altered due to playing surface (Di Michele et al., 2009; and Binnie et al., 2013). Neither Di Michele et al. (2009) (multi-stage running test) nor Binnie et al. (2013) (interval training) applied the same approaches to the present study but both reported higher HR when performing soccer

movements on AT vs NG and sand vs. NG respectively. Hughes et al. (2013) and Nedelec et al. (2013) applied more similar approaches to the present study in that they both used complex 90-minute soccer specific simulations and did not detect any difference in HRav and HRpeak between AT vs. NG however, neither quantified SH. The two main trends (although non-significant differences) were that sprint performance was better on the hard pitch and HR (average and peak) was a little higher on the soft pitch. Slower sprints coupled with slightly higher physiological demands (i.e., HR) together suggest that it is harder to produce the same effort on the soft vs. hard pitch.

Study two provides evidence that SH has the potential to influence performance (i.e., RSA) and physiological (HRpeak and HRav) responses however, RSA testing is not as extensive as testing in a more prolonged situation. The preliminary data from this RSA study justify the use of a longer, more soccer specific test used in study three.

8.1.3. Discussion – study three

When assessing the impact SH has on soccer performance, study three discovered that significant differences were detected between some performance and biomechanical responses although no differences were detected between the physiological responses and other performance and biomechanical responses. The main findings demonstrated that turning manoeuvres were significantly faster on the soft pitch during the SSP, and CTs were significantly shorter on the hard pitch during the SSA and SSP. All other performance responses did not significantly differ between surfaces (cutting and sprinting movements). The majority of biomechanical responses were unaltered during the SSP (FT SF, SwT, St, and SL) and SSA (SF, St, and SL) but SwT and FT were affected on both surfaces with an interaction effect between SH and lap number.

The occurrence of fatigue in study three illustrated how hard the players worked during the SSP which gave the best possible chance to detect differences between surfaces. This was indicated by slower sprints from set-one-to-four on both surfaces which resembles the pattern of fatigue and demands of a soccer match where sprint speed slows towards the latter periods of a match (Millet and Lepers, 2004; Krustrup et al., 2006; Andersson et al., 2008).

Shorter CTs detected on the hard pitch during both the SSA (d = 1.1; P<0.05) and SSP (d = 1.0; P<0.05) coincide with previous findings by Gaudino et al. (2013) as they found longer CTs on softer sand surfaces during maximal sprinting compared to firmer surfaces such as NG and AT. However, Gaudion et al. (2013) did not measure SH and used professional soccer players and a protocol consisting of maximal sprints and shuttle sprints over 12 m.

The importance of a shorter CT as a change required to improve sprinting has been established (Weyand et al., 2010) yet despite the shorter CTs on the hard pitch in the present study, sprint times were not significantly faster on the hard pitch during the SSP. Perhaps the players produced more force in less time so that the overall impulse was maintained on the hard pitch. The rate of force development (RFD) is an important determinant to measure force production and is defined as 'the speed at which the contractile elements of the muscle can develop force' (Aagaard et al., 2002). The RFD (measured in newtons per second; $N \cdot s^{-1}$) is often calculated by dividing the maximum force (in newtons; N) by the time to reach the maximum force (in seconds; s) (Haff et al., 2015). Neither of these measurements were recorded in the present study but the mean CTs in the SSP indicated that both surfaces (hard pitch: 0.148 ± 0.007 s vs. soft pitch: 0.155 ± 0.007 s) were examples of players developing force eliciting a fast-SSC (≤250 milliseconds) movement which is a common feature when sprinting (Taylor and Beneke, 2012). As the players produced shorter CTs on the hard pitch perhaps force was equal to that on the soft pitch but was accrued in a shorter time. Interestingly, during the SSA participants were required to jog at a controlled speed of 2.5 $m \cdot s^{-1}$ on both surfaces yet shorter CTs were detected on the hard vs. soft pitch. Shorter CTs on both surfaces during the SSA (hard pitch: 0.277 ± 0.018s vs. soft pitch: 0.294 ± 0.012 s) were examples of players developing force eliciting a slow-SSC (≥250 milliseconds) movement which is a common feature when jogging (Padulo et al., 2013). Similar to the SSP, perhaps the players produced shorter CTs on the hard pitch where the force was equal to that on the soft pitch but was accrued in a shorter time. An improved RFD is associated with an increase in muscle-tendon stiffness (Kubo et al., 2001), and neural drive during the early phase of the SSC (<100 milliseconds) (Van Cutsem et al., 1998), and enhanced muscle force production (Burgess et al., 2007). Unfortunately, the RFD was not measured in the present study so should be included in future investigation, although an innovative research design may need to be implemented to overcome many practical limitations.

FT was shorter ($P<0.05$) in lap three of the SSA compared to laps one and two on the hard pitch; SwT was also shorter ($P<0.05$) in lap three compared to all other laps on the hard pitch but neither biomechanical response showed a difference between surface (d = 0.4 and 0.1 respectively). During the SSA the players run at a consistent speed of 2.5 $m \cdot s^{-1}$ on both surfaces during the SSA protocol so it is debatable why the FT and SwT differences were observed. Perhaps as the players warmed up during the SSA protocol the mechanics of jogging became more efficient in terms of the triple flexion and extension of the three lower-extremity joints (ankle, knee, and hip) and associated lower-extremity musculature. However, FT and SwT did shorten from lap one-to-three on the hard pitch but this pattern was not evident in lap four.

When performing jogging and sprinting, it seems the softer the pitch, the greater the alteration in kinematics (Pinnington et al., 2005). A possible explanation for these changes is that on a softer surface, SF, plantar flexion, forward lean of the trunk and hip range of motion all increase (Pinnington et al., 2005). The latter three variables (plantar flexion, trunk inclination and hip range of motion) were not measured in the present study, but SF was. SF was not significantly different (d = 0.2 and 0.2 respectively) across the two surfaces in neither the SSA and SSP, which concurs with the findings from Gaudino et al. (2013) as they found no difference in SF between sand, NG, and AT surfaces.

Throughout neither of the SSA and SSP tests was any significant difference observed with the physiological responses (HR and BLa). Previous research supports this notion as Nédélec et al. (2013), Hughes et al. (2013) and Stone et al. (2014) all found that playing surface has little influence on physiological responses during SSP tests but none of these studies compared soft vs. hard NG, and SH was not quantified. There was a general decline from sets one-to-four with lower BLa concentration towards the end of the SSP on both surfaces, which concurred with similar work by Hughes et al. (2013) and Stone et al. (2014). The SSP was considered appropriate to simulate soccer match-play as on both surfaces the HRav was within the typical range (155 to 172 $beats \cdot min^{-1}$) found during soccer match-play (Rodrigues et al., 2007), BLa was within the typical range (4 - 8 mmol/l) found during soccer match-play (Rohde and Espersen, 1988; Roi et al., 2004). The TD covered in the SSP was within the typical range of 8-11 km covered by amateur players during competitive soccer match-play (Izzo et al., 2018). Hughes et al. (2013) and Stone et al. (2011) found similar BLa ranging between 3.9 - 6.0 mmol/l and 3.0 - 4.3 mmol/l respectively, in research involving the SSP. This showed how hard the participants worked in the present study as the time (i.e., 84-minutes) and distance (18 m

lane) was reduced compared to the SSP used by Hughes et al. (2013), giving the best possible chance to detect differences between surfaces. Although the physiological data (i.e., HRav and BLa) did not detect any significant difference between surfaces, it showed that the players were able to work to a consistent intensity and the performance data being different (i.e., turn times) shows a surface effect.

The performance responses demonstrated that sprints (mean and peak) were similar across both surfaces during the SSP. Sprints during the SSP in the present study closely resembled that same performance measure on NG in the Hughes et al. (2013) study, therefore, demonstrating the high level of motivation and fitness of the players in the present study, previously discussed relating to the age and standard of the soccer players. Higher energy restitution associated with the hard pitch possibly provided more resistance to apply force (Kerdok et al., 2002; Katkat et al., 2009) as shorter CTs were found on the hard pitch. However, perhaps the players had more traction on the soft pitch counteracting the ability to provide more resistance and subsequent force (Luo and Stefanyshyn, 2011) on the hard pitch. Nevertheless, traction and kinetic values were not measured in the present study and should be included in future work in this field.

The performance responses demonstrated that cutting manoeuvre times (mean and peak) were similar across both surfaces during the SSP which concurs with the findings from Hughes et al. (2013) and Stone et al. (2014) as they both found no difference in cutting manoeuvre times during the SSP when comparing AT vs. NG. Research has implied that friction and traction are important properties when it comes to generating ground reaction forces for an athlete to accelerate, decelerate and change direction (Barry, 2004; Luo and Stephanyshyn, 2011). Again, perhaps there was a trade-off between force production vs. traction on the hard vs. soft pitch respectively, explaining the similarity in cutting manoeuvre times on both surfaces.

Study three demonstrated that mean turn times were significantly faster on the soft pitch, but peak turn times were not different between both surfaces during the SSP. Research by Hughes et al. (2013) found no differences between mean and peak turn times using a similar SSP when assessed on AT and NG yet Gains et al. (2010) did find faster directional changes occurred on AT compared to NG but used a one-off sprint and turn performance. Neither Hughes et al. (2013) nor Gains et al. (2010) quantified SH making it difficult to compare to the present study. The turning motion in the present study was a 180-degree change in direction but players arced around a single cone lowering their centre of mass and shunting part of their base of support

(i.e., one foot) away from their centre of mass in the frontal plane. Possibly the players positioning themselves in a lower and more stable position allowed for a firmer and improved grip on the soft pitch resulting in faster turns.

There was a trend for mean and peak turn times to be marginally slower by 0.02 s and 0.04 s from set one-to-four on the soft pitch respectively which would be expected due to the rate of fatigue. However, the mean and peak turn times got faster from set one-to-four by 0.16 s and 0.20 s on the hard pitch respectively. One possible explanation could be that the hard pitch remained firm throughout the four sets of the 84-minute SSP, which could potentially have reduced any decline in turn times from set one-to-four on the hard pitch. The surface may have compacted as 48 turns were performed during the SA-R section of the SSP. This perhaps resulted in a hardening of the surface from set one-to-four of the SSP allowing for greater proficiency in force production. There was no observation of contrasting wear and tear on either of the soft and hard pitches following testing. The SH remained unchanged before and after each test period on both surfaces, suggesting the observed difference in turn time was a characteristic between the two surfaces and not one that could be attributed to wear and tear on the pitch.

In study three, 15 m repeated sprint times were to 2.46 s and 2.49 s for hard and soft pitches respectively. This demonstrated a high level of motivation and fitness of the players as in the current study as amateur-level (academy) players aged between 16-19 years were used whereas, the Hughes et al. (2013) study, used semi-professional players and Fletcher et al. (2009) used professional players. The participants in study three were at a lower level of the game than those used by Hughes et al. (2013) and Fletcher et al. (2009) and produced slightly faster 15 m sprint times. This was probably due to the fact that the overall distance (18-m instead of 20-m for the walking jogging and running) and intensity (players were required to complete a series of six 15-m repeated sprints midway through each set) of the SSP in study two was reduced compared to the SSP used in the Hughes et al. (2013) study. The SSP used by Fletcher et al. (2009) included three repeated sprints every 2-minutes for 20-minutes whereas in study two, two repeated sprints were performed every 3-minute 30 s which may have allowed the players to recover better between sprint bouts in study three.

Fletcher et al. (2009) and Hughes et al. (2013) both compared NG vs. AT, neither of their studies quantified SH nor did Fletcher et al. (2008) use the same testing protocol. Fletcher et

al.'s (2009) found slower repeated 15 m sprints ($P<0.05$) on NG (2.63 s) compared to the AT (2.59 s) whereas, Hughes et al. (2013) reported that both repeated sprint performance measures declined throughout the match simulation but surface type did not affect the decrease in performance.

Study three provides evidence that SH significantly influences certain performance (i.e., turning) and biomechanical (i.e., CT) responses but has less of an impact on other performance response (i.e., sprinting and cutting), biomechanical responses (FT SF, SwT, St and SL) and physiological responses (HR and BLa) during soccer simulated activity.

8.1.4. Discussion – study four

Study four illustrated that given the option, players and coaches would prefer to play on hard NG as opposed to soft NG. The findings demonstrated both positive and negative trends towards playing on a hard and soft pitch, but the phrases and subsequent themes discovered did show a preference towards playing on a hard vs. soft pitch.

The findings demonstrated that a hard pitch with greater SH allowed a player to produce faster reactions and improve their ability to bounce which implied movements such as turning, jogging, running, and sprinting would be more efficient therefore benefiting soccer performance. However, findings revealed that playing on a hard pitch can elicit a greater physical workload (i.e., greater stress on the body, joints, and muscles). Conflicting views exist in the literature as Polous et al. (2014) highlighted that players perceive it to be harder and tougher playing on a hard AT pitch due to its unforgiving nature that had poor shock absorption properties and caused harder impacts compared to NGPs. Similarly, Gallardon et al. (2010) showed that players prefer NG over AT due to the better shock absorbing properties and the lower burden of risk with lower body impact forces. However, Ávalos-Guillén et al. (2017) reported that the values for impacts and body loads were significantly greater on NG compared to AT. Sanchez-Sanchez et al. (2014) suggest that players found soccer related physical tests were more comfortable being performed on hard vs. soft AT pitches. Then contrasting views in study four and the associated research may be explained by a number of reasons. The inclusion of different surface comparisons in the literature i.e., AT Vs. NG and AT vs. AT, the lack of consistent and objective quantification of SH (i.e., SH on NG is not binary, it is on a continuum, so a hard surface in one study might be a relatively soft surface in another), the

diverse range of protocols used, and players included i.e., standard and age make it difficult for any comparisons to be made.

The general trend in study four supports the notion that it is more physically demanding (i.e., more tiring) playing soccer on a soft vs. hard pitch. This finding partially concurred with Andersson et al. (2008) as they reported that players preferred to play on NG over AT as it was less physically demanding although they used professional players and did not assess SH. Brito et al. (2012) suggested that players experienced greater physical demands on a soft surface when playing 5-a-side soccer that were attributed to external loads (i.e., ability/difficulty to run) rather than internal loads (i.e., physiological responses). The soft surface was sand which was compared to asphalt and AT. In contrast, one FG member from the present study suggested that it was physically more demanding playing on a hard pitch. Research by Ávalos-Guillén et al. (2017) indicated that surface type can cause a greater physical burden and effort which elicits HR response to increase when playing on NG vs. AT. Perhaps less traction and more impact force absorption is experienced on a soft pitch resulting in greater energy expenditure and muscle force required (Zamparo et al., 1992). Unfortunately, study four did not clarify whether the perceptions were related to performance (ability to run and sprint) and or physiological responses (i.e., HR and BLa).

Players and coaches indicated that it was easier to execute technical skills (i.e., efficiently striking and passing the ball) and movements (i.e., jumping) on a hard vs. soft pitch due to being less disrupted by the surface which concurred with Dixon et al.'s (2000) thoughts as they indicate that subtle changes in surface also disrupt movements and technical skills. Perhaps the ability to produce greater forces on a harder surface explains why players perceived it to be easier to execute movements such as jumping (Ekstrand and Nigg, 1989) on a hard surface.

A consensus showed that players believe it is tactically advantageous to play soccer on hard vs. soft pitches. Findings suggested a more direct style of play (i.e., lower number of passes and touches per play and a higher number of longer passes) is often implemented on a soft pitch making it more difficult to play soccer on, supporting Kempe et al. (2014) thoughts. Kempe et al. (2014) showed that soccer is faster on a hard pitch allowing for high-pressure tactics to be implemented more easily. The tactical perceptions obtained in the present study suggest the reason why soccer is faster on a hard pitch is that the players move more proficiently with less disruption (Dixon et al., 2000). Combining such thoughts, suggest that

both the player can move faster, and the ball can move more easily on a hard pitch (Dixon et al., 2000; Kempe et al., 2014).

The general trend in study four suggests that players and coaches perceive it to be easier to execute turning movements on the hard pitch vs. soft pitch however, one FG member disagreed. The findings imply that it is more difficult to turn on a soft pitch because of less control of the foot making it a more physically demanding task compared to turning on a hard pitch. One FG member disagreed and believed it was more difficult to turn on a hard pitch however reasons were not provided but perhaps it was due to having less traction. There was a general trend suggesting it was easier to perform movements on the hard vs. soft pitch. Reasons suggest a player moves faster and more explosively with more traction and firmness underfoot resulting in a higher ability to generate force (McGhie and Ettema, 2013) and a greater rate of force development (Aagaard et al., 2002).

The general trend suggested it was easier to execute movements on a hard vs. soft pitch. A possible reason was that a player can push off faster on a hard pitch due to having a higher energy restitution. It has been reported that a soft pitch reduces the ability to produce force (McGhie and Ettema, 2013), increases eccentric muscle activity (Richie et al., 1993), which in turn alters joint movements (Hamill et al., 1992).

Study four provides evidence that players and coaches believe that SH influences soccer performance and game characteristics in a positive and negative manner, yet the general trend showed a preference towards playing soccer on hard vs. soft NGPs. The meaningful insight illustrates that a more comprehensive study should aim to delve further into understanding if a pre-established bias towards a certain playing surface exists while considering age, years as a player, training surface type, competition surface, and percentage of careers on either soft vs. hard NG.

8.2 Connections between studies

8.2.1. Connections between studies one and four

a. In study one, the frequency of high intensity shuffling, running, low and high intensity activities and turning movements was greater on the soft vs. hard pitches which may be associated with the general perception found in study four, where it was perceived to be more tiring playing soccer on a soft vs. hard pitch. The higher frequency of movements coupled with the perception that it is harder to execute each movement may explain why players perceive it to be more tiring playing on a soft vs. hard pitch.

b. Playing surface did not significantly influence most game activities (i.e., pass, clearance, headed pass, shot, headed shot, and tackle) in study one but more dribbling movements, aerial challenges, and headed clearances were executed on the soft vs. hard pitch. In study four suggested that more long passes were performed on a soft pitch; this coupled with a higher number of headed clearances and aerial challenges executed on a soft pitch in study one may explain why this pattern was observed between different studies. However, dribbling was performed more frequently on the soft pitch in study one which disagrees with study four as it was perceived to be more difficult to technically execute game activities on a soft pitch.

c. There was a trend for more turns on the soft pitch in study one but there was a general perception in study four that turns were harder to execute on the soft pitch. Having to execute more turns coupled with the perception that it is physically harder to execute each turn may explain why players perceived it to be more physically demanding playing on a soft vs. hard pitch in study four. Faster turns were performed on the soft pitch in study three which contrasts the perceptions captured in study four.

8.2.2. Connections between study two and three (performance and physiological responses)

a. There was a trend for faster peak sprints (d = 0.6) and a greater decline in %DS (d = 0.8) on the hard pitch over the 40 m repeated sprint protocol in study two although the differences were not significant. The mean (d = 0.1) and peak (d = 0.2) sprints observed during the SSP were not different between surfaces. The mean and peak sprints slowed down at a similar rate on

both surfaces from set one-to-four during the SSP. The mean sprints (d = 0.1) were similar across both surfaces during the SSP.

b. Playing surface did not significantly influence most game activities (i.e., pass, clearance, headed pass, shot, headed shot, and tackle) in study one but more dribbling movements, aerial challenges, and headed clearances were executed on the soft vs. hard pitch. Findings from study four suggest that more long passes were performed on a soft pitch; this coupled with a higher number of headed clearances and aerial challenges executed on a soft pitch in study one may explain why this pattern was observed between the two different studies. However, dribbling was performed more frequently on the soft pitch in study one which disagrees with study four as it was perceived to be more difficult to execute technical game activities on a soft pitch.

c. However, two main trends in study two (although non-significant differences) showed that sprint performance was better on the hard pitch and HR (average and peak) was a little higher on the soft pitch together suggest that it is harder to produce the same effort on the soft vs. hard pitch.

d. The same trend was observed in study three (although non-significant differences) as sprint performance and cutting movements were marginally better on the hard pitch and HR (average) was a little higher on the soft pitch together imply that it is harder to produce the same effort on the soft vs. hard pitch.

