The influence of natural grass surface hardness on path changes, locomotive movements and game events in soccer: a case study

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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 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 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 current 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 current 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 team participated in the study. The regular performance activity of the participant was playing in Academy 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 current 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).

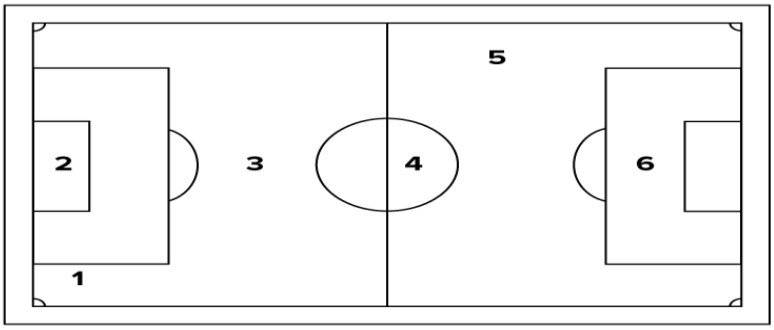

Figure 1. Six field test positions for quantifying surface hardness with the CIH (FIFA, 2012).

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 current 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^{o} or less. Sharp path changes to the left (right) were recorded when the average direction of movement after the path change was 45^{o} to 135^{o} 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^{o} 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^{o} 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 (small 0.2, medium 0.5 and large 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 (SMALL)
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 (SMALL)
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 d = 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; d = 1.5) and a greater number of headed clearances (2.6 to 1.0; d = 1.1) were performed on the softer grass. However, a greater number of passes were performed on the harder surfaces (45.27 ± 19.27, d = 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 current 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.

6. References

Andersson, H., Ekblom, B. and Krustrup, P. (2008). Elite soccer on artificial turf versus natural grass: Movement patterns, technical standards, and player impression, **Journal of Sports Sciences**, 26(2), 113–122.

Baker, S. W. and Canaway, P. M. (1993). Concepts of playing quality: Criteria and measurement, In: Carrow, R.N., Christians, N.E. and Shearman, R.C. (Eds.) **International Turfgrass Research Journal**, Intertec Publishing Corp., Kansas, pp. 172-181.

Baker, S. (1986). Playing standards for natural turf sports surfaces. In: Shildrick, J.P. (Ed.), **Pro. 3rd National Turfgrass Conference**, Nottingham, September 1985, pp. 31-41, National Turf grass Council.

Baker, S.W., Hammond, L.K. and Stewart, K.F. (2001). Technical note: Influence of clegg hammer weight on the relationship between surface hardness and ball rebound for cricket, **Journal of Turfgrass Science**, 77, 71-74

Bell, M.J. and Holmes, G. (1986). The playing quality of association soccer pitches. **Journal of Sports Turf Research Institute**, 64, 19-47.

Binnie, M.J., Peeling, P., Pinnington, H., Landers, G. and Dawson, B. (2013). Effect of training surface on acute physiological responses following interval training. **Journal of Strength and Conditioning Research**, 27(4), 1047-1056.

Baroud, G., Nigg, B. M. and Stefanyshyn, D. (1999). Energy storage and return in sport surfaces, **Sport Engineering**, 2, 173-180

Brosnan, J.T., McNitt, A.S. and T.J. Serensits. (2009). Effects of varying surface characteristics on the hardness and traction of baseball field playing surface. **International Turfgrass Society Research Journal**, 11, 1-13.

Burillo, P., Gallardo, L., Felipe, J.L. and Gallardo, A.M. (2014). Artificial turf surfaces: Perception of safety, sporting feature, satisfaction and preference of soccer users, **European Journal of Sport Science**, 14(1), 437-447.

Canaway,P.M. (1983). The effect of rootzone construction on wear tolerance and playability of eight turfgrass species subjected to soccer type wear. **Journal of Sports Turf Research Institute**, 59, 107-123.