8.2.3. Connections between study one and three (turning times)

a. A greater frequency of moderate intensity, sharp path changes to the right and, V-cut path changes were performed on the soft vs. hard pitch in study one. In study three, faster mean turning manoeuvre times were produced on the soft pitch in set one of the SSP when compared to set one on the hard pitch. The reason may in part be due to having greater traction and coefficient of friction allowing the players to change direction by having more grip on the soft pitch. A soccer player's ability to change direction, accelerate and decelerate has been shown to be influenced by the available traction between the soccer boot and playing surface (Sterzing et al., 2009; Pedroza et al., 2010). Optimum penetration of the soccer stud into NG has been shown to achieve maximum traction which benefits performance therefore, SH has been shown to affect traction in soccer (Kirk et al., 2007). Traction on a surface is increased with the presence of friction (McNitt, 2000; Barry, 2004; Luo and Stephanyshyn, 2011). Therefore,

despite not measuring traction and friction in the present project, it seems that both surface traction and friction are directly related to SH.

b. Longer CTs on the soft pitch were found during the linear sprinting section of the SSP in study three which concurred with Gaudino et al. (2013), as they found longer CTs on a soft surface during maximal sprinting compared to a firmer surface. It could be assumed that if CT is longer during linear sprinting on a hard pitch, then it may also be longer during the turning movement. Unfortunately, CT was not recorded during the turning movement in the present project. CT was only recorded during the 10-m section of the 15-m linear sprinting component of the SA-R during the SSP (figure 6.1. and 6.2.). The hard pitches in the present project may have increased the foot loading due to a more rigid base of support, although loading patterns were not measured. Measuring kinematic and kinetic variables specifically during the turning manoeuvre may provide further insight into understanding the mechanical changes at this critical point of the movement. A possible explanation for these changes is that on a soft pitch, stride frequency, plantar flexion, forward lean of the trunk and hip range of motion all increase (Pinnington et al., 2005). Similarly, foot preference, experience, confidence, turn types and surface properties may all influence the kinetic and kinematics of the movement (Pinnington et al., 2005). When performing running and sprinting, it seems the softer the surface, the greater alteration in kinematics and muscle activation patterns (Pinnington et al., 2005). Turn times got slower from set one-to-four on the soft pitch, which was expected due to fatigue factors, however, turn times got faster from set one-to-four on the hard pitch in study three.

8.3. Evaluation of the research and future research recommendations

8.3.1. Discussion summary

In summary, most game activities were performed at a similar frequency on both surfaces although more dribbling ($d = 0.8$; $P>0.05$), aerial challenges ($d = 1.5$; $P>0.05$), and headed clearances ($d = 1.1$; $P>0.05$) were performed on the hard vs. soft pitches. There was a tendency showing more movements on the soft vs. hard pitch including high intensity shuffling ($d = 1.7$; $P>0.05$), running ($d = 1.1$; $P>0.05$), low ($d = 1.1$; $P>0.05$) and high intensity activities ($d = 1.2$; $P>0.05$). Faster mean turn times ($d = 1.4$; $P<0.05$) and more frequent turns (sharp right - $d = 1.4$; $P<0.05$), smooth - $d = 0.5$; $P>0.05$ and V-cuts - $d = 0.7$; $P>0.05$) were performed on the soft vs. hard pitch during the SSP and competitive match-play respectively. However, the mean

(d = 0.1; P>0.05), and peak (d = 0.3; P>0.05), cutting manoeuvre times were not different across surfaces during the SSP. Faster repeated sprints (d = 0.6; P>0.05) were produced on the hard vs. soft pitch during the RSA protocol but this pattern was not observed during the SSP as the mean (d = 0.1; P>0.05) and peak (d = 0.2; P>0.05), 15-m sprints were similar across both surfaces. There was a trend for greater fatigue in sprint performance (d = 0.8; P>0.05) on the hard vs. soft pitch during the RSA but a similar decline in mean (d = 0.1; P>0.05) and peak (d = 0.2; P>0.05) sprint performance from sets one-to-four on both surfaces during the SSP. Shorter CTs were observed during steady state jogging (d = 1.1; P<0.05) in the SSA and sprinting movements (d = 1.0; P<0.05) in the SSP implying that surface hardness influenced the mechanics of jogging and sprinting but did not influence overall sprint performance (faster sprint times). From a psychological perspective, players and coaches showed a preference towards playing soccer on a hard vs. soft pitch because of less physical demand and better technical execution (game-related events), tactical options, movements (i.e., linear and turning movements), and improved execution of movements.

Many of the biomechanical responses were similar across both surfaces during the SSA (SF (d = 0.2; P>0.05), St (d = 0.2; P>0.05) and SL (d = 0.5; P>0.05)) and SSP (FT (d = 0.1; P>0.05), SF (d = 0.2; P>0.05), SwT (d = 0.1; P>0.05), St (d = 0.2; P>0.05) and SL (d = 0.1; P>0.05)). The physiological responses were similar across both surfaces during the RSA protocol (HRav - d = 0.3; P>0.05 and HR peak d = 0.4; P>0.05) and SSA (HRav - d = 0.2; P>0.05) and SSP (HRav - d = 0.2; P>0.05 and BLa - d = 0.1; P>0.05). Performance responses that were similar across both surfaces during the SSP included the mean (d = 0.1; P>0.05) and peak (d = 0.3; P>0.05) cutting manoeuvre times and peak turn times (d = 0.3; P>0.05).

8.3.2. Research design and methods

Despite the added time and resources required to conduct a mixed-methods project, the combined approach of using two distinct methodologies was perceived to add scientific value (McKim, 2017), gain a broader and deeper understanding of the research question under investigation (Hurmerinta-Peltomaki and Nummela, 2006).

Soccer performance and the ability of a player is influenced by a multitude of variables (Reilly, 2003) therefore, by adopting a multidisciplinary approach to answer the research question, the researcher thought it would broaden the understanding of the research question and enhance

the ability to generalise the findings (Sands, 1999). Basing the study around the ergonomic model of soccer participation (Reilly, 2003) would allow for the project to investigate the physical, physiological, and psychological factors related to soccer performance.

The ecological validity of human movement is an important research concept often underestimated (Shiffman et al., 2008) therefore, for scientific research, it is often best to measure behaviour in real-time and within the participants' environment (Shiffman et al., 2008). With that in mind, the current project incorporated the use of field-based, real-life situations or at least tried to mimic such situations to strengthen the ability to generalise the findings (i.e., competitive soccer matches, and simulated soccer activity). The uncontrollable variables such as the weather and environmental condition challenged the selected research design but with concise planning and monitoring, those challenges were overcome. Another option would have been to try to execute elements of the research project in the laboratory however, other impractical challenges would have occur such as trying to use natural grass as a surface in an indoor environment.

Surface hardness was the only mechanical property investigated in the project. The evaluation of SH was achieved (in research and by FIFA) using a Clegg Impact Hammer (CIH), which is a device that is easy to operate, portable, efficient, and cost-effective (Al-Amoudi et al., 2002). Despite the simplicity of the Clegg Impact Hammer, it was still a relatively expensive instrument (i.e., £3000). The study did not investigate surface properties such as soil density, grass coverage, water content, sward height, evenness, and levelness; nor did it investigate other mechanical properties such as force reduction, vertical deformation, energy restitution, and traction. A longitudinal study whereby surface and mechanical properties are captured simultaneously would gain a broader understanding of how such properties change during a soccer season. Costly instrumentation would have be required to measure the aforementioned mechanical properties (Advanced Artificial Athlete (£20,000) – force reduction, vertical deformation, and energy restitution; Rotational Traction Device (£12,000) – Traction).

The quantitative experimental design element of the study (study two and three) where subjects were repeatedly measured on two different conditions was selected over a descriptive study (subjects usually measured once) as the later type only establishes associations between variables whereas, the former establishes a cause and effect between two variables and amongst a group of variables from different disciplines.

The case study (study one) was selected as a pilot study to help analyse data at a small level to see if any particular trends or themes were observed. The descriptive nature of the case study helped to determine to see if movement strategies changed by the player when performing on soft and hard NGPs. The case study employed in study one was an exploratory and descriptive case study selected to explore a series of soccer matches on soft and hard NGPs. The point of interest was to observe one participant perform in a series of competitive soccer matches. Other methods considered at this stage included an explanatory case study however, it was felt that this type of study examines the data and explains the phenomenon occurred in the data. The project wanted to follow up study one with two empirical studies (study two and three) and a perception based study (study four) to try and provide a more thorough answer to the research question.

Unlike laboratory testing situations, the natural world typically does not provide a quiet, supportive, distraction-reduced environment. However, field-based tests were selected for empirical studies two and three due to scoring high in ecological validity due to the specificity to replicate soccer match-play (Stone et al., 2011). Studies incorporating the ecological validity of human movement are an important research concept often underestimated. The applicability of using real-life situations or at least trying to mimic or replicate such situations strengthen the generalisation of the research findings (Shiffman et al., 2008). Therefore, for scientific research, it is best to measure behaviour in real-time and within the participants' environment (Shiffman et al., 2008). Laboratory based empirical research was not selected in the current project due to having low ecological validity (Shiffman et al., 2008). The opportunity to perform controlled experiments in a laboratory setting was lost in the current project due to time, resources, cost and not overcoming certain practicalities (i.e., natural turf surfaces in a laboratory). Planned future research aims to overcome any impractical issues and execute controlled experiments in a laboratory to make up for the lack of experimentation in the current project.

All experiments area a combination of signal (the true effect of a variable on an outcome), and noise (the random error inherent in the experimental technique). The ultimate goal when designing and analysing experiments is to maximise the signal-to-noise ratio so that accurate conclusions can be drawn. Common means incorporated in the current project to maximise the

signal-to-noise ration included (1) making repeated measurements of one independent variable (surface hardness) and multiple dependent variables (i.e., performance, physiological and biomechanical responses) (2) randomised experiments (i.e., cross-over design) in the empirical experiments to prevent section and accidental bias (Suresh, 2011), and (3) repeated experiments (i.e., condition A and B). The key strength of the repeated measures design is that it makes an experiment more efficient and helps to keep the variability low. This enhances the validity of the results while allowing for smaller than usual subject groups. Drawbacks of repeated measures such as period, carryover, or sequence effect (El Kati, 2012) were reduced by using the randomised cross-over design. Independent measures design was not the preferred option in the current project due to the potential error due to individual differences between groups of participants.

It was imperative for the project to have a logical and systematic decision making process to help address the critical elements. By implementing an organised approach, it was less likely to miss important factors. The logical order of the project involved a case study, two empirical studies, then a perception based study. The intention was to explore areas in the case study that would help shape and link the two empirical studies. Data obtained from the three quantitative studies helped to investigate the perceptions in study four.

8.3.3. Strengths of the project

A key strength of the project was the mixed-methods research design. The approach to combine three quantitative studies with one qualitative study was perceived to add scientific value by combining two distinct methodologies, despite the added time, resources, and expertise required to conduct a project of this nature (McKim, 2017). Collecting a second data set in a mixed-methods research design increases the validity of the findings, therefore adding value by gaining a broader, deeper understanding of the research question under investigation (Hurmerinta-Peltomaki and Nummela, 2006). The integration component is another added value of the mixed-methods design as it gives the reader greater confidence in the results and conclusions drawn from a particular study (O'Cathain et al., 2010). Similarly, mixed methods cultivate future research ideas often due to researchers working together from a quantitative and qualitative background (O'Cathain et al., 2010). Some authors believe that mixed-methods

research is the only way to be sure of findings (Coyle and Williams, 2000) and interpretation (Morse and Chung, 2003).

Research on NGPs is certainly needed (Stiles et al., 2009; Brito et al., 2012) due to the technical problems arising from conducting field-based research. Laboratory-based research offers more reproducible conditions; however, tests are repeated on the same surface area and participant behaviour and range of motion is often limited (Kirk et al., 2007). Field-based research can be problematic due to uncontrollable variables such as temperature, precipitation (Low and Dixon, 2014), altitude, wind, humidity and barometric pressure (Haugen and Buchheit, 2016). To detect 'true' changes in performance, highly rigorous methodological procedures are required (Haugen, and Buchheit, 2016). Several factors were carefully considered and implemented during studies two and three and included building an efficient research team, using forecasts to predict weather conditions, weatherproofing equipment, using long electrical leads, and tests were run with several participants being tested simultaneously to reduce time. It is often impractical to carry out field-based research due to the environmental factors however, the present project demonstrated that it is possible to obtain data on NGPs in the field environment. Other factors that pose difficulties including the geographical, temporal (seasonal), and spatial (pitch) variability. A cross-over design (figure 5.1.) was selected for studies two and three to capture data during two testing days interspersed with approximately 72 h. The two NG surface conditions were geographically only 800 m apart which reduced the transition time between pitches. Temporal considerations were addressed by setting the RSA, SSA, and SSP tests on one day with a morning (9:00 am) and afternoon (2:00 pm) period. The research team set up each schematic layout on both surface conditions (figures: 6.1., 6.2., and 6.3.) early in the morning to make the cross-over design feasible. Spatial (pitch) considerations were factored in by setting up the schematic layouts using the length and width of each pitch to allow for the simultaneous setup of both the SSA and SSP.

One main advantage of a cross-over design (2 x 2) over a parallel group is that it provides an opportunity to compare the effects of the condition within participants. The participants in a cross-over study act as their own control, minimizing the effects of potential confounding factors between participants (i.e., carryover, period, or sequence effects) (Wang et al., 2016). The carryover effect is defined as the 'effect of the prior treatment persisting to the subsequent treatment effects' becomes the main issue (Senn, 1993). The existence of carryover effects was ruled out in the present study by randomising the allocation of participants in a 2 x 2 cross-over

design, using conditions A and B therefore strengthening the validity of the findings. This procedure prevented any bias due to possible changes in the participants over time and the use of a 72 h 'recovery' and 'washout period' was administered between period 1 and 2 to rule out any wash out period. The design was also uniform 'within sequences' and 'within periods' characterised by each condition appearing the same number of times within each sequence and each period (Piantadosi, 2005), therefore ruling out carryover, period and sequence effects as the treatment difference is the same in period 1 and 2. (figure 8.1; section 1.).

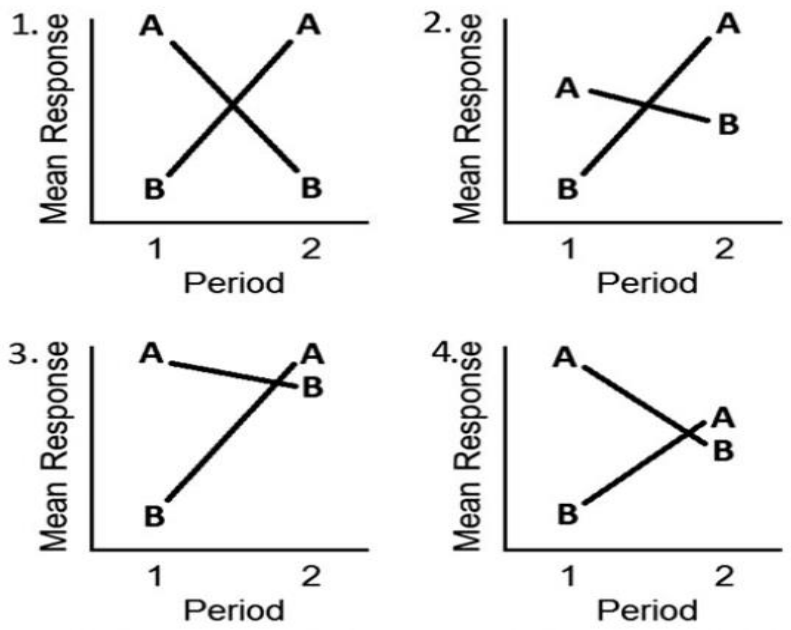

Figure 8.1: 1: No period, carryover or sequence effect. Treatment difference is the same in period 1 and 2. 2: Period effect, no carryover, or sequence effect. Treatment difference is the same in both periods. 3: Carryover effect. 4: Sequence effect (adopted from Wang et al., 2016).

Adopting a multi-disciplinary approach in the present project did manage to address the research question via four different disciplines to broaden the understanding of the research area. Triangulating multi-disciplines with the integration of field-based research involving NGSH did measure the extent that SH influences soccer performance and game characteristics (Stiles et al., 2009; Potthast et al., 2010). Field-based research was selected to improve the specificity of the evaluation (MacDougall and Wenger, 1991; Balsom, 1994). An array of methods were used in all four studies. The CIH was used in study one, two, and three to objectively quantify SH as it was an endorsed, reliable and valid device (Clegg, 1976; Bell and Holmes, 1988; Saunders et al., 2011; FIFA, 2012) that is easy to operate, portable, efficient and cost-effective (Baker and Canaway, 1993 Al-Amoudi et al., 2002).

The applicability of using real-life and real-time situations within the participants' environment was considered in study one by using competitive soccer matches to strengthen the ability to generalise the findings (Shiffman et al., 2008). Each game recorded underwent detailed analysis using software (Sports-Code Elite, version 5.1.9, Sportstec International, Warriewood, New South Wales, Australia) to strengthen the accuracy, reliability, and validity of the performance variables measures in study one. Two researchers independently used the computerised system by using the timed version of the kappa statistic to enhance the reliability of the movements entered in studio-code.

Kinematic analysis was incorporated in studies one and three due to the accuracy, validity and reliability of the motion capture and analysis systems (Sony, HVR-Z5, Japan; VideoLan VLC Media Player, Paris; NHC Software, Videopad Video Editor, Australia; Kinovea version 0.8.15; Worldwide). The systems were relatively low cost despite the significant time required to analyse multiple laps, participants, and variables (Minetti and Ardigò, 2001).

In study two, RSA tests were used to replicate an intense period of play (Oliver et al., 2006) over 40-m equating to <5 s per repetition to provide logical validity and relevance to match-play (Krustrup et al., 2002; Mohr et al., 2003; Krustrup et al., 2006; Oliver et al., 2006; Glaister, 2008; Girard et al., 2011). RSA protocols involving straight-line movements have been criticised as non-specific protocols that lack validity and relevance to soccer performance, therefore, combining repeated sprints with COD seemed more specific (Little and Williams, 2005). The inclusion of the SSP involving the SA-R in study three allowed for a more valid method of assessing the physical capabilities of soccer players (Stone et al, 2011). The field-based SSP was selected to improve the ecological validity of the test to replicate soccer-match-play (Stone et al., 2011) more so than the previously used RSA.

The two-way within-subjects repeated measures ANOVA design in study two and three was appropriate as multiple measures of the dependent variables (all performance, physiological and biomechanical variables under investigation) were taken using the same participants (paired-samples) under two conditions (hard pitch and soft pitch) over two separate periods (period one and two) (Huck & Cormier, 1996).

Internal validity can be compromised with repeated measures research designs due to practice and carryover effects (Suresh and Chandrashekara, 2015). Such concerns were minimalised as the carryover effects have been addressed earlier in this section and only one pilot testing session was carried out with the selected participants to reduce any practice effects. An advantage of the repeated measures design in studies two and three was that individual differences could not influence the results across the two conditions as the same participants were used allowing the accurate measurements of the performance or variable under investigation across both groups.

A four-stage procedure was used to process and analyse the data generated from the fourth qualitative study in the project (Patton, 2002; section 2.6.). The endorsed four stage procedure was purposely utilised to triangulate the themes from the three quantitative studies with the intention of enhancing the internal validity (Shenton, 2004) and confidence that the research question under scrutiny was answered (Lincoln, 1995). The inclusion of member checking ensured the accuracy (Côté, 1993; Shenton, 2004) and trustworthiness (Brewer and Hunter, 1989; Miles and Humberman, 1994; Pitts, 1994) and biases (Côté, 1993; Patton, 2002) of the transcript. The results generated from study four were confirmed as logical and reasonable by being related back to the existing body of knowledge (Burnard, 1991; Morse and Richards, 2002).

Four criteria (credibility, transferability, dependability, and confirmability) essential for qualitative research devised by Guba (1981) (table 2.10.) were embedded in study four. Nearly all the points under each of the four quality criterion were met apart from points 3 (random sampling of individuals serving as informants), 6 (iterative questioning in data collection dialogues) and 7 (negative case analysis) under the credibility criterion and point 5 under the confirmability criterion (use of diagrams to demonstrate "audit trail"). Purposive sampling was used instead of random sampling to select a homogenous group of participants with expertise and knowledge in the research area of interest (Bernard, 2002; Patton, 2002; Cresswell and Plano Clark, 2011; Etikan et al., 2016). Nine planned open-ended questions and occasional probing questions were used as a guided replicable structure to ensure all planned themes were covered in the FG. However, iterative questioning in data collection dialogues was not carried out due to the nature of the one-time FG. Categorising key phrases to key themes to either soft or hard pitch conditions demonstrated that negative case analysis was evident. Possible explanations and patterns emerged from the data analysis and did not detract from or contradict

the original transcript. The transferability quality criterion was established as a detailed description of the research question allowed for comparisons to be made to background data and research in the same or similar field. The dependability quality criterion was established as an in-depth methodological description was executed to allow for the study to be repeated if required. The employment of 'overlapping methods' strengthened the dependability of the study. Planned methodological triangulation was used to create overlapping data and therefore, cross validating the findings across the four studies within the project. The confirmability quality criterion was met as all points were achieved except point 5. A diagram to demonstrate the 'audit trail' may have been useful for illustrative purposes but was not included in the present project.

8.3.4. Limitations of the project

It was important to recognise the shortcomings of the present project and their potential effects. Limitations of the project included the ecological validity, uncontrollable variables, analysis, sample size, sampling method, instrumentation, generalisability (context/sport/setting), and transferability. The methods embedded across the four studies significantly enhanced the ecological validity but, it is important to remember that despite this, no physical test will replicate soccer match-play exactly due to individual differences and the complex demands of the sport (Svensson and Drust, 2007).

The uncontrollable variables mentioned in section 8.1.3. included the weather and environmental condition. In studies two and three, it was essential to consider the location, NGP, day, time, and previous weather conditions. It is well documented that atmospheric variables can influence sporting activities conducted in the outside environment (Pezzoli and Cristofori, 2008; Pezzoli et al., 2012). Past weather trends and environmental conditions were monitored to gain valuable and specific information that led to making decisions based on the predictability of future weather conditions (Pezzoli et al., 2013). Previous authors have highlighted the usefulness of using weather forecasts in the management of sports performance (Pezzoli and Cristofori, 2008; Pezzoli et al., 2012). Coaches and managers often underestimate the importance of analysing the environment for sport performance due to the lack of knowledge associated with the added value of measuring such variables to predict future meteorological parameters (Pezzoli et al., 2013). The environmental analysis (surface hardness and weather) in the present project was carried out over a long-term timescale of >30 days

before any testing was carried out, which is supported by previous work in this area (Pezzoli et al., 2013). The objective measurement of the environmental variables (Pezzoli et al., 2013) may provide more detail on how such a variable influences soccer performance, as it is deemed an important part of the analysis of soccer performance (figure 8.2.).

Figure 8.2: Wheel of the Sport Performance Analysis (adopted form Pezzoli et al., 2013).

A relatively small sample size existed in both the qualitative and quantitative studies partially limiting the ability to generalise the findings. Conducting an investigation that uses markedly larger sample sizes such as 23-40 human subjects (Blog et al., 1999; Bonato and Cataliotti, 2000) requires additional considerations. Anderson and Vingrys (2001) stated that "studies using small sample sizes are not meant to quantify general performance within a population but merely to document the existence of an effect, and so the number of participants is less important." Often there is a wish to demonstrate that certain findings are not abnormal, and investigators perform replications of such studies. It is argued that findings should be "taken as representing the performance of the population at large" (Anderson and Vingrys, 2001). A researcher needs to consider the extra time, costs, equipment, resources, participants, and personnel required to conduct a larger-scaled study (Anderson and Vingrys, 2001). Quantitative studies are different from qualitative studies as they aim to quantify magnitudes rather than observe different patterns in a data-set (Sandelowski, 1995). Suggestions for how many participants are needed for qualitative FGs and interviews range from 12-101 with an

average of 30-40 participants (Braun and Clarke, 2013). Justifications for these numbers often focused on the depth of analysis desired and the resources available. Guidelines for FGs where thematic and content analysis is carried out, suggest between 2-4 participants (Braun and Clarke, 2013). Sandelowski (1995) argues that "the sample size is small enough to manage the material and large enough to provide a new and richly textured understanding of experience" (p. 183). Four participants were included in the one-time FG in the qualitative study of the present project which did provide the desired depth of analysis and enough material to manage, as suggested by Braun and Clarke (2013). The quantitative studies in the present project emphasized the importance of reliability and generalisability (Henn et al., 2006), with the aim of applying the relationship attained among specific variables to the general population. (Karasar, 1999). This emphasised the essential importance of selecting a sample representative of the population (Karasar, 1999). The sample size used in the quantitative studies was appropriate to meet the goals of the project although a larger scaled sample may gain greater statistical power (Minke, 1997) although research constraints (i.e., time, money, resources, and personnel) limited the magnitude of the sample. Selecting participants randomly from a broader population including male and female soccer players and coaches from a range of ages and levels many enrich any qualitative and quantitative research in the future by enhancing the ability to generalise the findings.

The reliability of measurement comes from a variety of factors such as the equipment, environment and participants. The current project did consider habituation in terms of the research design (i.e., order effect, and time of day). Warm-up activities were standardised prior to all tests in studies two and three across both conditions for consistency. Participant underwent one pilot test 72 h prior to each of the tests in study two (i.e., RSA) and three (i.e., SSA and SSP) to ensure familiarity of the protocol to decrease apprehension of performing a new protocol allowing the participants to focus more on the physical performance and less on the protocol (Atkinson and Nevill, 2001). The experimental procedures for tests in study two and three were structured in a randomised cross-over design where participants were randomly assigned to one of two groups (soft pitch first - group A; hard pitch first - group B). Randomising the surface condition for each group changed the order of surface condition experienced, therefore reduced the period, carryover, or sequence effect (El Kati, 2012). The time of day for each test performed remained the same for consistency.

A suitable method to assess test reliability is by the typical error of performance measures (TE) (Hopkins, 2000). The TE is a current measurement of reliability and represents the variation in subjects' test scores from one measurement to another (Hopkins, 2000). The fusion timing gates used in study two and three have been shown to reliably assess speed as Waldron et al. (2011) evaluated rugby players performing two over-ground sprints (TE = 1% to 1.54%). Spencer et al. (2006) found that the RSA test on two separate occasions (7-days apart) was very reliable when presented as the total sprint time. The total sprint time was very reliable as the TE was 0.7%. Wragg et al. (2000) reported a TE of 1.8% in their protocol involving 7 × 34-m sprints, departing every 25 s and including an agility component, which could possibly decrease the reliability. Fitzsimons et al. (1993) reported the TE to be 0.8% in their study involving 6 × 40-m sprints departing every 30 s and Waldron et al. (2011) assessed the reliability of sprint performance with a standing start over various distances and reported a TE of 1.7% for 10 m sprint performance and 0.7-1% for 20 m sprints.

The current project did not formally assess reliability for the experimental procedures and instruments used in studies two and three but there is a precedent for good reliability in other studies that have used similar procedures. This is evidenced by the strong reliability of the test variables such as sprint performance (Waldron et al., 2011), repeated sprint performance (Spencer et al., 2006; Wragg et al., 2000), and timing gates systems (Waldron et al. (2011).

8.3.5. Contribution to knowledge

When practicing and competitively playing soccer, many variations exist when considering all surface types (i.e., NG, reinforced NG, AT), surface properties (i.e., damping, shock absorption, traction, and the coefficient of friction and variation), external variables (i.e., season, precipitation and temperature) and SH (i.e., soft and hard). Sports governing bodies and research provide either standard, acceptable or preferred guidelines on several surface properties yet amateur-level NGPs often do not meet such guidelines. Trying to compare all surface property variations would be insurmountable so focusing on two types of NG (soft vs. hard) has provided novel information related to how a soccer player is affected when SH differs.

Prior to this project, it has been well documented that soccer performance and movement characteristics can change due to variations in playing surface (Potthast et al., 2010). Previous soccer studies exist and have focused on many physical and psychological responses to changes in surface chrematistics in terms of injury rate and occurrence (Steffen et al., 2007; Williams et al., 2011), mechanical behaviour of surfaces (Sánchez-Sánchez et al.,2014), performance analysis (Andersson et al., 2008), players' psychological perceptions (Andersson et al., 2008; Zanetti, 2009; Gallardo-Guerrero, et al., 2010; Roberts et al., 2014; Sánchez-Sánchez et al., 2014), performance responses (Fleming, 2011; Brito et al., 2012; Hughes et al., 2013; Stone et al., 2014), biomechanical responses (Ford et al., 2006; Stiles et al., 2011; McGhie and Ettema, 2013) and physiological responses (Hughes et al., 2013; Stone et al., 2014).

The project represents a pioneering study of soccer performance simultaneously with amateur-level NGSH, adding new perspectives to the existing body of research. Previous research has compared certain physical and psychological responses using different types of the same surface (i.e., AT vs. AT (Sanchez-Sanchez et al., 2014) and AT vs NG (FIFA, 2006; Andersson et al., 2008; Clarke and Carre, 2010; Hughes et al., 2013; Poulos et al., 2014; Stone et al., 2014). Fewer studies have compared different forms of the same surface i.e., NG vs. NG (Low and Dixon, 2014) and their impact on soccer performance. Prior to this project, a lack of research had compared the impact of SH on soccer performance in the field with the inclusion of the objective assessment of solely soft and hard NGPs. The environmental and practical challenges when quantifying physical responses to contrasting surfaces may explain the lack of research in this area (Low and Dixon, 2014). Despite such challenges, soccer-based movements have been assessed on two different NG surfaces with contrasting SH i.e., 80 ± 4.0 Gmax and 102 ± 3.0 Gmax but were carried out in a laboratory setting (Low and Dixon, 2014). Therefore, the original contribution of the present project emerges from a small gap in the 'natural grass' and 'soccer' research areas in that it performed controlled experiments to compare many physical responses performed during soccer performance on solely NGPs where SH was objectively measured.

Fourteen NGPs (ten pitches in study one; two pitches in study two and three) were used across three studies in the project providing a comprehensive dataset of SH measurements that can be used to assist future research in understanding the spatial (pitch) variation in SH. The project impacts on sports engineers in terms of surface engineering, construction, and maintenance at amateur-level soccer and the quality improvement required for NGPs. From a physical and

psychological perspective, the project also impacts 'grass-roots' soccer players who train and perform on NGPs and coaches can draw valid findings to help shape future performance preparation and performance.

8.3.6. The practical impact of the research outcomes

The practical impact of the research outcomes relate in general to the amateur-level soccer community, particularly players, coaches, administrators, sport engineers and ground staff. Coaches and players may benefit from the research outcomes by planning physical, technical and tactical preparation on NGPs that resemble NGPs where upcoming matches are planned at certain stadia. If a player or coach is aware of an upcoming match on a certain type of pitch (i.e., soft or hard), practise prior to such performance may take place on a pitch possessing similar characteristics. By practising the technical execution of movements and game activities, as well as the tactical patterns on a NGP with similar surface characteristics to an imminent competitive match, may contribute to an enhanced technical and tactical outcome. However, to invest in such activities may be beyond the time and resources available for an amateur-level soccer team.

The project impacts on sports engineers in terms of surface engineering, construction, and maintenance at amateur-level soccer. The ultimate goal is to provide NGPs that offer the best possible surface to enhance performance (of the surface and player) and safety (reduce the likelihood of an injury safety) throughout a soccer season. The safety and performance of a NGP is enhanced when maintenance is carried out to improve the overall condition (consistency, and deformation). The project established that NGSH varies in terms of the spatial (pitch) variation therefore, ground staff and coaches may confer to try and establish more compliant and consistent SH conditions.

The SH values recorded in the current project fell within the recommended minimum and basic quality standard in the PQSs. However, administrators of soccer may seek to determine the compliance of the PQSs across a range of amateur NPGs to gauge the temporal (season) and spatial (pitch) variations of SH. Understanding the spatial and temporal variation of NGPs in terms of SH may help to establish more benchmark data that helps to shape future safety considerations for players by means of better maintenance, construction, and upgrading of NGPs. It would be beneficial if administrators in soccer close the gap between the stringent

testing and benchmarking of data surrounding surface properties of elite-level NGPs and AT pitches and did the same in amateur-level soccer for NGPs. However, the challenge will be to resource and fund such activities at the amateur-level soccer.

CHAPTER 9. GENERAL CONCLUSION AND FUTURE RESEARCH RECOMMENDATIONS

9.1. General conclusion

This project is the first to make a controlled comparison of biomechanical, physiological, and performance responses to soccer activity using amateur-level players on soft vs. hard NGPs where SH was objectively measured. The novel project found that SH did significantly affect a soccer player in terms of certain performance responses (i.e., more turns on soft pitches during competitive soccer match play, faster turns on soft pitches during soccer simulation) and biomechanical responses (i.e., shorter CTs on hard pitches during steady state jogging and sprinting). Although a non-significant difference, players were faster sprinting on the hard vs. soft pitch during the RSA protocol. Perceptions of playing soccer on soft vs. hard pitches predominantly show preference toward the latter surface due to better physical, technical, tactical, and biomechanical factors. The HRav response did not significantly differ between surfaces during the SSA and SSP However, there was a trend (although a non-significant difference) which showed that HR (average and peak) was a little higher on the soft pitch during repeated sprints in the RSA test and the SSP. There was a trend (although non-significant differences) for slower sprints coupled with slightly higher physiological demands on the soft vs. hard pitch (i.e., HR), suggesting that it is harder to produce the same effort on the soft vs. hard pitch.

The project has demonstrated a new application of theory onto an existing body of data, adding to the view that SH influences sporting performance as previously thought in sports such as tennis (Fernandez et al., 2006), cricket (Baker et al., 2001) and rugby (Fernando et al., 2015). The conclusions of the present project are aligned with four key objectives in chapter one (section 1.3.2).

1. The first objective was to explore the influence of NGSH on path changes, movements, and game events of an academy-level (amateur) soccer player through analysing performance measures during competitive matches. The findings showed that:

a. There was a tendency showing that more movements were performed on soft vs. hard pitches (i.e., high intensity shuffling, running, low and high intensity activities) compared to hard pitches.
b. There was a trend for more turns (i.e., sharp, smooth, V-cuts) to be performed on soft vs. hard pitches.
c. The frequency of most game activities was performed at a similar frequency on hard and soft pitches, although there was a trend for more dribbling movements, aerial challenges, and headed clearances on hard vs. soft pitches.

2. The second objective was to characterise the physiological and performance responses of soccer players while performing repeated sprint activity on soft and hard NG. The findings showed that:

a. Two main differences (although non-significant differences) showed that sprint performance was better on the hard pitch and HR (average and peak) was a little higher on the soft pitch.
b. Based on the physiological demands (i.e., HR) being a little higher, and sprint performance being less good together suggests that it is harder to produce the same effort on the soft pitch.

3) The third objective was to quantify and explain the effect of contrasting NGSH on physiological, biomechanical, and performance responses during steady state activity (SSA) and a match simulation (soccer simulation protocol - SSP). The findings showed that:

a. Only one biomechanical response (i.e., CT) was significantly shorter on the hard vs. soft pitch during the SSA and SSP.
b. One performance response (i.e., turn time) was significantly faster on the soft vs. hard pitch during the SSP.
c. Physiological responses (i.e., HRav and BLa) did not significantly change between surface during the SSA and SSP but HR was a little higher on the harder surface during the SSP.
d. Slower sprinting and cutting movements coupled with slightly higher physiological demands (i.e., HR) together suggest that it is harder to produce the same effort on the soft vs. hard pitch.

4) The fourth objective was to evaluate the perceptions of players and coaches on the effect of playing soccer on soft and hard NGPs. The findings showed that:

a. Players and coaches showed inconsistent views on the impact of SH on soccer performance but in general showed a preference towards playing soccer on hard pitches in terms of less physical demand and better technical execution (game-related events), tactical options, movements (i.e., linear and turning movements) and improved execution of movements.

9.2. Future research recommendations

1. Future work must assess the spatial (pitch variation) and temporal (seasonal variation) variation in mechanical behaviour (i.e., SH) of a wider range of NGPs where amateur-level soccer is played and investigate how physical and psychological responses are affected. This will help to identify the uniformity of NGPs that may potentially be more important than the mean SH value (Stiles et al., 2011). The spatial variation of SH was measured in the present project (table 4.1; 5.1; and 6.1) and highlighted in relation to where on the pitch testing procedures were carried out. Research should seek to measure SH and consider temporal variations to broaden the understanding of the behaviour of SH throughout the soccer-season.
2. Future work ought to involve solely NG and measure additional surface properties including soil density, grass coverage, water content, and mechanical properties such as damping, shock absorption, traction, and the coefficient of friction and variation.
3. In the present study, the mean SH differed by 28, 18, and 37 Gmax in studies one, two, and three respectively. Utilising greater mechanical extremes between the soft (i.e., 30-40 Gmax) and hard (i.e., 110-120) pitches to extend the difference in SH to approximately 80 Gmax may maximise the chance to further establishing how contrasting NG surface properties respond to and effect player interaction.
4. Perform controlled experiments to compare physical responses (i.e., kinematic and kinetic) when performing sprinting and turning movements on NGPs of contrasting SH.
5. Future work should seek to find more detailed information as to why players and coaches show a preference for playing soccer on either soft or hard pitches. Important

variables such as age, playing position, years as a player, training surface type, and competition surface need to be investigated in the present study to determine their influence on perceptions.

9.4. Future original, applied research studies

Study 1:

Title: The effect of seasonal and weather changes on the spatial (pitch) and temporal (seasonal) variation of natural grass surface hardness throughout a soccer season.

Aim: The aim of the study is to investigate the extent that spatial and temporal variation of natural grass surface hardness is influenced by seasonal and weather changes during a soccer season. Studies one (match performance characteristics), two (repeated sprint performance) and three (match simulation) in the current project illustrated that spatial (pitch) variation exists with surface hardness measurements on natural grass pitches during a certain period (i.e., May). However, the spatial and temporal variation of surface hardness needs to be assessed throughout the whole soccer season.

Objective: The surface hardness of thirty amateur-level NGPs will be assessed throughout a soccer season. Objective surface hardness assessment will be quantified each month using a Clegg Impact Hammer using the six-site method (FA, 2004). A Clegg Impact Hammer (CIH) will objectively measure surface hardness (gravitational deceleration force of the impact measured in gravities (Gmax)).

Purpose: It would be pertinent to see if (1) surface hardness differs throughout the season and (2) surface hardness stays within the minimum and standard surface hardness range stipulated by previous research and soccer administrators.

Study 2:

Title: The effect of seasonal and weather changes on the spatial (pitch) and temporal (seasonal) variation of natural grass surface and mechanical properties throughout a soccer season.

Aim: The aim of the study is to investigate the extent to which the spatial and temporal variation of natural grass surface properties (i.e., soil density, grass coverage, water content, sward height, evenness, and levelness) and, mechanical properties (i.e., force reduction, vertical deformation, energy restitution, and traction) are influenced by seasonal and weather changes during a soccer season. A longitudinal study whereby surface and mechanical properties are captured simultaneously would gain a broader understanding of how such properties change during a soccer season.

Objective: The surface and mechanical properties of thirty amateur-level NGPs will be objectively quantified each month during the full soccer season using a number of scientific devices (Advanced Artificial Athlete – force reduction, vertical deformation, and energy restitution; Rotational Traction Device – Traction).

Purpose: Quantifying the surface and mechanical properties of amateur-level NGPs would provide the opportunity to determine if the data falls within the recommended and accepted benchmark categories set out by the soccer authorities.

Study 3:

Title: The effect of soft vs. hard natural grass pitch hardness on specific soccer movements.
Aim: This study aims to investigate the extent to which greater mechanical extremes between the soft and hard pitches affect soccer specific movements (i.e., repeated sprint ability, sprint performance, soccer simulations).

Objective: The surface hardness of amateur-level NGPs will be assessed with the intention of locating two pitches with greater mechanical extremes (i.e., ≥60 GMax) between a soft vs hard pitch. A surface hardness difference of this magnitude will be two-fold what was previously used in the main project of the thesis. If these requirements are not found nor met, an attempt will be made to create such surfaces manually on a designated area of a pitch appropriate for testing.

Purpose: Exposing soccer players to perform a number of soccer specific activities on very hard (i.e., 100≥ GMax) and very soft (i.e., ≤40 GMax) pitches, focusing on the acceptable

conditions (between 35-120 GMax), not the preferred conditions (45-90 GMax), may provide valuable detail regarding performance and safety consideration experienced by amateur-level soccer players in the UK.

Study 4:

Title: The effect of natural grass pitch hardness and traction on physical responses while performing specific soccer movements.

Aim: This study aims to investigate the impact of surface hardness and traction of natural grass pitches on kinematic and kinetic measurements while performing soccer specific movements. Previous studies (one, and two of the project) found that faster turning movements were performed more frequently on a soft vs hard pitch on soft grass.

Objective: Create hard and soft natural grass samples, and conduct a controlled experiment to compare the kinematic (joint angles, and leg stiffness) and kinetic (ground reaction forces, rate of force development, and impulse) during running (i.e., sprinting), turning (V-Cuts), and jumping (countermovement jumps) movements.

Purpose: The purpose of this study is to further understand the impact natural grass surface hardness and traction has on soccer players performing soccer specific movements in a controlled experiment. By overcoming many practical barriers, the manipulation of the pitch conditions (i.e., very soft vs very hard), and or producing natural grass samples to locate in a laboratory will remain the biggest challenges in this study

Study 5:

Title: The perception of soccer players on the effect of playing soccer on a very hard vs very soft natural grass pitch.

Aim: The aim of this study is to evaluate the perceptions of players on the effect of playing soccer on soft and hard natural grass pitches with a theme from the previous focus group study in the thesis, to delve deeper into why players and coaches may prefer a certain type of pitch.

Objective: Eleven soccer players will play a 90-minute competitive game on a soft and hard pitch and participate in a focus group or interview following the matches, to determine their perceptions of playing on both surface types.

Purpose: The purpose of this study is to delve deeper into the important data surrounding the age, playing position, years of playing, level of competition, type of training surface, and competition surface. Capturing perceptions more rigorously and controlled, may provide more insight into what influences player perceptions of playing on a soft and hard pitch.

CHAPTER 10. REFERENCES

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CHAPTER 11. APPENDICES

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11.1. Informed consent and assent forms for participant(s), parent(s) and or guardian(s)

11.1.1. Informed consent form – study one

Informed Consent Form

Project Title: The Influence Of Natural Turf Variation On Football Performance And Game Characteristics

Lead Researcher: Wesley Sleat

Contact Details: Email:
wesleat@cardiffmet.ac.uk
wsleat@fit2train.co.uk

Please complete all the details below. This information is required for our records.

Name (Print):

I have read the information sheet concerning this project and I am aware of the purpose of the tests and what will be involved. All my questions have been answered to my satisfaction. I understand that I am free to request further information

I know that:

- My participation is entirely voluntary. I know that I am not obliged to complete the tests and I am free to stop the test at any point and for any reason without disadvantage.
- I will be required to play 10-12 competitive football matches for my football club.
- As part of the study a video camera will film my physical movements during the game and analyses will be drawn and used only for the purpose of the research project.
- The test results will only be used for the purpose of the research project. All information and data collected will be held securely at the university. The results of the study may be published but my anonymity will be preserved.

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Signature of Participant: …….

Date: ……

Physical Activity Readiness Questionnaire (PAR-Q) -			
Name of Participant: Please circle 'YES' or 'NO' to the following questions:			
1	Do you currently suffer from asthma or any breathing-related condition?	YES	NO
2	Have you ever consulted your doctor as a result of suffering from a heart-related condition?	YES	NO
3	Have you/do you suffer from any chest pains which may be aggravated by exercise?	YES	NO
4	Do you suffer from bouts of dizziness or from feeling faint?	YES	NO
5	Have you ever been told by a medical consultant that you suffer from a bone and/or joint condition which might be further aggravated by exercise?	YES	NO
6	Have you ever been diagnosed with high blood pressure?	YES	NO
7	Have you ever been diagnosed with diabetes?	YES	NO
8	Are you unaccustomed to regular vigorous exercise?	YES	NO
9	Is there a significant physical reason not mentioned above why you should not take part in the research project?	YES	NO
If you have circled 'YES' to any of the questions, please provide further details in the space below. Also, if there are any health and fitness related conditions that could affect your participation in the research which are not covered in questions 1-8, please provide further information below Should your situation change regarding any of the conditions mentioned above, please notify one of the researchers as soon as possible.			
Signed (participant):			

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Signed (principal investigator): Date:	

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11.1.2. Informed consent form – study two

Informed Consent Form

Project Title: The Influence Of Natural Turf Variation On Football Performance And Game Characteristics

Lead Researcher: Wesley Sleat

Supervisors: Dr Michael Hughes, email: MGHughes@cardiffmet.ac.uk
Dr Peter O Donoghue, email: PODonoghue@cardiffmet.ac.uk
Dr Ian Bezodis, email: Ibezodis@cardiffmet.ac.uk

Contact Details: Email:
wesleat@cardiffmet.ac.uk
wsleat@fit2train.co.uk

Please complete all the details below. This information is required for our records.

Name (Print):

I have read the information sheet concerning this project and I am aware of the purpose of the tests and what will be involved. All my questions have been answered to my satisfaction. I understand that I am free to request further information

I know that:

- My participation is entirely voluntary. I know that I am not obliged to complete the tests and I am free to stop the test at any point and for any reason without disadvantage.
- The time (seconds) it takes you to complete each trial will be recorded and used only for the purpose of the research project.
- The test results will only be used for the purpose of the research project. All information and data collected will be held securely at the university. The results of the study may be published but my anonymity will be preserved.

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Signature of Participant: ……..

Date: ……
Signature of Researcher: .....
Date: .....

Physical Activity Readiness Questionnaire (PAR-Q) -			
Name of Participant: Please circle 'YES' or 'NO' to the following questions:			
1	Do you currently suffer from asthma or any breathing-related condition?	YES	NO
2	Have you ever consulted your doctor as a result of suffering from a heart-related condition?	YES	NO
3	Have you/do you suffer from any chest pains which may be aggravated by exercise?	YES	NO
4	Do you suffer from bouts of dizziness or from feeling faint?	YES	NO
5	Have you ever been told by a medical consultant that you suffer from a bone and/or joint condition which might be further aggravated by exercise?	YES	NO
6	Have you ever been diagnosed with high blood pressure?	YES	NO
7	Have you ever been diagnosed with diabetes?	YES	NO
8	Are you unaccustomed to regular vigorous exercise?	YES	NO
9	Is there a significant physical reason not mentioned above why you should not take part in the research project?	YES	NO
If you have circled 'YES' to questions 1-9 please provide further details in the space below. Also, if there are any health and fitness related conditions that could affect your participation in the research which are not covered in questions 1-9, please provide further information below: Should your situation change regarding any of the conditions mentioned above, please see the principle researcher as soon as possible. If you answer 'Yes' to questions 1-9 in the informed consent then this will be followed up and if the condition is still an issue then you may be withdrawn from the study. If, in the event the participant is actively training and competing and is well, then the inclusion will be considered.			
Signed (participant):			

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Signed (principal investigator): Date:	

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11.1.3. Informed consent form: 18± yrs – study three

Informed Consent Form – 18± yrs

Reference Number: 20013617
Participant name or Study ID Number:
Title of Project: The influence of natural grass variation on football performance and game characteristics
Name of Researcher: Wesley Sleat

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

3. I agree to take part in the above study. ☐

_____ _____

Signature of Participant Date

_____ _____

Name of person taking consent Date

_____

Signature of person taking consent

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** When completed, 1 copy for participant & 1 copy for researcher site file*

Blood donation declaration

1.	Do you agree to donate blood for this study?	YES ☐	NO ☐
2.	Have you ever been advised not to give blood?	YES ☐	NO ☐
3.	Are you taking any medication which may affect the ability of your blood to clot?	YES ☐	NO ☐

Donor: Print Name _____ Signature _____ Date _____

Phlebotomist: Print Name _____ Signature _____ Date _____

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11.1.4. Parent / guardian consent form – study three

Parent/Guardian - Informed Assent Form

Reference Number: 20013617
Participant name or Study ID Number:
Title of Project: The influence of natural grass variation on football performance and game characteristics
Name of Researcher: Wesley Sleat

Participant to complete this section: **Please initial each box.**

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that the participation is voluntary and that my son is free to withdraw at any time, without giving any reason. ☐

3. I agree for my son to take part in the above study. ☐

_____ _____

Signature of Parent/Guardian Date

_____ _____

Name of person taking consent Date

_____

Signature of person taking consent

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** When completed, 1 copy for participant & 1 copy for researcher site file*

Blood donation declaration

1.	Do you agree to donate blood for this study?	YES ☐	NO ☐
2.	Have you ever been advised not to give blood?	YES ☐	NO ☐
3.	Are you taking any medication which may affect the ability of your blood to clot?	YES ☐	NO ☐

Donor: Print Name _____ Signature _____ Date _____

Phlebotomist: Print Name _____ Signature _____ Date _____

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11.1.5. Informed assent form: u18 yrs – study three

Participant - Informed Assent Form: u18 yrs

Reference Number: 20013617
Participant name or Study ID Number:
Title of Project: The influence of natural grass variation on football performance and game characteristics
Name of Researcher: Wesley Sleat

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that the participation is voluntary and that my son is free to withdraw at any time, without giving any reason. ☐

3. I agree for my son to take part in the above study. ☐

_____ _____

Signature of Parent/Guardian Date

_____ _____

Name of person taking consent Date

_____

Signature of person taking consent

** When completed, 1 copy for participant & 1 copy for researcher site file*

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Blood donation declaration

1.	Do you agree to donate blood for this study?	YES ☐	NO ☐
2.	Have you ever been advised not to give blood?	YES ☐	NO ☐
3.	Are you taking any medication which may affect the ability of your blood to clot?	YES ☐	NO ☐

Donor: Print Name _____ Signature _____ Date _____

Phlebotomist: Print Name _____ Signature _____ Date _____

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11.1.6. Informed consent form – study four

Informed Consent Form

Reference Number: 17/3/01R
Participant name or Study ID Number:
Title of Project: Ex-professional players', coaches', coach-educators' and academy-level (amateur) players' perceptions of playing soccer on grass pitches of contrasting surface hardness.

Name of Researcher: Wesley Sleat

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that the participation is voluntary and that I can withdraw at any time, without giving any reason. ☐

3. I allow permission for the focus group to be recorded using a video camera and dictaphone. ☐

4. I agree to take part in the above study. ☐

5. I agree to the non-disclosure of any information discussed within the focus group. ☐

_____ _____

Signature of Participant Date

_____ _____

Name of person taking consent Date

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_____

Signature of person taking consent

** When completed, 1 copy for participant & 1 copy for researcher site file*

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11.2. Participant information sheets for participant(s), parent(s) and or guardian(s)

11.2.1. Participant information sheet – study one

Participant Information Sheet

Project Title: Natural turf surface conditions and the influences it has on football performance and game character.

Principal Investigator: Wesley Sleat
Research Team: Dr Michael Hughes, Dr Peter O Donoghue, Dr Ian Bezodis
Contact details: Email: wsleat@fit2train.co.uk

Dear participant,

Purpose of this information sheet

This information sheet has been written in order to help you better understand a research project performed by researchers at the Cardiff Metropolitan University (CMU). The information provided in the rest of the information sheet is to help you decide if you wish to participate in the testing. It is really important that you understand that taking part in this study is voluntary and if you do not want to continue you can withdraw from the project at any time.

Aims of the research

The aim of the research is to investigate whether the condition of natural turf influences football performance and game character.

To achieve this aim the outline of the research requires you to play football while performance analysis is implemented to identify your movements and performance variables via the use of a video camera. The project will focus on a case study involving you playing 10-12 competitive football matches at youth academy-level (amateur) level (under 19's). We will be looking at whether there are any differences in performance and game character on different surface condition and hardness.

What will happen once you agree to participate in the study?

If you should agree to participate in this study, you will be required to perform a total of 10-12 competitive football matches to complete the project. Testing will be performed at different grounds in the Welsh academy-level (amateur) youth league.

You will be expected to perform 10-12, 90-minute matches with two 45-minute halves and a 15-minute recovery at half time throughout the 2012/2013 season.

Movement patterns of interest will include frequency of walking, jogging, sprinting, cutting movements, acceleration, deceleration, turns to the right and left along with performance measures including successful/unsuccessful passes, successful/unsuccessful tackles (in 3 zones), goals, shooting/attempts, success rate, methods of attack and time of match goals are scored.

Any differences when comparing the results of different turf conditions will be identified once analysis has been completed.

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It is important that you prepare for each match in the same way that you would for any other match.

What type of participants are we hoping to recruit?
We are looking for one currently active male academy-level (amateur) level football players aged 18 or over.

What are the risks of participating in the study?
The risks associated with the study are minimal. You may experience moderate levels of fatigue and muscle soreness following the completion of each match, however, given that the you are accustomed to the type and level of fatigue of football match-play any discomfort should be similar to that experienced after any football match. Considering you are planning to play these games in the 2012/2013 Welsh football youth league season anyway no unfamiliar fatigue or physical stress will be experienced.
Additionally, should any incidences arise where you sustain an injury or feel unwell please stop performing immediately.

Benefits to you, the participant
You have the option to receive a written record of your performance data from the matches analysed. This record will provide you with details of specific frequencies of performance measures identified above which may be of interest to you.

Benefits to us, the research team
This research will help us to understand the influences different natural turf conditions have on football performance and character of the game. Measuring the hardness of the playing surface will allow the pitch to be quantified and therefore objective assessment can be made. This information is valuable to all amateur level footballers who regularly play and train on different natural turf conditions as well as coaches and governing bodies.

What will happen to the data and information collected during the study?
Anonymity of individuals will be maintained during the research, meaning we will not share your results with other participants. An individual's performance data will only be seen by the research team and the individual themselves. Copies of all data collected during the testing period will be stored centrally within a secure holding location in UWIC for up to a period of 7 years. Only the research team will be able to access the data once stored in UWIC. Results of this study may be published but any data included will in no way be associated with any specific participant.

What next?
Please feel free to ask any questions to a member of the research team at any time. You may contact me using the e-mail address above. If you would like to take part in the study, please complete the Informed Consent Form and return to one of the research team.

This project has been approved by the University Research Ethics Committee.

Many thanks,

Wesley Sleat
Cardiff School of Sport

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11.2.2. Participant information sheet – study two

Participant Information Sheet

Project Title: The Influence Of Natural Turf Variation On Football Performance And Game Characteristics

Principal Investigator: Wesley Sleat
Research Team: Dr Michael Hughes, Dr Peter O Donoghue, Dr Ian Bezodis
Contact details: Email: wsleat@fit2train.co.uk

Dear participant,

Purpose of this information sheet

This information sheet has been written in order to help you better understand a research project performed by researchers at the Cardiff Metropolitan University. The information provided in the rest of the information sheet is to help you decide if you wish to participate in the testing. It is really important that you understand that taking part in this study is voluntary and if you do not want to continue you can withdraw from the project at any time.

Aims of the research

The aim of the research is to investigate the extent to which natural turf surfaces of contrasting hardness influence football performance and game characteristics.

To achieve this aim the outline of the research requires you to perform in a repeated sprint ability (RSA) test on two separate occasions.

What will happen once you agree to participate in the study?

If you should agree to participate in this study, you'll be required to perform a total of 10 sprint repetitions of 40 metres starting every 40 seconds with active recovery interspersed between trials. Testing will be performed on two separate occasions at two football pitches of contrasting hardness with >48 recovery between tests.

The study is interested in your sprint performance over 10 repetitions to see the extent you fatigue as you complete the 10 tests. Any differences when comparing the results on different turf conditions will be identified once analysis has been completed.

It is important that you prepare for each of the two testing sessions in the same way.

What type of participants are we hoping to recruit?

We are looking to recruit 20 active male academy-level (amateur) level football players aged 18 or over.

What are the risks of participating in the study?

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The risks associated with the study are minimal. You will experience moderate levels of short-lived fatigue and muscle soreness following the sprint trials, however, given that the you are accustomed to the type and level of fatigue of football match-play any discomfort should be similar to that experienced during and after any football match.
Additionally, should any incidences arise where you sustain an injury or feel unwell please stop performing immediately.

Benefits to you, the participant

You have the option to receive a written record of your performance data from the RSA tests. This record will provide you with details of specific sprint performance measures identified above which may be of interest to you.

Benefits to us, the research team

This research will help us to understand the influences different natural turf conditions have on football performance. Measuring the hardness of the playing surface will allow the pitch to be quantified and therefore objective assessment can be made. This information is valuable to all amateur level footballers who regularly play and train on different natural turf conditions as well as coaches and governing bodies. This may also be of relevance to the wider sporting community where natural turf surface is used.

What will happen to the data and information collected during the study?

Anonymity of individuals will be maintained during the research, meaning we will not share your results with other participants. An individual's performance data will only be seen by the research team and the individual themselves. Copies of all data collected during the testing period will be stored centrally within a secure holding location in Cardiff Met for up to a period of 7 years. Only the research team will be able to access the data once stored. Results of this study may be published but any data included will in no way be associated with any specific participant.

What next?

Please feel free to ask any questions to a member of the research team at any time. You may contact me using the e-mail address above. If you would like to take part in the study, please complete the Informed Consent Form and return to the principle researcher.

This project has been approved by the University Research Ethics Committee.

Many thanks,

Wesley Sleat
Cardiff School of Sport

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11.2.3. Participant information sheet – study three

Participant Information Sheet

Reference number: 20013617 (student number)
Title of Project: The influence of natural grass variation on football performance and game characteristics
Participation Information Sheet
Background
The project aims to understand how softer and harder natural grass pitches affect soccer specific movements at different intensities. The effect of the playing surface can change the demands of a soccer performance therefore understanding the physical and mechanical changes when surface hardness changes will help us to understand the complex topic further. Soccer specific movements have been compared on different artificial turf types, but no research has looked into natural grass of contrasting hardness in game-related scenarios. The results will be presented as a report and might also be published.
Your participation in the research project
Why you have been asked

You have been invited to take part in the project as you are currently an academy-level (amateur) College soccer player which is the population of interest.
.

What would happen if you agree to take part in the project?
If you should agree to participate in this study, you'll be required to perform in two separate physical tests, please see below:
1) Steady State Activity: Participants will run for 6 minutes at a pre-determined slow to moderate pace and complete multiple laps of approximately 200 m while the amount of oxygen needed to perform this test and the motion of running will be captured on a video for further analysis.
2) Soccer simulation protocol: The SSP will require participants to complete six, 16-minute sets of simulated football activity including a 15-minute half-time break and with three-minute rests between each of the six sets. Variables measured will include sprints, decline in sprints, heart rate and blood lactate.
Are there any risks?
There will be no significant risks to you from taking part in the study. If you feel unwell, we'd advise that you do not take part. In any case, you should not do anything that you do not want to – just tell us.
What happens to the results of the evaluation?
Anonymity of individuals will be maintained during the research, meaning we will not share your results with other participants. An individual's performance data will only be seen by the research team and the individual themselves. Copies of all data collected during the testing period will be stored

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centrally within a secure holding location in Cardiff Met for up to a period of 10 years. Only the research team will be able to access the data once stored in Cardiff Met. Results of this study may be published but any data included will in no way be associated with any specific participant.

Are there any benefits from taking part?

You have the option to receive a written record of your performance data for all tests completed. This record will provide you with details of specific performance data which may be of interest to you.

What happens next?

Please feel free to ask any questions to a member of the research team at any time. You may contact us using the e-mail address below. If you would like to take part in the study, please complete the Informed Consent Form and return to one of the research team.

With this letter you'll find an information sheet. There are also two forms to complete. The first is for you to give permission to be involved in the project. The second is a different form for your parent/guardian to complete to confirm that they are giving permission for you to take part. If you are willing to participate, these forms should be completed and returned to the research team.

How we protect your privacy:

The privacy of all data collected will be treated with utmost respect. Results of this study may be published but any data included will in no way be associated with any specific participant. All the information will be stored securely away from the consent and assent forms. At the end of the evaluation study we will destroy the information we have gathered about you. We will only keep the consent and assent forms with your name and address. We keep these for ten years because we are required to do so by the University.

What will happen?

Once we have heard back from you confirming your decision, please complete the Informed Consent form and return to the principle researcher. Please feel free to ask any questions to a member of the research team at any time. You may contact us using the e-mail address below. All tests will be explained and instructed in detail prior to any tests being carried out. Both tests will be completed within one week in January, 2016.

Do I have to?

No, you do not have to take part, and no-one is forcing you to do so. If you decide to take part it will be extremely helpful for us but if you wish to drop out at any time, this is entirely up to you.

What do we do?

If you decide to take part and we collect the relevant information, it will be of value to us and all amateur level footballers who regularly play and train on different natural grass conditions as well as coaches and governing bodies.

Further information or any questions?

If you have any questions about the research or how we intend to conduct the study, please contact us.

Wesley Sleat – principle researcher (MPhil / PhD student)

- 02921400732
- wesleat@cardiffmet.ac.uk

11.2.4. Parent / guardian information sheet – study three

Parent/Guardian Information Sheet

Reference number: 20013617 (student number)

Title of Project: The influence of natural grass variation on football performance and game characteristics

Parent / Guardian Information Sheet

Background

The project aims to understand how softer and harder natural grass pitches affect soccer specific movements at different intensities. The effect of the playing surface can change the demands of a soccer performance therefore understanding the physical and mechanical changes when surface hardness changes will help us to understand the complex topic further. Soccer specific movements have been compared on different artificial turf types, but no research has looked into natural grass of contrasting hardness in game-related scenarios. The results will be presented as a report and might also be published.

Your child's participation in the research project

Why your child has been asked

Your child has been invited to take part in the project as they are currently an academy-level (amateur) College soccer player which is the population of interest.

What would happen if you agree for your child to take part in the project?

If you should agree to participate in this study, you'll be required to perform in two separate physical tests, please see below:

1) Steady State Activity: Participants will run for 6 minutes at a pre-determined slow to moderate pace and complete multiple laps of approximately 200 m while the amount of oxygen needed to perform this test and the motion of running will be captured on a video for further analysis.

2) Soccer simulation protocol: The SSP will require participants to complete six, 16-minute sets of simulated football activity including a 15-minute half-time break and with three-minute rests between each of the six sets. Variables measured will include sprints, decline in sprints, heart rate and blood lactate.

Are there any risks?

There will be no significant risks to your child from taking part in the study. If he is feeling unwell, we'd advise that he doesn't take part. In any case, he should not do anything that he doesn't want to – just tell us.

What happens to the results of the evaluation?

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Anonymity of individuals will be maintained during the research, meaning we will not share the results with other participants. An individual's performance data will only be seen by the research team and the individual themselves. Copies of all data collected during the testing period will be stored centrally within a secure holding location in Cardiff Met for up to a period of 10 years. Only the research team will be able to access the data once stored in Cardiff Met. Results of this study may be published but any data included will in no way be associated with any specific participant.

Are there any benefits from taking part?

You have the option to receive a written record of your performance data for all tests completed. This record will provide you with details of specific performance data which may be of interest to you.

What happens next?

Please feel free to ask any questions to a member of the research team at any time. You may contact me using the e-mail address below. If you would like your child to take part in the study, please complete the Informed Assent Form and return to one of the research team.

With this letter you'll find an information sheet for your child. There are also two forms to complete. The first is for you to give permission for your child to be involved in the project. The second is a different form for your child to complete to confirm that he is willing to take part. If you are willing for your child to participate, and he is too, these forms should be completed and returned to the research team.

How we protect your privacy:

The privacy of all data collected will be treated with utmost respect. Results of this study may be published but any data included will in no way be associated with any specific participant. All the information will be stored securely away from the consent and assent forms. At the end of the evaluation study we will destroy the information we have gathered about you and your child. We will only keep the consent and assent forms with your name and address. We keep these for ten years because we are required to do so by the University.

What will happen?

Once we have heard back from you and your child confirming the decision, please complete the Informed Assent form and return to the principle researcher. Please feel free to ask any questions to a member of the research team at any time. You or your child may contact us using the e-mail address below. All tests will be explained and instructed in detail prior to any tests being carried out. Both tests will be completed during the spring of 2016.

Do I have to?

No, your child does not have to take part, and no-one is forcing them to do so. If they decide to take part it will be extremely helpful for us but if you wish to drop out at any time, this is entirely up to you.

What do we do?

If your child decides to take part and we collect the relevant information, it will be of value to us and all amateur level footballers who regularly play and train on different natural grass conditions as well as coaches and governing bodies.

Further information or any questions?

If you have any questions about the research or how we intend to conduct the study, please contact us.

Wesley Sleat – principle researcher (MPhil / PhD student)

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11.2.5. Participant information sheet – study four

Participation Information Sheet

Reference number:

Title of Project: Ex-professional players', coaches', coach-educators' and academy-level (amateur) players' perceptions of playing soccer on grass pitches of contrasting surface hardness.

Background

The aim of the study is to develop a comprehensive insight into the ex-players', coaches' and coach-educators' perceptions of the influence of the grass playing surface on a game of football. The objective is to implement a focus group, designed to capture and ascertain an insight of perceptions and thoughts around the discussion topics highlighted below:

1) Technical and tactical emphasis:

How the characteristics of a grass pitch (surface hardness) influence the way the game is played i.e. time motion, turn types and frequencies, technical frequencies, playing style, formation, pattern of play, playing position and technical and tactical preparation.

2) Physical emphasis:

The perceptions with any current and previous playing or coaching experience involving grass pitches of contrasting hardness, related to physiological attributes i.e. repeated-sprint ability, steady state activity, soccer-specific activity, training prescription, physical demands and fatigue.

3) Psychological emphasis:

The perceptions with any current and previous playing or coaching experience on grass pitches related to psychological attributes i.e. players' and coaches' opinions and thoughts on surface hardness and the influence it has on football performance and game characteristics (including any advantages and disadvantages).

Your participation in the research project

Why you have been asked?

You have been invited to take part in the project as you meet one or more of the target populations below:

- Ex-professional player,
- Lecturer in Sport (Football),
- Ex-professional/Football academy-level (amateur) director,

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- Welsh Schools U18s manager/FAW coach-educator,
- Welsh Schools U18s coach/FAW coach-educator,
- Cardiff & Vale College academy-level (amateur) players.

What would happen if you agree to take part in the project?

If you should agree to participate in this study, you'll be required to attend and contribute to a one-time focus group which will last approximately two hours. The focus group will be held in a conference room at Leckwith stadium, Cardiff. The principle researcher will record the session using a dictaphone and video camera to accurately capture all the discussions for data analysis purposes only.

Are there any risks?

There will be no significant risks or physical exertion to you while taking part in the study. The nature of a focus group will carry no physical risks to any candidates involved due to the focus group being set within a boardroom/conference room at Leckwith Stadium, Cardiff International Sports Campus. The management of data obtained throughout the focus group will be kept secure and treated sensitively maintaining anonymity. All participants will be informed of who will be present and what topics will be discussed during the focus group. The nature of the focus group will not engage in sensitive topics and will therefore be considered minimal risk. The session will be audio and video recorded and will only be used for data analysis for the proposed study. The principle researcher will take every precaution to maintain confidentiality of the data although the nature of a focus group is such that confidentiality cannot be guaranteed. All participants must agree to not repeat any information discussed in the focus group therefore must agree to a statement of non-disclosure evident in the informed consent. All precautions will be implemented to ensure the welfare of all participants is maintained throughout the focus group.

What happens to the results of the evaluation?

Anonymity of individuals will be maintained during the research, meaning we will not share your results with other participants. An individual's perceptions and opinions will only be seen by the research team and the individual themselves. Data collected during the focus group will be stored centrally within a secure holding location in Cardiff Met for up to a period of ten years. Only the research team will be able to access the data once stored in Cardiff Met. Results of this study may be published but any data included will in no way be associated with any specific participant.

Are there any benefits from taking part?

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You have the option to receive a written record of the focus group once completed. This record will provide you with details of specific discussion points which may be of interest to you.

What happens next?

Please feel free to ask any questions to a member of the research team at any time. You may contact us using the e-mail address below. If you would like to take part in the study, please complete the Informed Consent Form and return to one of the research team.

How we protect your privacy:

The privacy of all data collected will be treated with the utmost respect in line with the data protection policy at Cardiff and Vale College. Results of this study may be published, but any data included will in no way be associated with any specific participant. All the information will be stored securely and kept for ten years because we are required to do so by Cardiff Metropolitan University.

What will happen?

Once we have heard back from you confirming your decision, please complete the Informed Consent form and return to the principle researcher. Please feel free to ask any questions to a member of the research team at any time. You may contact us using the e-mail address below. The purpose of the focus group will be explained on the day and the principle researcher will facilitate such proceedings. The focus group will be carried out during either February or March 2017depending on the availability of all participants involved and will take place within a boardroom/conference room at Leckwith Stadium, Cardiff International Sports Campus.

Do I have to?

No, you do not have to take part, and no-one is forcing you to do so. If you decide to take part it will be extremely helpful for us but if you wish to drop out at any time, this is entirely up to you.

What do we do?

If you do decide to take part and we collect the relevant information, it will be of value to us and the wider footballing community who regularly play and train on different natural grass conditions as well as coaches and governing bodies.

Further information or any questions?

If you have any questions about the research or how we intend to conduct the study, please contact us.

Wesley Sleat – principle researcher (MPhil / PhD student)

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11.3. CSSREC Approved Ethical applications

11.3.1. Approved ethical application – study one

All Principal Investigators (PI) undertaking a research project which involves human participants should complete and sign this application form.

The document *Guidelines for obtaining ethics approval* gives full details of how to complete this form and is available via the research pages of the UWIC website. You should refer to this document in order to avoid unnecessary delays with your application.

As a PI, you are responsible for exercising appropriate professional judgement in this review and for operating within UEC (and any School and professional) guidelines in the conduct of the study.

Participant recruitment or data collection must not commence until ethics clearance has been obtained.

Principal Investigator:	Wesley Sleat
Supervisor (if student project):	Dr Michael Hughes; Dr Peter O'Donoghue; Dr Ian Bezodis
School:	Cardiff School of Sport
Type of researcher:	Postgraduate Student (no teaching)
Programme enrolled on:	MPhil/PhD
Project Title:	Natural turf surface conditions and the influences it has on football performance and game character.

PART ONE – ETHICS REVIEW CHECKLIST

ERC1: Will the study involve NHS patients or staff?	No

If **YES**, you do not need to complete Part Two of this form. Instead, an application for ethics approval must be submitted to the appropriate external NHS Research Ethics Committee. Complete Declaration A overleaf and forward a copy of your NHS application plus Part One of this form to your School Ethics Committee for information.

ERC2: Does your research fall ***entirely*** within one of the following three categories: • Paper-based, involving only documents in the public domain • Laboratory based, not involving human participants or human tissue samples (eg electronics, chemical analysis) • Practice-based, not involving human participants (eg exhibitions, curatorial, reflective analysis, practice audit)	No

If **YES**, you do not need to complete Part Two of this form. Instead, complete Declaration B overleaf and send the completed form to your School Ethics Committee for information.

If **NO**, you must complete Part Two of this form and submit your application (Part One and Part Two) to your School Ethics Committee for consideration.

DECLARATION A	
I confirm that the information contained in this form is correct My research involves human participants and ERC1 indicates I must obtain ethics clearance from the appropriate external health authority ethics committee. Signature of Principal Investigator: W.Sleat	
Date:	

DECLARATION B	
I confirm that the information contained in this form is correct My research falls entirely within the categories described in ERC2 and I do not need to take further action to obtain ethics clearance. Signature of Principal Investigator:	
Date:	Click here to enter a date.
Brief synopsis of project:	
Click here to enter text.	

FOR STUDENT PROJECTS ONLY I confirm that I have read and agreed the information contained in this form	
Name of Supervisor: Click here to enter text.	Date: Click here to enter a date.
Signature of Supervisor:	

School Research Ethics Committee use only	
☐ Considered and supported	☐ Considered and not supported
Name: Click here to enter text.	Date: Click here to enter a date.

PART TWO – APPLICATION FOR ETHICS APPROVAL

Expected Start Date:	01/08/2012		
Approximate Duration:	Maximum 1 year		
Funding Body (if applicable):	N/A		
Other researcher(s) working on the project	Supervisory team support		
Does your project require ethical approval from an NREC or other body?			No
If yes, please name the NREC or other body	Click here to enter text.		
Does your project use Human Tissue?	No		
Has CRB clearance been given?	No	If yes, which organisation holds details of the check[1]?	Click here to enter text.

DECLARATION	
I confirm that the information contained in this form is correct Signature of Principal Investigator: Wesley Sleat	Date: 28/05/2012
FOR STUDENT PROJECTS ONLY I confirm that I have read and agreed the information contained in this form	
Name of Supervisor:	Date:
Signature of Supervisor:	

Research Ethics Committee use only	
Decision reached:	Project approved ☑ Project approved in principle ☐ Decision deferred ☐ Project not approved ☐ Project rejected ☐
Project reference number: Click here to enter text.	
Name: Click here to enter text.	Date: Click here to enter a date.
Signature:	

A – PROJECT DETAILS	
A1 In order to give members of the ethics committee some idea of the nature of your research, please answer the following questions with regard to this project:	
Will you take blood or tissue samples from participants?	No

[1] In cases where a CRB check has been sought by an external organisation, confirmation from that organisation that a satisfactory check has been received is required by UWIC at application stage.

Will the study involve prolonged or repetitive testing OTHER THAN repetitive training exercises of a type which form part of the participants normal activities (such as athletics or music training)?	No
Are drugs, placebos or other substances (eg vitamins) to be administered to participants?	No
Could the study induce physiological or psychological stress or anxiety significantly greater than the participants are likely to experience in their daily lives?	No
Does the study involve participants who are unable to give informed consent?	No
Will the study involve children? (NB: Projects in professional practice involving groups of children in a public place in school, with the permission of the school, are exempted)	No
Is pain or more than mild discomfort likely to result from the study?	No
Will financial inducements, other than reasonable expenses and compensation for time, be offered to participants?	No
Will deception of participants to necessary during the study?	No

A2 Briefly describe the rationale behind your project	
Football performance and movements can change remarkably due to changes in the turf (Potthast *et al*., 2010). A deeper understanding of player-surface interaction when pitch hardness changes may provide an insight into how this impacts on football performance and game character. There is an undoubted need for objective tests which can characterise the playing quality of sports pitches. There are presently no investigations comparing different natural turf conditions and the influences on performance and game character while performing in a competitive football match therefore an objective analysis is required to quantify surface hardness in order to develop an understanding of the ergonomic interface with the characteristics of natural turf and how it impacts on the player. Furthermore, it is proposed that if natural turf surfaces are to help meet the provision of sports surfaces, advancements in the construction and sustainability of natural turf surface design is required (Stiles *et al*., 2009). Developments in pitch quality at amateur level may contribute to improving future football performance in the UK. Findings from the initial case study will influence the objective performance measures of interest during further physiological and biomechanical studies with a larger sample.	
A3 What are the aims of the research?	
The aim of the research is to investigate whether the condition of natural turf influences football performance and game character. We aim to make a comparison on various movement characteristics and performance measures to determine whether the hardness of natural turf playing surface influences competitive football.	
A4 Will you be using an approved protocol in your project?	No
A5 If yes, please state the name and code of the approved protocol to be used[2]	
Click here to enter text.	

If your project does involve the use of an approved protocol, please indicate when answering the following questions, which areas of your study are covered by the protocol

[2] An Approved Protocol is one which has been approved by UWIC to be used under supervision of designated members of staff; a list of approved protocols can be found at [INSERT LINK]

A6 What methods of data collection and analysis will you adopt?
Initially a single case study research design will be implemented using both qualitative and quantitative analysis. Ethical approval and informed consent will be granted prior to commencing. A Clegg Soil Impact Hammer (2.25kg) will be used to quantify playing surface hardness. Three test procedures will be performed on 6 sites of a full-sized pitch: (i) corner, (ii) goalmouth, (iii) wing, (iv) penalty area, (v) centre circle (vi) area between halfway line and 18-yard box. The mean of 5 tests will be taken to represent surface hardness. This method is a well-established technique that is endorsed by the Institute of Groundsmanship (IOG). One participant will perform in twelve competitive 90-minute football matches at grounds in the Welsh academy-level (amateur) youth league throughout the 2012/2013 season. Criteria for the inclusion of each match will require the participant to exceed 60 minutes on the field of play. A two-dimensional video analysis (Sony HDR-XR155E digital video camera, China) will be used to provide objective measures of movement patterns. A perpendicular set up on the halfway line with an elevated position will optimise capture of movement patterns of interest including frequency of walking, jogging, sprinting, cutting movements, acceleration, deceleration, turns to the right and left along with performance measures including successful/unsuccessful passes, successful/unsuccessful tackles (in 3 zones), goals, shooting/attempts, success rate, methods of attack and time of match goals are scored. Matches will be analysed using Prozone3 Match Viewer software.
A7 What remuneration (if any) will be offered to participants?
No remuneration will be granted for the participant of this study.
A8 From which group(s) will participants be recruited and what sampling method and criteria will be used?
One amateur male football player will be recruited for the study.
A9 How many participants will be involved?
One participant.
A10 Where and how will the participants be recruited and what method of initial contact will you use?
The participant will be recruited from a College based on the following criteria. That they are currently an academy-level (amateur) level youth player, that they are over 18 years of age and that they are available for 12 competitive matches throughout the 2012/2013 season. Typically, the initial contact will be between the researcher (lecturer) and participant (students).
A11 What previous experience of research involving human participants relevant to this project do you have?
The PI has research experience at undergraduate and postgraduate level in Performance Analysis, Physiology and Biomechanics. Attended and presented undergraduate dissertation (Performance Analysis) at BASES student conference 2002. Conducted a multidisciplinary research project on asymmetrical gait patterns within clinical biomechanics.
A12 **Student projects only** What previous experience of research involving human participants relevant to this project does your supervisor have?
Dr Michael Hughes has extensive experience in research and use of procedures using human participants. The researcher has been a BASES-accredited exercise physiologist since 2001. He has been involved in a wide range of projects using human participants, including testing for his own PhD research (between 2000 & 2004), professional consultancy work for a variety of sport bodies with adult (including FIFA, Badminton England, Welsh Badminton, Welsh Athletics) and junior participants (Chelsea FC for the 'Football Icon project', Badminton England and Welsh Badminton) and from his three years employed as a physiologist with the British Olympic Association. He has

been involved in academic studies that have been published in a range of journals (including Journal of Applied Physiology, Medicine and Science in Sports & Exercise, Journal of Sports Sciences, International Journal of Sports Medicine).

B – POTENTIAL RISKS
B1 What potential discomfort or inconvenience to the participants do you foresee?
The participant may experience temporary fatigue following each match however the 90-minute performance does not differ away from their normal sporting activity.
B2 How do you propose to deal with the potential risks?
Make sure the participant is injury free prior to analysis. Informed consent/PAR-Q forms must be completed by the subjects prior to sampling. Subject must be warmed up prior to competing. Subject performs on safe, regulated and officiated pitches.
B3 Do you intend to use a questionnaire to ascertain an individual's level of physical fitness or health before accepting them as a participant? If yes, please give details.
Yes – PAR-Q
B4 What potential risks to the interests of the researchers do you foresee?
None
B5 How will you deal with these potential risks?
Not applicable

C – CONSENT	
C1 Will informed consent be sought from participants?	Yes
C2 IF NO, explain why informed consent will not be sought	
C3 IF YES, describe how informed consent will be obtained and attach copies of relevant documents	
Participants will be fully informed verbally and in writing about the nature and demands of the study, as well as the anticipated risks. The player will voluntarily participate in the study, giving written informed consent following the completion of a health screening questionnaire.	
C4 If you are using an approved protocol, has the approved wording for participants been included in your Participant Information Sheet?	Choose an item.
C5 If NO, why not?	
Click here to enter text.	
C6 If there are doubts about participants' abilities to give informed consent, what steps have you taken to ensure that they are willing to participate?	
Click here to enter text.	
C7 If participants are aged under 18, describe how you will seek informed consent	
Not applicable	
C8 How will consent be recorded?	
Through the completion of informed consent form.	

D – OTHER DETAILS	
D1 Will participants be informed of their right to withdraw without penalty?	Yes
If no, please detail the reasons	
Click here to enter text.	
D2 How will you ensure participants' confidentiality and anonymity?	

All information collected will be held at the University and will only accessible by members of the research team. Copies of all the data collected during the testing period will be stored centrally within a secure holding location in CMU for up to a period of 7 years.
D3 How will issues of data storage be addressed?
Only the principal researcher and his co-investigators will be able to access the data. Results of this study may be published but any data included will in no way be linked to any specific participant.
D4 Are there any further points you wish to make with regard to the proposed research?

NB: When submitting your application, in addition to this form your School Ethics Committee will expect to see copies of the documentation you will use during your project. Depending on what your project entails, this may include:

- Participant information sheet (See Section C)
- Participant consent form (See Section C)
- Parents information sheet (See Section C)
- Parents consent form (See Section C)
- Participant questionnaire (See A6)
- Health questionnaire (See B3)
- Letter to the organisation at which research will take place

Refer to the document *Guidelines for obtaining ethics approval* for further details on which documents you should provide and exemplar forms for your reference when compiling this information.

11.3.2. Approved ethical application – study two

When undertaking a research or enterprise project, Cardiff Met staff and students are obliged to complete this form in order that the ethics implications of that project may be considered.

If the project requires ethics approval from an external agency such as the NHS or MoD, you will not need to seek additional ethics approval from Cardiff Met. You should however complete Part One of this form and attach a copy of your NHS application in order that your School is aware of the project.

The document ***Guidelines for obtaining ethics approval*** will help you complete this form. Once you have completed the form, sign the declaration and forward to your School Research Ethics Committee.

PLEASE NOTE:
Participant recruitment or data collection must not commence until ethics approval has been obtained.

PART ONE

Name of applicant:	Wesley Sleat
Supervisor (if student project):	Dr Michael Hughes; Dr Peter O'Donoghue; Dr Ian Bezodis
School:	School of Sport
Student number (if applicable):	20013617.
Programme enrolled on (if applicable):	MPhil/PhD
Project Title:	The Influence Of Natural Turf Variation On Football Performance And Game Characteristics
Expected Start Date:	31/03/2013
Approximate Duration:	01/12/2013
Funding Body (if applicable):	Employer funded – Cardiff and Vale College
Other researcher(s) working on the project:	None
Will the study involve NHS patients or staff?	No
Will the study involve taking samples of human origin from participants?	No

In no more than 150 words, give a non technical summary of the project
The overarching aim of the research is to investigate the extent to which natural turf condition influences football performance and game characteristics. We aim to make a comparison of various

movement characteristics and performance measures to determine whether contrasting surface hardness of natural turf alters player performance and overall game characteristics.
Repeated sprint ability (RSA) tests have been commonly used in field-based team sport responses which are designed to replicate match performances (Spencer et al., 2005) to measure sprint speed (Glaister, 2008) and fatigue (Mohr et al., 2003).
The objective of the RSA study will be to quantify sprint performance and the extent of fatigue (the ability to maintain sprint speed during 10 trials) of 20 academy-level (amateur) level football participants on two pitches of contrasting hardness.
Participants will perform ten repetitions every 40 seconds over 40 metres with sub-maximal active recovery between bouts. Both pitch tests will be carried out using timing gates during similar times of the season to overcome differences in fitness levels and climate changes.
A Clegg Impact Hammer (CIH) will objectively measure surface hardness (gravitational deceleration force of the impact measured in gravities (g). Evidence supports the CIH as a valid and reliable tool for discriminating between different levels of surface hardness (Saunders et al., 2011; FIFA, 2012).

Does your project fall entirely within one of the following categories:	
Paper based, involving only documents in the public domain	No
Laboratory based, not involving human participants or human tissue samples	No
Practice based not involving human participants (eg curatorial, practice audit)	No
Compulsory projects in professional practice (eg Initial Teacher Education)	No
If you have answered YES to any of these questions, no further information regarding your project is required. If you have answered NO to all of these questions, you must complete Part 2 of this form	

DECLARATION: **I confirm that this project conforms with the Cardiff Met Research Governance Framework**	
Signature of the applicant: Wesley Sleat	Date: 12/02/2013
FOR STUDENT PROJECTS ONLY	
Name of supervisor: Dr Michael Hughes	Date:
Signature of supervisor:	

Research Ethics Committee use only	
Decision reached:	Project approved ☑ Project approved in principle ☐ Decision deferred ☐ Project not approved ☐ Project rejected ☐

Project reference number: Click here to enter text.	
Name: Click here to enter text.	Date: Click here to enter a date.
Signature:	
Details of any conditions upon which approval is dependant: Click here to enter text.	

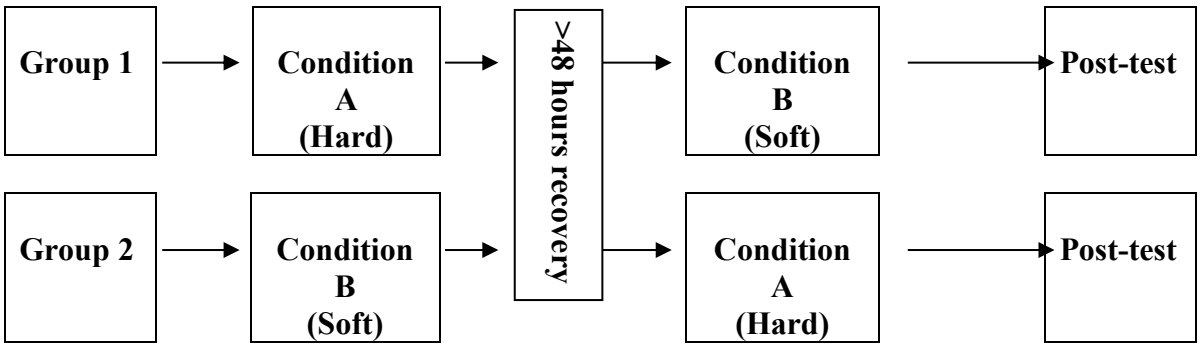
PART TWO

A RESEARCH DESIGN	
A1 Will you be using an approved protocol in your project?	No
A2 If yes, please state the name and code of the approved protocol to be used[3]	
Not applicable	
A3 Describe the research design to be used in your project	

Research methods

RSA will be used to quantify fatigue (the ability to maintain sprint speed during 10 trials) and sprint performance on two pitches of contrasting hardness.
Twenty participants will perform 10 repetitions of forty metre repeated sprints starting every 40 seconds interspersed with sub maximal recovery between bouts.
A counterbalanced measures design will be used as there are two conditions, A (hard surface) and B (soft surface. Participants will be divided into two groups and one group is tested with condition A, followed by condition B, and the other is tested with condition B followed by condition A.

Counterbalanced Measures Design - Counterbalancing Test Groups



Sample and Sampling
Twenty participants will be sampled for the intended RSA study.

Recruitment of participants
Twenty participants will be recruited from a Further Education College based on possessing the following criteria; (i) they are currently an academy-level (amateur) level youth player (ii) that they are over 17 years of age (iii) that they are free from injury and available half way through the 2012/2013 season for two testing sessions with >48 hour recovery between testing conditions. Typically, the initial contact will be between the PI and participant (student). Informed consent, PAR-Q and participant information will be completed prior to selection.

Analytical techniques
A CIH (2.25kg) will be used to quantify playing surface hardness. The mean of 5 tests will be taken to represent surface hardness (gravitational deceleration force of the impact measured in gravities (g). This method is a well-established technique that is endorsed by the Institute of Groundsmanship (IOG) and FIFA (2012).

[3] An Approved Protocol is one which has been approved by Cardiff Met to be used under supervision of designated members of staff; a list of approved protocols can be found on the Cardiff Met website here

Timing gates will measure the RSA performance of all trials. RSA will be used to quantify the extent of fatigue (the ability to maintain sprint speed during 10 trials) and sprint performance on two pitches of contrasting hardness.	
A4 Will the project involve deceptive or covert research?	No
A5 If yes, give a rationale for the use of deceptive or covert research	
Not applicable.	

B PREVIOUS EXPERIENCE
B1 What previous experience of research involving human participants relevant to this project do you have?
The PI has research experience at undergraduate and postgraduate level in Performance Analysis, Physiology and Biomechanics. He has attended and presented an undergraduate dissertation (Performance Analysis) at a BASES student conference 2002 and conducted a multidisciplinary research project on asymmetrical gait patterns involving amputeed participants. Current work commitments include lecturing in Further and Higher Education institutions and the construction of a laboratory for testing human participants with an emphasis on physiological and biomechanical disciplines.
B2 **Student project only** What previous experience of research involving human participants relevant to this project does your supervisor have?
Dr Michael Hughes has extensive experience in research and use of procedures using human participants. The researcher has been a BASES-accredited exercise physiologist since 2001. He has been involved in a wide range of projects using human participants, including testing for his own PhD research (between 2000 & 2004), professional consultancy work for a variety of sport bodies with adult (including FIFA, Badminton England, Welsh Badminton, Welsh Athletics) and junior participants (Chelsea FC for the 'Football Icon project', Badminton England and Welsh Badminton) and from his three years employed as a physiologist with the British Olympic Association. He has been involved in academic studies that have been published in a range of journals (including Journal of Applied Physiology, Medicine and Science in Sports & Exercise, Journal of Sports Sciences, International Journal of Sports Medicine).

C POTENTIAL RISKS
C1 What potential risks do you foresee?
The participants may be susceptible to injury due to the nature of maximal sprint exertion. Subjects will perform the RSA tests on two full size pitches of contrasting hardness (Cyncoed and another TBC). The participant will experience temporary fatigue following the RSA performance, but this does not differ away from their normal sporting activity. RSA tests are meant to stimulate game sport activity which would be of similar nature to a training drill.
C2 How will you deal with the potential risks?
Make sure the participant is injury free prior to analysis and to ensure Informed consent, PAR-Q and participant information have been distributed and completed by the subjects prior to sampling. If a participant has a positive answer 'Yes' to questions 1-9 in the informed consent, then this will be followed up and if the condition is still an issue then the participant will be withdrawn from the study. If, in the event the participant is actively training and competing and is well, then the inclusion will be considered. Participants must be warmed up prior to testing using a 15-20-minute raise, activate, mobilise and potentiate (RAMP) method. Testing will be carried out on safe and official full-size natural turf pitches.

When submitting your application, you **MUST** attach a copy of the following:

- All information sheets
- Consent/assent form(s)

Refer to the document ***Guidelines for obtaining ethics approval*** for further details on what format these documents should take.

11.3.3. Approved ethical application – study three

When undertaking a research or enterprise project, Cardiff Met staff and students are obliged to complete this form in order that the ethics implications of that project may be considered.

If the project requires ethics approval from an external agency (e,g., NHS), you will not need to seek additional ethics approval from Cardiff Met. You should however complete Part One of this form and attach a copy of your ethics letter(s) of approval in order that your School has a record of the project.

The document ***Guidelines for obtaining ethics approval*** will help you complete this form. It is available from the Cardiff Met website. The School or Unit in which you are based may also have produced some guidance documents, please consult your supervisor or School Ethics Coordinator.

Once you have completed the form, sign the declaration and forward to the appropriate person(s) in your School or Unit.

Participant recruitment or data collection MUST NOT commence until ethics approval has been obtained.

PART ONE

Name of applicant:	Wesley Sleat
Supervisor (if student project):	Dr Michael Hughes; Dr Peter O'Donoghue; Dr Ian Bezodis
School / Unit:	Cardiff School of Sport
Student number (if applicable):	20013617
Programme enrolled on (if applicable):	MPhil / PhD
Project Title:	The influence of natural grass variation on football performance and game characteristics
Expected start date of data collection:	05/01/2016
Approximate duration of data collection:	Twelve months
Funding Body (if applicable):	Not applicable
Other researcher(s) working on the project:	Not applicable
Will the study involve NHS patients or staff?	No
Will the study involve taking samples of human origin from participants?	Yes

Does your project fall entirely within one of the following categories:	
Paper based, involving only documents in the public domain	No
Laboratory based, not involving human participants or human tissue samples	No
Practice based not involving human participants (eg curatorial, practice audit)	No
Compulsory projects in professional practice (eg Initial Teacher Education)	No
A project for which external approval has been obtained (e.g., NHS)	No
If you have answered YES to any of these questions, expand on your answer in the non-technical summary. No further information regarding your project is required. If you have answered NO to all of these questions, you must complete Part 2 of this form	

In no more than 150 words, give a non-technical summary of the project
No investigation has compared how hard and soft natural grass pitches influence responses to soccer activity which represent competitive soccer to the extent of match-play (Potthast et al., 2010). Soccer specific movements have been compared on different artificial turf types which showed differences, although movements were not in game scenarios (Kati et al., 2012). The aim of the project is to evaluate the influence of pitch hardness on the physiological and biomechanical responses to soccer activity. The two objectives are to 1) investigate the physiological responses of soccer players during steady state running and a soccer simulation protocol and 2) to compare the kinematics of running activity on pitches of contrasting hardness.

DECLARATION: **I confirm that this project conforms with the Cardiff Met Research Governance Framework**	
Signature of the applicant: Wesley Sleat	Date: 17/11/2015
FOR STUDENT PROJECTS ONLY	
Name of supervisor: Michael Hughes	Date: 18-11-15
Signature of supervisor:	

Research Ethics Committee use only	
Decision reached:	Project approved ☑ Project approved in principle ☐ Decision deferred ☐ Project not approved ☐

Project rejected ☐	
Project reference number: Click here to enter text.	
Name: Click here to enter text.	Date: Click here to enter a date.
Signature:	
Details of any conditions upon which approval is dependant: Click here to enter text.	

PART TWO

A RESEARCH DESIGN	
A1 Will you be using an approved protocol in your project?	No
A2 If yes, please state the name and code of the approved protocol to be used[4]	
Click here to enter text.	
A3 Describe the research design to be used in your project	

A cross-over design will be administered with each of the steady state activity (SSA) and soccer simulation protocol (SSP) tests on two pitches of contrasting hardness over a one-week period. A 2.25 kg Clegg Impact Hammer will be used to objectively measure pitch hardness prior to carrying out the SSA and SSP and such testing will only be carried out when weather conditions remain relatively consistent.

The SSP has been developed by staff at Cardiff Met and ethical approval has previously granted for its use with over-18-year-old players (submitted to ethics committee Jun 2010).

The effect of surface hardness on the physiological responses of amateur soccer players.
Fifteen under-nineteen (majority under-eighteen) College academy-level (amateur) soccer players will complete a SSA and SSP where physiological responses will be measured prior to, during and after testing to objectively quantify the extent to which natural grass pitch hardness affects the physical requirements and demands a soccer player experiences while performing on natural pitches of contrasting hardness. The research is fully supported by Cardiff and Vale College with permission to use its grounds which include Leckwith Stadium, Cardiff. A second pitch will either be at Cardiff Met or another venue within a similar area depending on surface hardness and seasonal variations. The SSP (Stone et al., 2011) is a valid simulation of soccer activity and requires participants to complete six, 16-minute sets of simulated football activity including a 15-minute half-time break and with three-minute rests between each of the six sets. Blood lactate concentration (BLa) will be assessed following each 16-minute set and analysed immediately using a Biosen C-Line lactate analyser (EFK Diagnostics, Barleben, Germany). The principle researcher will be taking all blood samples and is trained and experienced/competent in the management of general hygiene, hand / gloves, biohazard disposal / biological waste and minimizing risk with this type of procedure. Heart rate will be continuously monitored and recorded throughout the SSA and SSP tests (Polar Team System, Kempele, Finland) with heart rate averaged every 5 s. Running speed will be controlled during the study using smart speed light-gates (Fusion Sport., UK).

[4] An Approved Protocol is one which has been approved by Cardiff Met to be used under supervision of designated members of staff; a list of approved protocols can be found on the Cardiff Met website here

A kinematic analysis of amateur football players while running on softer and harder natural grass.

Kinematic analysis will take place while soccer players perform in the SSA and SSP to determine the extent that pitch hardness alters (a) the characteristics of step kinematics while speed is controlled and (b) joint kinematics (lower limb and trunk, to allow calculation of two-dimensional ankle, knee, hip and trunk angles) during steady state running and linear sprinting as previous research has identified their importance for this type of movement (Murphy et al., 2000; Lockie et al., 2011; Lockie et al., 2012). Decreasing ground contact time during running is considered the most important kinematic change for improving sprinting speed (Weyand et al., 2010).

A) SSA protocol:

Fifteen participants will run for 6 minutes at a controlled jogging speed of 2.5 m s^{-1} and complete multiple laps of approximately 200 m with O_2 consumption (portable on-line gas analysis), joint angles (ankle, knee, hip and trunk), ground contact and flight time measured. Two-dimensional static high-speed cameras with a sampling rate of 200Hz will be set to capture several foot contacts during each lap of the SSA.

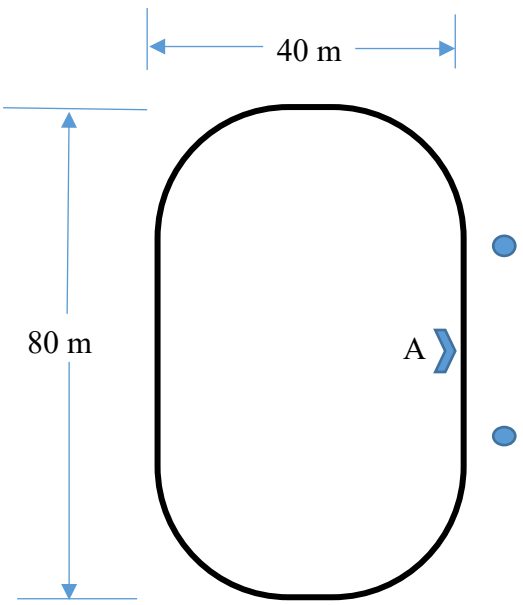


Figure 2. Schematic of the layout for the 200m lap used for the SSA protocol. Participants will run anti-clockwise at a controlled jogging speed of 2.5 m s^{-1} monitored by smartspeed timing gates (filled circles). A high-speed camera will be positioned at point A to capture left foot contacts for five stride cycles per lap to determine all kinematic variables identified above (section A).

B) SSP protocol:

The SSP will require participants to complete the procedure below while sprints, decline in sprints, HR and BLa are measured.

Each set consists of 8 cycles and includes the following:

- One repeated sprint (RS: 6 × 15 m sprints departing every 18 s) block between cycles 4 and 5.
- 3 × 20 m at a walking pace of 1.43 m s^{-1}
- 1 × sprint-agility run (S-AR) at maximal intensity (20 s for sprint and recovery)
- 3 × 20 m at a running speed of 2.5 m s^{-1}
- 3 × 20 m at a running speed of 4.0 m s^{-1} (Stone et al., 2011).

During RS: 6 X 15m sprints departing every 18 s between cycles 4 and 5; all defined kinematic variables (ankle, knee, hip, and trunk angle, step frequency, step length, contact time and flight time) will be measured using a two-dimensional high-speed camera (see figure 3).

Figure 3. Schematic of the layout for the SSP. The 20 m lane A will be used for the movements (walking, jogging and running at controlled intensities. Lane B will be used for the sprint-agility run (number order: 1-2-3-2-1) and repeated sprints (15 m). Open circles are marker cones and small filled circles are timing gates. One filled circle (large) at the side of lane B demonstrates where a two-dimensional high-speed camera will be positioned with a sampling rate at 200Hz.

A4 Will the project involve deceptive or covert research?	No
A5 If yes, give a rationale for the use of deceptive or covert research	
Not applicable	
A6 Will the project have security sensitive implications?	No
A7 If yes, please explain what they are and the measures that are proposed to address them	
Not applicable	

B PREVIOUS EXPERIENCE
B1 What previous experience of research involving human participants relevant to this project do you have?
The principle researcher has gained research experience at undergraduate and postgraduate level in Performance Analysis, Physiology and Biomechanics (BSc (hons), MSc, PGCE, PGCert, PGDip). Previous research experiences include an undergraduate project studying the sporting phenomenon of home advantage in soccer and a postgraduate multidisciplinary research project on asymmetrical gait patterns within a biomechanics scientific support placement. Recent research includes the preparation and imminent completion of two publications (contributing toward an MPhil Award) one of which will be submitted to the International Journal of Performance Analysis.
B2 **Student project only** What previous experience of research involving human participants relevant to this project does your supervisor have?
Dr Michael Hughes has extensive experience in research and use of procedures using human participants. The researcher has been a BASES-accredited exercise physiologist since 2001. He has been involved in a wide range of projects using human participants, including testing for his own PhD research (between 2000 & 2004), professional consultancy work for a variety of sport bodies with adult (including FIFA, Badminton England, Welsh Badminton, Welsh Athletics) and junior participants (Chelsea FC for the 'Football Icon project', Badminton England and Welsh Badminton) and from his three years employed as a physiologist with the British Olympic Association. He has been involved in academic studies that have been published in a range of journals (including Journal

of Applied Physiology, Medicine and Science in Sports & Exercise, Journal of Sports Sciences, International Journal of Sports Medicine).

C POTENTIAL RISKS
C1 What potential risks do you foresee?
The participant may experience temporary fatigue following each of the SSP tests however the 90 min simulation will not differ from the candidates' normal sporting activity. The SSA poses very little risk as the intensity level will remain below steady state. Child protection considerations are required due to the majority of participants being under-eighteen. Environmental risks include unsafe pitch condition due to severe weather conditions whereby injury could potentially occur. The management of data obtained throughout the project needs to be kept secure and sensitively treated maintaining anonymity.
C2 How will you deal with the potential risks?
Make sure the participant is injury free prior to analysis. Informed assent /PAR-Q forms must be completed prior to sampling. Participants must be warmed up prior to carrying out both the SSA and SSP tests and all will be performed on safe, 11 a-side grass turf pitches. The SSA and SSP tests will be carried out when conditions are safe to proceed while all risks are minimised. The principle researcher and any research assistant will hold and have a current DBS available and will be an employee of Cardiff and Vale College. Data will be stored securely with password protected I.T. equipment and only the research team will have access to such data. No reputational damage will occur as only one College is involved in the research project with no other external Colleges participating.

When submitting your application, you **MUST** attach a copy of the following:

- All information sheets
- Consent/assent form(s)

An exemplar information sheet and participant consent form are available from the Research section of the Cardiff Met website.

11.3.4. Approved ethical application – study four

When undertaking a research or enterprise project, Cardiff Met staff and students are obliged to complete this form in order that the ethics implications of that project may be considered.

If the project requires ethics approval from an external agency (e,g., NHS), you will not need to seek additional ethics approval from Cardiff Met. You should however complete Part One of this form and attach a copy of your ethics letter(s) of approval in order that your School has a record of the project.

The document ***Ethics application guidance notes*** will help you complete this form. It is available from the Cardiff Met website. The School or Unit in which you are based may also have produced some guidance documents, please consult your supervisor or School Ethics Coordinator.

Once you have completed the form, sign the declaration and forward to the appropriate person(s) in your School or Unit.

PLEASE NOTE:
Participant recruitment or data collection MUST NOT commence until ethics approval has been obtained.

PART ONE

Name of applicant:	Wesley Sleat
Supervisor (if student project):	Dr Michael Hughes; Dr Peter O'Donoghue; Dr Ian Bezodis
School / Unit:	Sport
Student number (if applicable):	20013617
Programme enrolled on (if applicable):	PhD
Project Title:	Ex-professional players', coaches', academy-level (amateur) college players' and coach-educators' perceptions of playing soccer on grass pitches of contrasting surface hardness
Expected start date of data collection:	01/12/2016
Approximate duration of data collection:	3 months
Funding Body (if applicable):	N/A
Other researcher(s) working on the project:	None
Will the study involve NHS patients or staff?	No
Will the study involve human samples and/or human cell lines?	No

Does your project fall entirely within one of the following categories:	
Paper based, involving only documents in the public domain	No
Laboratory based, not involving human participants or human samples	No
Practice based not involving human participants (eg curatorial, practice audit)	No
Compulsory projects in professional practice (eg Initial Teacher Education)	No
A project for which external approval has been obtained (e.g., NHS)	No
If you have answered YES to any of these questions, expand on your answer in the non-technical summary. No further information regarding your project is required. If you have answered NO to all of these questions, you must complete Part 2 of this form	

In no more than 150 words, give a non-technical summary of the project
Currently no investigation has compared how hard and soft natural grass pitches influence responses to soccer activity which represent competitive soccer to the extent of match-play (Potthast et al., 2010). Soccer specific movements have been compared on different artificial turf types which revealed differences, although movements were not in game scenarios (Kati et al., 2012). The style and pace of soccer is thought to be influenced by the performance characteristics of different field surfaces (Dragoo and Braun, 2010) however, knowledge is sparse in terms of understanding the effect of different pitch surfaces on the perceived exertion and exercise intensity during a soccer game (Brito et al., 2012). Match characteristics and outcomes are affected by surface type and hardness (Baker et al., 2001; Fernandez et al., 2006; Andersson et al., 2008; Stiles et al., 2009; Potthast et al., 2010; Poirier et al., 2011) and subtle changes in surface characteristics may affect a player's movements, potentially disturbing their technical skills during competition (Dixon et al., 2000). Four studies (CSSREC approved) precede the current proposal which focused on the physical demands of playing football on grass surface of contrasting hardness and involved disciplines including physiology (2 x studies), biomechanics (1 x study) and performance analysis (1 x study). Gaining a psychological perspective from the proposed study will triangulate the design to provide a more thorough understanding of the influence of contrasting grass surface hardness on soccer performance and game characteristics. The aim of the study is to develop a comprehensive psychological insight into the ex-players', coaches', players' and coach-educators' perceptions of the influence of the grass playing surface on a game of soccer. The objective is to implement a focus group, designed to capture and ascertain an insight of perceptions and thoughts around the discussion topics highlighted below (section 2; A3) and the principle researcher (Wesley Sleat) will carry out the proposed focus group. It is hopeful the findings will provide professional comments and feedback related to opinions and experiences and will either affirm that the summaries from the previous research studies will or will not reflect their feelings, experiences and views. The overall goal of this study is to provide professional insights that are original, reliable and authentic therefore strengthening the credibility of the full project which will be of interest to the wider soccer community.

DECLARATION:
I confirm that this project conforms with the Cardiff Met Research Governance Framework

I confirm that I will abide by the Cardiff Met requirements regarding confidentiality and anonymity when conducting this project.

STUDENTS: I confirm that I will not disclose any information about this project without the prior approval of my supervisor.	
Signature of the applicant: Wes Sleat	Date: 26/10/16
FOR STUDENT PROJECTS ONLY	
Name of supervisor: Peter O'Donoghue	Date: 15/11/16
Signature of supervisor:	

Research Ethics Committee use only	
Decision reached:	Project approved ☐ Project approved in principle ☑ Decision deferred ☐ Project not approved ☐ Project rejected ☐
Project reference number: 17/3/01R	
Name: Dr Brendan Cropley	Date: 07/03/2017
Signature:	
Details of any conditions upon which approval is dependant: 1. The researcher must have an up-to-date DBS form (presented to the supervisory team and stored with this document) prior to commencing the research.	

PART TWO

A RESEARCH DESIGN	
A1 Will you be using an approved protocol in your project?	No
A2 If yes, please state the name and code of the approved protocol to be used[5]	

[5] An Approved Protocol is one which has been approved by Cardiff Met to be used under supervision of designated members of staff; a list of approved protocols can be found on the Cardiff Met website here

Click here to enter text.
A3 Describe the research design to be used in your project
Prior to focus group: Participants will be selected from a homogenous sample with either playing or coaching soccer experience in some capacity. A one-time focus group is planned to last approximately two-hours and will be focusing on three main topics including a technical and tactical, physical and psychological emphasis highlighted below. **Participants:** Nine candidates will participate in the study and consist of a (1) lecturer in sport and exercise (2) Director of Football (Yeovil Ladies Football Club/Cardiff and Vale College) (3) Director of Welsh Schools Football Association (U18s) (4) Welsh Schools Football Association Coach (U18s) (5) Football Association Wales Coach-educator and (6) three College academy-level (amateur) soccer players and an ex-professional soccer player. **Procedure:** The location will be secure, private, comfortable and quiet in order to not discourage participants from talking and expressing their opinions. Preparation prior to the focus group will include familiarity with the questioning route, reducing any distractions and ensuring all participants listen with discipline. The principle researcher will start the open-circle focus group with a concise introduction comprising of welcoming the group, providing an overview of the topic, setting ground rules and starting with an introductory question. Probing questions will be used such as "would you give an example?" or "would you explain further?" Subtle group control will be utilised for dominant talkers, shy candidates and ramblers. The focus group will be recorded using a dicta-phone and video camera for accuracy when processing the transcript. Verbal and non-verbal communications will be observed and recorded by the facilitator. A three-step conclusion will complete the focus group comprising of a summary, reviewing the purpose and ask if anything has been missed. A thematic approach will be conducted to get a sense of the interview as a whole before breaking it into parts for further analysis. It is anticipated major themes will begin to emerge identifying a thematic framework, writing short phrases, concepts and ideas to highlighting and sorting quotes to compare and contrast between the findings of the study and research of similar nature. Content analysis will be used with some induction to identify themes related to explanations of the forthcomings but being framed in a deductive manner based on the findings from the previous studies. **Discussion/Question Topics:** **1) Technical and tactical emphasis:** How the characteristics of a grass pitch (surface hardness) influence the way the game is played i.e. playing style, formation, pattern of play, playing position and technical and tactical preparation. **2) Physical emphasis:** The perceptions with any current and/or previous playing or coaching experience on grass pitches related to physiological attributes i.e. training prescription, physical demands and fatigue. **3) Psychological emphasis:** The perceptions with any current and previous playing or coaching experience on grass pitches related to psychological attributes i.e. players' and coaches' opinions and thoughts on surface hardness, advantages or disadvantages.

A4 Will the project involve deceptive or covert research?	No
A5 If yes, give a rationale for the use of deceptive or covert research	
Click here to enter text.	
A6 Will the project have security sensitive implications?	No

A7 If yes, please explain what they are and the measures that are proposed to address them
Click here to enter text.

B PREVIOUS EXPERIENCE
B1 What previous experience of research involving human participants relevant to this project do you have?
The principle researcher has gained research experience at undergraduate and postgraduate level in Performance Analysis, Physiology and Biomechanics (BSc (hons), MSc, PGCE, PGCert, PGDip). Previous research experiences include an undergraduate project studying the sporting phenomenon of home advantage in soccer and a postgraduate multidisciplinary research project covered asymmetrical gait patterns within a biomechanics scientific support placement. Recent research includes four separate studies which contribute to an MPhil/PhD project relating to the influence natural grass surface hardness has on football performance and game characteristics. The publication for study one can be seen below: Sleat, W., O'Donoghue, P., Hughes, M. and Bezodis, I.N. (2016). The influence of natural grass surface hardness on path changes, locomotive movements and game events in soccer: a case study, International Journal of Performance Analysis in Sport, 16, 216-233.
B2 **Student project only** What previous experience of research involving human participants relevant to this project does your supervisor have?
Dr Michael Hughes has extensive experience in research and use of procedures using human participants. The researcher has been a BASES-accredited exercise physiologist since 2001. He has been involved in a wide range of projects using human participants, including testing for his own PhD research (between 2000 & 2004), professional consultancy work for a variety of sport bodies with adult (including FIFA, Badminton England, Welsh Badminton, Welsh Athletics) and junior participants (Chelsea FC for the 'Football Icon project', Badminton England and Welsh Badminton) and from his three years employed as a physiologist with the British Olympic Association. He has been involved in academic studies that have been published in a range of journals (including Journal of Applied Physiology, Medicine and Science in Sports & Exercise, Journal of Sports Sciences, International Journal of Sports Medicine). Dr Ian Bezodis has over 10 years' experience in sports biomechanics research and Dr Peter O'/Donoghue has over 20 years' experience in performance analysis research.

C POTENTIAL RISKS
C1 What potential risks do you foresee?

The nature of a focus group will carry no physical risks to any candidates involved due to the focus group being set within a boardroom/conference room at Leckwith Stadium, Cardiff International Sports Campus. All candidates will be 18 years or over and, therefore, no child protection considerations will be required. The management of data obtained throughout the focus group needs to be kept secure and treated sensitively maintaining anonymity. All participants will be informed of who will be present and what topics will be discussed during the focus group. The nature of the focus group will not engage in sensitive topics and will therefore be considered minimal risk. Participants will be informed before the focus group starts that the session will be audio and video recorded and will only be used for data analysis for the proposed study. The principle researcher will take every precaution to maintain confidentiality of the data although the nature of a focus group is such that confidentiality cannot be guaranteed. All participants must agree to not repeat any information discussed in the focus group therefore a statement of non-disclosure will be evident in the informed consent. The focus group discussions will pose no specific risk to a particular institution (i.e. Cardiff Metropolitan University; Cardiff and Vale College) as the topics relate to sporting and coaching experiences only. All precautions will be implemented to ensure the welfare of the principle researcher and all participants is maintained throughout the focus group. Given the nature of the focus group, it remains highly unlikely any information solicited during the focus group will be illegal, illicit and/or has potential for harm.
C2 How will you deal with the potential risks?
Informed consent will be gained, and information related to the focus group will be given to all participants prior to running the focus group. All participants will need to answer "no" to all the stipulated criteria on the informed consent form prior to attending. Participation is voluntary and therefore candidates can withdraw at any stage of the process. The principle researcher is a current employee of Cardiff and Vale College and holds a current DBS. Data will be stored securely with password protected I.T. equipment and only the research team will have access to such data. No reputational damage will occur as only one College (Cardiff and Vale College) is involved in the research project with no other external Colleges participating. The principle researcher will emphasise the importance to be aware of the impact that relationships between participants might have on responses and data quality. Prior to commencing the focus group, the research team will make sure all consent forms and preliminary instructions are processed and completed and that participants should respect the confidentiality of fellow participants. Participants will be informed that they will be audio/video recorded for use related to the proposed study only. All information shared in the focus group should be treated with privacy and should not be shared with anyone outside of the focus group. The informed consent document will offer all participants an option where they must agree by ticking the non-disclosure box. If a difficulty arises in sensitive research in that the researcher could be a party to 'guilty knowledge' the researcher will decide the limits of tolerance, beyond which he will not venture. A final measure will be put in place which will violate informed consent and non-disclosure should illegal, illicit and/or any information with potential for harm is revealed.

When submitting your application, you **MUST** attach a copy of the following:

- All information sheets
- Consent/assent form(s)

An exemplar information sheet and participant consent form are available from the Research section of the Cardiff Met website.

International Journal of Performance Analysis in Sport 2016, 16, 216-233
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The influence of natural grass surface hardness on path changes, locomotive movements and game events in soccer: a case study

Abstract

Sporting performance and outcomes are affected by surface type and hardness. Natural grass surface characteristics can vary considerably at amateur level sport which can influence technical skills and locomotive movements. Surface hardness and human responses need to be objectively measured in order to fully understand movement responses and subsequent performance. In the present study, one academy-level (amateur) u-19 soccer player played in eleven competitive matches. Surface hardness was measured using a Clegg Impact Hammer and pitches were categorised into either harder or softer groups (67.7 to 93.0 Gmax and 41.4 to 58.3 Gmax respectively). The frequency of high intensity shuffling was significantly greater on softer grass (11.2±2.1) when compared to harder grass (6.1±3.8) ($p < 0.05$). A large effect size was revealed with running, dribbling, low and high intensity activities as greater frequencies were evident on softer grass when compared to harder grass. There were no significant differences for any of the game events, but there was a large effect size for aerial challenges and headed clearances which were performed more often on softer surfaces than on harder surfaces. There was a greater frequency of moderate intensity, sharp path changes to the right and V-cut path change performed on softer surfaces than on harder surfaces and the effect sizes were large. To conclude, movement activity and game events performed were influenced by natural grass surface hardness. Future research should endeavour to explore differences in the physical work-rate in terms of the biomechanical and physiological demands.

Key words: soccer performance, academy-level (amateur) soccer, work-rate, game-related activity.

1. Introduction

Sport is played on a range of surfaces including asphalt, wooden, artificial turf, clay, cement, sand, and ice with natural grass being a common playing surface for many sports including rugby, cricket, hockey, American football, tennis and soccer. Match characteristics and outcomes are affected by surface type and hardness (Baker et al., 2001; Fernandez et al., 2006; Andersson et al., 2008; Stiles et al., 2009; Potthast et al., 2010; Poirier et al., 2011) and subtle changes in surface characteristics may affect a player's locomotive movements, potentially disturbing their technical skills during competition (Dixon et al., 2000).

The mechanical behaviour of natural grass is termed "the reaction of the surface in response to a physical force" (Capel, 2011). Surface hardness has been defined as "the ability of a surface to absorb the impact energy created by any object striking that surface" (Rogers, 1988). The term "surface hardness" in the present study indicates the resistance of the surface towards deformation (James, 2011). Softer surfaces have been shown to absorb a larger percentage of the energy applied upon impact compared to harder surfaces (Bell and Holmes, 1988). The interaction between an athlete and the surface is through foot-to-shoe-to-surface interaction (Baker and Canaway, 1993), with the level of traction and the surface's ability to absorb energy being two important properties of any sports surface (Brosnan et al., 2009). Variations in natural grass surfaces have been shown to influence biomechanical parameters during running and turning movements on three different compositions of natural grass surfaces (sandy, clay and rootzone - mixture of sand, peat with soil), but these parameters were measured in a laboratory setting (Stiles et al., 2011).

Evidence suggests that performance of cricketers is influenced by the hardness of pitches due to the effects on the pace and bounce of the ball (Baker et al., 2001). Tennis has different demands depending on the surface, with different cushioning and frictional properties influencing the ball rebound and game speed. Two common playing surfaces in tennis are clay, characterised by a slow game, and hard court, characterised as fast. Therefore, tennis players adjust their game according to surface hardness (Fernandez et al., 2006). The hardness of ice has been shown to be influential on ice hockey performance and maximum player speed due to differences in the coefficient of friction (Poirier et al., 2011).

Soccer is the most popular sport in the UK with nearly one in five adults – 8.2 million people participating in the game in some form (FA, 2015). Irrespective of the level of the sport, certain pitch standards are desired as the surface performance is critical to the sporting outcome (Capel, 2011). In soccer there are strict criteria on the markings within the playing area, size of the playing area and even the player's footwear and clothing. Meanwhile judgements on the suitability of a surface are left to the discretion of the referee (Bell and Holmes, 1988). Until the late 1970s little work had been conducted in the UK on playing characteristics while performing on natural grass (Baker, 1986). However, a need for a set of reproducible measures that provides quantitative assessment

of the characteristics and suitability of a surface for a given sport has been recognised (Canaway, 1983; Ward, 1983; Stiles et al., 2009; Potthast et al., 2010).

Over the past 40 years, soccer has experienced change concerning playing surface, with traditionally used natural grass being the preferred surface (Burillo, 2014). However, since recent improvements in artificial grass, on-going deliberations from sporting organisations continue on which type of playing surface best serves athletes' needs (Gallardo et al., 2009).

Soccer players are required to move in a high-intensity, intermittent fashion that includes multiple sprints of varying distances and durations, acceleration, deceleration, agility, jumping and other locomotive movements (Little and Williams, 2005). A feature of a surface that affects athletic performance is the energy stored and returned (Baroud et al., 1999). The energy that an athlete requires for each jump, stride, step and landing movement is influenced by reused and returned energy from the surface (Katkat et al., 2009). This suggests that if a surface permits a greater energy return, an athlete can complete a given physical activity using less energy (Katkat et al., 2009).
In the 2015/16 UEFA European Under-17 Championship, it was acceptable to play matches on artificial turf provided that such turf met the FIFA International Artificial Grass Standard (UEFA, 2015). Similarly, the 2014 U-20 women's World Cup and FIFA 2015 women's World Cup used artificial grass throughout the tournament (European Synthetic Turf Organisation, 2015).

It remains inconclusive how a soccer player's loading response is affected when changes in natural grass cushioning differs with time of season, temperature and precipitation (Ford et al., 2006). Evidence suggests that possible effects of playing on a hard surface do exist with greater density of surface reducing the cushioning of loads experienced by an athlete (Dixon et al., 2008; Low and Dixon, 2014) which may influence a player's physical work-rate.

The predominant use of natural grass in amateur soccer has attracted little research attention. Therefore, the current investigation aimed to compare soccer performances on surfaces of different hardness. Surface hardness and human responses need to be objectively measured in order to fully understand movement responses and subsequent performance (Stiles et al., 2009; Potthast et al., 2010). The purpose of the current investigations was to describe surface effect on locomotive movement, path changes and turns, and game events. This would require considerable data collection for each performance. Therefore, a case study approach was used in the present study as an effective way of examining factors influencing sport performance by using the same player which ensured that differences could be attributed to surface variation rather than being down to inter-individual movement differences. In addition, the case study served to provide an exploratory description and discovery to identify the direction of further research in the area (Halinen and Tornroos., 2005; Vissak, 2010).

2. Methods

2.1. Participant

One male (aged 18.1 years; stature 1.77 m; and body mass 75.5 kg), central-midfield soccer player from an under-nineteen College academy-level (amateur) team participated in the study. The regular performance activity of the participant was playing in academy-level (amateur) College league matches. The player was informed of the procedure and purpose of the study and gave written informed consent to participate. The study gained approval prior to starting through the Research Ethics Committee of Cardiff School of Sport at Cardiff Metropolitan University. The player's performance was video recorded in 11 matches for the purpose of the present study.

2.2. Surface hardness measurement

Immediately prior to and following matches, a 2.25 kg Clegg Impact Hammer (CIH) (S.D. Instrumentation, Bath, United Kingdom) was used to objectively quantify playing surface hardness. CIH tests were performed five times on six individual sites on 11 v 11 size soccer pitches: (I) corner, (II) goalmouth, (III) penalty area, (IV) area between halfway line and 18-yard box, (V) centre circle and (VI) wing (Figure 1: FIFA, 2012). CIH tests were not made on joints or inlaid lines. Within each designated CIH testing site each measurement was located on an untested area of grass where no surface deformation existed (within a 0.15 m^2 area) and drop height of the hammer was 0.457 m which is a standard drop height for the 2.25kg CIH model (Clegg, 1992). The means ± standard deviations were taken to represent surface hardness of five separate drops on each site and overall surface hardness of each pitch was calculated as a mean of the six sites (30 drops) both pre and post-match (60 drops in total). Evidence supporting the CIH as a valid and reliable tool for discriminating between different levels of surface hardness is that it is endorsed by the Institute of Groundsmanship (IOG) and the Football Association (FA) (Clegg, 1976; Bell and Holmes, 1986; Saunders et al., 2011; FIFA, 2012). Ten gravities ("Gmax") per one Clegg unit indicated gravity units regarding the force applied by the hammer for an individual blow. Chivers and Aldous (2004) have classified surface hardness as shown in Table 1. This defines surface hardness as the gravitational deceleration force of the impact measured in gravities (Gmax), with a decreasing number indicating a lessening of hardness and an increasing number indicating higher stiffness of the grass within the region of impact (Chivers and Aldous., 2004).In this study, the surface hardness in seven of the 11 matches was classified as "Low", it was "Normal / Preferred" in three matches and "High" in the other according to Chivers and Aldous's (2004) classification. It was, therefore, decided to arrange the surface hardness values of the 11 pitches in the current investigation into two clusters, with five and six matches in each of the two clusters. The two clusters were termed "harder" (77.3 ± 10 Gmax) and "softer" (50.8 ± 6.5 Gmax) surfaces within the sample.

Table 1. 'Acceptable' and 'preferred' benchmark ranges are evident for impact hardness of natural grass pitches assessed (Chivers and Aldous, 2004).

Hardness Class	Unacceptably Low	Low	Normal Preferred Range	High	Unacceptably High
Hardness (Gmax/10)	<30	30 to 69.9	70 to 89.9	90 to 120	>120

Values in gravities (Gmax).

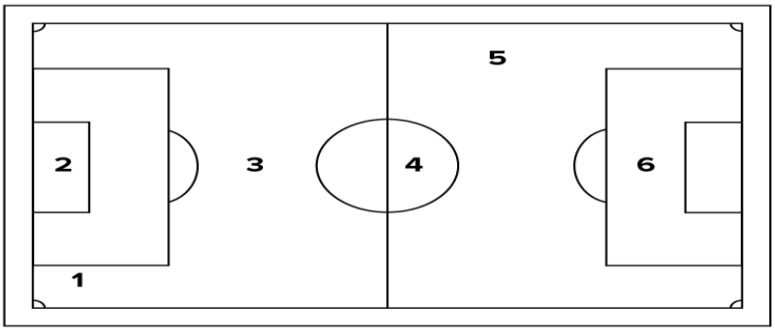

Figure 1. Six field test positions for quantifying surface hardness with the CIH (FIFA, 2012).

2.3. Recording player performance

Eleven competitive and officiated matches were recorded over a 6-month period. Matches needed to have a duration of greater than 60 min to be included in the study. The participant was asked to perform naturally, with no alterations to performance due to the observation. A two-dimensional video camera (Sony HDR-XR155E digital video camera, Japan) was used to record video footage of the player's performance in all 11 matches, set up on the halfway line. All matches were recorded and analysed by the same experienced observer.

2.4. Variables

The study included three sets of dependent variables; locomotive movements, on-the-ball game-related skills and turns. The locomotive movements were based on the definitions of the even categories used by Huey et al. (2001). However, a limitation of Huey et al.'s (2001) approach is that all shuffling / skipping movement was included in a single movement category that was counted as high intensity activity. This led to an over-estimation of the amount of high intensity activity performed by players. Therefore, separate low intensity and high intensity shuffling movement classes are included in the system used in the current investigation. Huey et al. (2001) also merged the running and sprinting movements into a single movement category. This prevents analysis of the two movements separately which is problematic because recent research into soccer work-rate has separated sprinting from high speed running (Di Salvo et al., 2009; Gregson et al., 2010). Huey et al. (2001) did not separate dribbling from other on-the-ball activity in their hockey study. There is a separate set of variables for on-the-ball events used in the current investigation. However, the frequency of these events will be counted rather than the short durations of such events being timed. Dribbling can be performed over much longer periods than some of the more "instantaneous" events and, therefore, dribbling with the ball is distinguished from movement without the ball and other on-the-ball activity within the locomotive movements recorded in the current investigation. The guidelines for recognising the different movements are as follows:

- Stationary – this included standing, sitting, stretching or lying in a prone position.
- Walking – walking forwards.
- Backing – walking in a backwards or sideways direction.
- Jogging – slow running movement without obvious effort or acceleration.
- Running – running with obvious effort excluding sprinting.

- Sprinting – running with all-out sprinting effort.
- Low Intensity Shuffling – shuffling backwards or sideways or on-the-spot shuffling movement with the feet performed at low or moderate intensity.
- High Intensity Shuffling – shuffling backwards or sideways or on-the-spot shuffling movement with the feet performed at high intensity.
- Game related activity – ball contact or challenging for the ball during ball-in-play time (excluding dribbling).
- Dribbling – moving in possession of the ball during ball-in play time.

On-the-ball game-related skill variables were collected separately from locomotive movement data. Therefore, dribbling was not included. The game-related events included are listed below:

- Pass – playing the ball with feet with the intention of the ball being received by a team-mate, including crosses.
- Headed pass – playing the ball with the head with the intention of the ball being received by a team-mate.
- Clearance – playing the ball with feet with the primary intention of the ball exiting the defensive third.
- Headed clearance – playing the ball with the head with the primary objective of the ball exiting the defensive third.
- Shot – playing the ball with feet with the intention of scoring a goal.
- Headed shot – playing the ball with the head with the intention of scoring a goal.
- Tackle – an attempt to dispossess an opponent with the ball using the feet.
- Aerial challenge – an attempt to play the ball with the head while an opponent is also competing for the ball in the air.

Turns and path changes were recorded if they were performed at moderate or high intensity. Turns and path changes were then categorised into five types including sharp right, sharp left, V-cuts (Robinson et al., 2011), smooth turns and linear turns (Robinson et al., 2008) and classified as involving moderate or high intensity. Turn definitions were characterised as follows:

- Smooth turn – where the player slightly changed the path travelled while turning, similar to an arced run except the radius was less than 1m.
- The sharp path changes counted in the present study used the definitions made by Robinson et al. (2011) and included some movement at moderate intensity or higher during each path change. Unlike smooth turns, sharp path changes involved straight line movement prior to the path of path change and after the path change. Movement was considered to be sufficiently straight-line movement if the direction of movement deviated from the average direction during the period of interest by 15° or less. Sharp path changes to the left (right) were recorded when the average direction of movement after the path change was 45° to 135° to the left (right) of the average direction of movement before the path change.
- Linear turn – where the player made a turn while continuing to move in the same path of movement, possibly with a slight change of path of less than 45° to the left

or right. The player's body may have been facing forward, backwards, left or right with respect to the path of movement before the linear turn and facing a different aspect afterwards.

- V–cut path changes –where the player moved in a straight line before and after the path change, where the player changed path to travel back in the direction from where they were travelling. Thus, the angle of path change greater than 135° degrees to the left or right (Robinson et al., 2011).

2.5. System

Each match underwent three separate analyses. Firstly, path changes and turns were manually recorded using Microsoft Excel noting the time, type, intensity and movement before and after each path change and turn. Match analysis software was used to separately register the locomotive movements and then game events performed in each match (Sports Code Elite, version 5.1.9, Sportstec International, Warriewood, New South Wales, Australia) according to the definitions and guidelines described earlier.

2.6. Reliability

Two of the co-authors independently used the computerised system for locomotive movement timing and game events and the manual data collection process for identifying path changes performed by the player. The timed version of the kappa statistic was calculated after merging the timelines of locomotive movements entered in studio-code. Table 2 shows the proportion of time recorded for each locomotive movement by each of the observers. The proportion of time where the observers agreed on the movement being performed, P_0, was 0.714. When the proportion of time the observers are expected to agree by chance, P_C, of 0.405 was considered, the kappa value was 0.519 which represents a moderate strength of inter-observer agreement.

For the purpose of the reliability study, the two observers did not merely tally game events, turn and path change types, but also recorded the video times at which these occurred. This allowed the kappa statistic to be calculated for the variables involved. There were occasions where one or other of the two observers recorded a game-related event while the other didn't. This required a "None" event to be included, meaning that the kappa statistic here was particularly stringent because "None" could be included in disagreements but not within agreements. Table 3 shows that there were 58 occasions where the two observers agreed that some event was performed by the player. There were 7 additional events being recorded by Observer 1 and 10 additional events being recorded by Observer 2. Of the 58 occasions where the observers agreed that some event was performed, there were only three occasions where they disagreed on the type of event. The overall proportion of agreement, P_0, was 0.733 with an expected agreement by guessing, P_C, of 0.230. Therefore, the kappa value was 0.654 which represents a good strength of inter-observer agreement between the two observers.

Table 2. Time [s] recorded for different locomotive movements by two independent operators.

Observer 1	Observer 2										
	Stationary	Walking	Backing	Jogging	Running	Sprinting	Low Int Shuffling	High Int Shuffling	Game-related activity	Dribbling	Total
Stationary	272.8	250.6	30.3	10.4	6.7	0.0	3.4	0.1	2.9	0.0	577.3
Walking	60.5	2343.4	16.5	125.8	35.2	3.1	7.8	1.1	2.4	0.0	2595.7
Backing	20.1	58.7	58.7	6.5	6.7	1.0	0.7	0.1	2.1	0.0	154.5
Jogging	0.1	156.1	5.7	455.0	16.9	1.1	31.5	2.3	10.3	2.0	681.1
Running	1.1	31.1	3.4	6.2	13.9	0.0	1.3	1.0	3.5	0.0	61.5
Sprinting	5.0	24.7	2.1	9.4	11.0	3.4	6.3	0.9	9.5	0.0	72.2
Low Int shuffling	0.1	26.2	0.0	87.2	9.4	2.0	71.2	19.7	8.3	0.8	224.9
High Int shuffling	0.0	1.8	0.0	1.0	0.0	0.0	1.3	1.4	1.1	0.0	6.5
Game-related activity	7.0	41.3	1.3	21.4	7.1	0.1	15.8	6.7	28.0	0.3	128.9
Dribbling	0.0	4.7	0.0	6.5	1.1	0.0	4.0	0.5	30.0	4.7	51.6
Total	366.6	2938.6	117.9	729.4	108.0	10.6	143.3	33.7	98.1	7.9	4554.0

Table 3. Game related events recorded by the two independent observers.

Observer 1	Observer 2									
	Pass	Clearance	Headed Pass	Headed Clearance	Shot	Headed Shot	Tackle	Aerial Challenge	None	Total
Pass	25	1							6	32
Clearance		1								1
Headed Pass			6						1	7
Headed Clearance										0
Shot					2					2
Headed Shot										0
Tackle		1					14			15
Aerial Challenge			1					7		8
None	1	2		1			3	3		10
Total	26	5	7	1	2	0	17	10	7	75

Table 4 shows that there were 127 occasions where the two observers agreed that some turn or path change was performed by the player. There were 17 occasions where such events were only recorded by Observer 1 and 40 occasions where such events were only recorded by Observer 2. Observer 1 recorded almost twice as many linear path changes as Observer 2 while Observer 2 recorded a greater frequency of the remaining turn and path change events. These disagreements limited P_0 to 0.538. The expected agreement by chance, P_C, was 0.173 meaning that the kappa value was 0.442 which represents a moderate strength of inter-observer agreement.

Table 4. Turns and path changes recorded by the two independent observers.

Observer 1	Observer 2						
	Left Sharp	Linear	Right Sharp	Smooth	V-Cut	None	Total
Left Sharp	29		1	1	3	3	37
Linear	4	16	2	2	2	9	35
Right Sharp		1	25	1	1	3	31
Smooth	7		1	20			28
V-Cut	1			1	9	2	13
None	12	1	13	13	1		40
Total	53	18	42	38	16	17	184

The majority of disagreements were occasions where only one of the two observers recorded a turn or path change. These errors have been accounted for in the calculation of the kappa value for type of turn or path change. Therefore, the kappa values for direction of movement before, the direction of movement after and the intensity with which the turn or path change was performed were calculated using 127 occasions where both observers agreed that some turn or path change had been performed. Table 5 and Table 6 show the number of times different directions were recorded for the movement before and after events respectively. The kappa values for direction of movement performed before and after events were 0.754 and 0.668 respectively which represent good strengths of inter-observer agreement. Table 7 shows the intensity recorded for the 127 agreed turn and path change events by the two independent observers. The kappa value of 0.493 represented a moderate strength of inter-operator agreement.

Table 5. Movement performed before turns and path changes recorded by the two independent observers.

Observer 1	Observer 2				
	Backwards	Forwards	Left	Right	Total
Backwards	2	1	2		5
Forwards		106	3		109
Left		2	5		7
Right				6	6
Total	2	109	10	6	127

Table 6. Movement performed after turns and path changes recorded by the two independent observers.

Observer 1	Observer 2				
	Backwards	Forwards	Left	Right	Total
Backwards	2	1	2		5
Forwards		106	3		109
Left		2	5		7
Right				6	6
Total	2	109	10	6	127

Table 7. Intensity of turns and path changes recorded by the two independent observers.

Observer 1	Observer 2		
	High	Moderate	Total
High	29	14	43
Moderate	15	69	84
Total	44	83	127

2.7. Statistical Analysis

The matches had various durations with all being over 60 minutes. Therefore, all frequency variables were converted to frequencies per minute. This was done by multiplying the frequency by dividing by the match duration (mins). Means ± standard deviations were calculated for the frequency per minute of all game related events, turns and the times and frequencies of locomotive movements in softer and harder conditions. Data analyses were completed using SPSS version 17 (SPSS, an IBM company, Amarouk, NJ), with the level of significance calculated using a series of independent samples t-tests ($p < 0.05$). Independent samples t-tests were preferred to nonparametric Mann Whitney U tests, because t-tests were calculated using the values whereas Mann Whitney U tests would have involved a lot of information loss by ranking the sets of 11 values for each variable of interest. Effect sizes (ES; Cohen's d) were calculated (trivial 0.2, medium 0.5 and large $\geq$ 0.8) when interpreting the practical meaningfulness of the surface effect as only one set of five and one set of six values were collected for each variable making statistical significance difficult to obtain.

3. Results

Table 8 shows the frequency, mean duration and the percentage of match time spent performing each locomotive movement. The modal activity was walking which accounted for over 67% of match time on softer and harder surfaces. The independent samples t-tests revealed that the frequency of high intensity shuffling was significantly greater on softer grass (11.2±2.1) when compared to harder grass (6.1±3.8). The similar duration of high intensity shuffling events on each surface combined with the higher frequency on softer surfaces meant that the percentage of time spent performance high intensity shuffling movement was also greater of softer surfaces. A large effect size was revealed for the frequency of running, low and high intensity activities which had greater frequencies on softer grass when compared to harder grass. There was also a large effect

on the frequency of dribbling movements, and these were performed more on harder surfaces and with longer duration per instance than on softer surfaces. Table 9 compares the frequencies of game-related events performed on harder and softer surfaces. There were no significant differences for any of these frequency variables, but there was a large effect size for aerial challenges and headed clearances which were performed more often on softer surfaces than on harder surfaces. The number of headed shots, however, was very low on both surfaces due to the midfield role of the player. Table 10 shows that there was a greater frequency of moderate intensity turns performed on softer surfaces which consequently led to a greater frequency of turns in general on softer surfaces. There was a greater frequency of each type of turn performed on softer surfaces than harder surfaces except for linear turns. The player was right footed and made more sharp path changes to the left which would involve pushing off with the dominant right leg. This was the case on both surfaces, but the difference was much more pronounced on harder surfaces.

Table 8. Frequency per minute, mean duration and percentage time spent performing different locomotive movements (mean±SD).

Movement	Frequency per minute				Mean duration (s)				%Time		
	Harder	Softer	Cohen's d		Harder	Softer	Cohen's d		Harder	Softer	Cohen's d
Stationary	0.88±0.27	0.88±0.35	0.1 (TRIVIAL)		5.3±0.9	5.3±1.1	0.0 (TRIVIAL)		8.0±3.1	7.0±1.7	0.4 (SM/MED)
Walking	2.83±0.50	3.26±0.85	0.5 (MEDIUM)		14.9±3.3	13.3±2.2	0.6 (MEDIUM)		67.9±3.8	67.3±3.2	0.2 (TRIVIAL)
Backing	0.56±0.10	0.57±0.18	0.1 (TRIVIAL)		3.3±0.6	3.0±0.6	0.5 (MEDIUM)		3.1±0.9	2.7±0.8	0.5 (MEDIUM)
Jogging	1.46±0.73	1.74±0.41	0.5 (MEDIUM)		8.5±6.6	5.1±0.6	0.9 (LARGE)		13.9±2.1	15.2±4.1	0.4 (SM/MED)
Sprinting	0.23±0.08	0.22±0.06	0.1 (TRIVIAL)		3.1±0.4	2.3±1.1	1.1 (LARGE)		1.2±0.5	1.0±0.5	0.5 (MEDIUM)
Running	0.49±0.15	0.65±0.15	1.1 (LARGE)		3.1±0.2	3.0±0.4	0.3 (SM/MED)		2.5±0.7	2.9±0.5	0.5 (MEDIUM)
Low Int shuf	0.48±0.10	0.59±0.43	0.5 (MEDIUM)		1.7±0.3	2.4±2.0	0.6 (MED/LARGE)		1.4±0.4	1.6±0.6	0.5 (MEDIUM)
High Int shuf	0.07±0.04	0.12±0.02	1.7 (LARGE)		1.8±0.3	1.7±0.3	0.3 (SM/MED)		0.2±0.1	0.4±0.1	1.2 (LARGE)
Dribbling	0.12±0.06	0.07±0.05	0.8 (LARGE)		3.2±0.8	2.5±0.7	0.9 (LARGE)		0.6±0.3	0.4±0.3	0.8 (LARGE)
Game-related	0.45±0.14	0.56±0.19	0.5 (MEDIUM)		1.8±0.4	1.8±0.4	0.1 (TRIVIAL)		1.4±0.6	1.6±0.6	0.4 (SM/MED)
Low Intensity	1.02±0.15	1.25±0.19	1.1 (LARGE)		56.9±10.7	47.5±6.5	1.2 (LARGE)		94.3±1.1	94.0±0.6	0.6 (MEDIUM)
High Intensity	1.00±0.15	1.24±0.19	1.2 (LARGE)		3.5±0.4	3.0±0.3	1.1 (LARGE)		5.7±1.1	6.0±0.7	0.3 (SM/MED)

* Independent samples t-test revealed a significant difference ($p < 0.05$).

Table 9. Frequency of game skills performed per minute (mean±SD)

Skill	Harder	Softer	Cohen's d
pass	0.50±0.21	0.41±0.13	0.5 (SM/MED)
headed pass	0.10±0.06	0.11±0.04	0.0 (TRIVIAL)
headed clearance	0.01±0.01	0.02±0.02	1.1 (LARGE)
clearance	0.02±0.02	0.03±0.01	0.6 (MEDIUM)
shot	0.04±0.01	0.04±0.05	0.1 (TRIVIAL)
headed shot	0.01±0.01	0.00±0.00	0.7 (MED/LARGE)
tackle	0.27±0.10	0.25±0.06	0.4 (SM/MED)
aerial challenge	0.04±0.03	0.09±0.04	1.5 (LARGE)

Table 10. Frequency of path changes performed per minute (mean±SD).

Type	Harder	Softer	Cohen's d
Moderate intensity turns	1.07±0.31	1.36±0.25	0.8 (LARGE)
High intensity turns	0.57±0.14	0.60±0.13	0.1 (TRIVIAL)
Total Turns	1.65±0.30	1.97±0.32	0.7 (MED/LARGE)
Right sharp	0.52±0.08	0.66±0.03	1.4 (LARGE)
left sharp	0.62±0.12	0.67±0.14	0.2 (TRIVIAL)
smooth	0.28±0.11	0.38±0.13	0.5 (MEDIUM)
linear	0.15±0.04	0.14±0.07	0.1 (TRIVIAL)
V-cut	0.08±0.02	0.12±0.06	0.7 (MED/LARGE)

4. Discussion

The study aimed to compare soccer performances on surfaces of contrasting hardness and provides evidence suggesting natural grass surface hardness has an impact on game activity and locomotive movements in soccer which concurs with previous findings (Andersson et al., 2008; Potthast et al., 2010). The frequency of high intensity shuffling was significantly greater on softer grass when compared to harder grass ($P<0.05$). A greater number of turn types were performed on the softer grass with medium to large effects for the differences in three (moderate intensity, right sharp, and V-cuts showing ES = 0.8; 1.4; 0.7 respectively) of the turn types. These two findings suggest that the player had to work harder on softer grass with less traction, more absorption of impact forces, with more muscular force and energy expenditure needed (Zamparo et al., 1992).

The frequency of running instances was greater on the softer surface which also led to the percentage of time spent running being greater on softer grass due to the duration of running instances being similar between the two types of surface. This combined with the knowledge that softer surfaces increase energy demands from players (Zamparo et al., 1992) indicates that playing soccer on softer surfaces is more physically demanding than on harder surfaces. Potentially a higher energy restitution association with a greater firmness of a surface may have caused a higher workload on the softer grass (Kerdok et al., 2002; Katkat et al., 2009). A lower impact peak on softer grass may be attributable to the inability to produce force rapidly (McGhie and Ettema., 2013) which may have altered joint movement patterns (Hamill et al., 1992), influencing the vertical deformation (Sánchez-Sánchez et al., 2014) and increasing the eccentric muscle activity (Richie et al., 1993). There were also greater frequencies of low and high intensity periods on the softer surfaces meaning high intensity activity was more intermittent on softer surfaces. Intermittent activity can elevate workload through short recoveries. A laboratory study by Hughes et al. (2005) revealed that repeated 6s bursts lead to higher heart rate response, lactate accumulation and reduced power output when performed every 25s rather

than every 45s or 55s. The current investigation revealed that the player performed bursts of high intensity activity of 3.0s on average with average recovery periods of 47.5s in between on softer surfaces. The corresponding values on harder surfaces were 3.5s for the high intensity periods and 56.9s for the recovery periods. These recovery durations are comparable with the two longest recovery durations studied by Hughes et al. (2005) where there was no significant difference in heart rate response or blood lactate accumulation. However, in soccer performance not all recoveries are of the average duration. Therefore, the shortest recovery periods experienced on softer surfaces could lead to fatigue more than the shortest recovery periods experienced on harder surfaces.

More than double the number of aerial challenges (8.1 to 3.5; ES = 1.5) and a greater number of headed clearances (2.6 to 1.0; ES = 1.1) were performed on the softer grass. However, a greater number of passes were performed on the harder surfaces (45.27 ± 19.27, ES = 0.51) suggesting the ball was off the playing surface more frequently on the softer grass. An explanation may be that the harder surface, with less precipitation and deformation, attracted a shorter passing game on the surface compared to tactics with more long aerial and lofted passes on the softer grass. The frequency, mean duration and the percentage of match time spent dribbling were all greater on harder grass, possibly suggesting harder grass may have assisted with a smoother ball roll and subsequent control.

The current investigation compared softer and harder surfaces that were more similar than the low and high hardness surfaces classified by (Chivers and Aldous, 2004); low being 30 to 70 Gmax and high being between 90-120 Gmax. The differences in movement and game events found between softer and harder surfaces in the current investigation have been found despite the restricted range of hardness of the surfaces the player competed on. Thus, more pronounced differences may be found in future research comparing performances on surfaces with greater differences in terms of hardness. In summary, the findings support previous research where the surface hardness of natural grass has been found to influence soccer player's performance in terms of their technical and turn frequencies and time spent performing locomotive movements (Andersson et al., 2008; Potthast et al., 2010) although further research is needed to investigate the physiological and biomechanical responses when surface hardness changes.

5. Conclusions

The complex interaction between a soccer player and a natural grass playing surface appears to influence player performance. Future work must characterise the nature of natural grass in terms of variations in areas of the pitch and seasonal considerations while trying to gain a greater understanding how an athlete responds to changes in surface hardness. Differences occurred between softer and harder natural grass in the present study for path changes and turns, locomotive movements and game activity. Complementary future research should endeavour to explore differences in the physical work-rate in terms of the biomechanical and physiological demands.

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