Capel, M. (2011). Mechanical behaviour of natural turf sports surfaces. PhD Thesis, Cranfield University.

Chivers, I. and Aldous, D. (2004). Performance monitoring of grassed playing surfaces for Australian rules soccer. **Journal of Turfgrass and Sports Surface Science**, 70, 73-80.

Clegg. B. (1976). An impact testing device for ill situ base course evaluation. **Australian Road Res**. BUI; Proc. 8. 1-6.

Clegg, B. (1992). Clegg Impact, Testing recreation turf with Clegg Impact Soil Tester. (Online) Retrieved September, 2015, from: http://sdinst.com/sites/default/files/downloads/nl11rev2.pdf.

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P. and Drust, B. (2009). Analysis of high intensity activity in Premier League soccer. **International Journal of Sports Medicine**, 30, 205-212.

Dixon, S. J., Collop, A. C. and Batt, M. E. (2000). Surface effects on ground reaction forces and lower extremity kinematics in running, **Medicine and Science in Sports and Exercise**, 32, 11, 1919-1926.

Dixon, S.J., Jamci, I.T., Blackburn, D.W.K. et al. (2008). Influence of footwear and soil density on loading within the shoe and soil surface during running. Proceedings of the Institution of Mechanical Engineers, Sport Engineering and Technology, 222, I-IC.

European Synthetic Turf Organisation (2015). Synthetic turf for FIFA women's world cup Canada. (Online) Retrieved August, 2015, from: http://www.theesto.com/member-news-menu-link/synthetic-turf-for-fifa-women-s-world-cup-canada-2015.

FA (2015). Taking part in football; football participation continues to rise in England. (Online) Retrieved October, 2015, from: http://www.thefa.com/news/my-football/2015/jan/football-participation-on-rise.

Fernandez, J., Mendez-Villanueva, A. and Pluim, B.M. (2006). Intensity of tennis match play. **British Journal of Sports Med**, 40(5), 387–91.

FIFA (2012). **FIFA Quality Concepts for Soccer Turf, Handbook of test methods for soccer Turf**, Zurich, Switzerland.

Ford, K. R., Manson, N. A., Evans, B. J., Myer, G. D., Gwin, R. C., Heidt Jr., R. S. and Hewett, T. E. (2006), Comparison of in-shoe foot loading patterns on natural grass and synthetic turf. **Journal of Science and Medicine in Sport**, 9(6), 433- 440.

Gallardo, L., Burillo, P., Garcıa Tascon, M., & Salinero, J. J. (2009). The ranking of the Regions with regard to their sports facilities to improve its planning in sport: The case of Spain. **Social Indicators Research**, 94(2), 297-317.

Gregson, W., Drust, B., Atkinson, G. and Di Salvo, V. (2010). Match-to-match variability of high-speed activities in Premier League Soccer. **International Journal of Sports Medicine**, 31, 237-242.

Halinen, A. and Tornroos, J.A. (2005). Using case study methods in the study of contemporary business networks. **Journal of Business Research**, 58(9), 1279-1285.

Hamill, J., Bates, B.T. and Holt, K.G. (1992). Timing of lower extremity joint actions during treadmill running. **Medicine of Science in Sports and Exercise**, 24, 807-813.

Hughes, M.G., Rose, G. and Amaral, I. (2005). The influence of recovery duration on blood lactate accumulation in repeated sprint activity. **Journal of Sports Sciences**, 23, 130-131.

Huey, A., Morrow, P. and O'Donoghue, P.G. (2001). From time-motion analysis to specific intermittent high intensity training, Proceedings of the World Congress of Performance Analysis, Sports Science and Computers (PASS.COM) (Edited by Hughes, M. and Franks, I.M.), 26-29 June 2001, Cardiff: CPA Press, UWIC, pp29-34.

James, I. T. (2011). Advancing natural turf to meet tomorrow's challenges. **Sports Engineering and Technology**, 225, 115-129.

Katkat, D., Bulut, Y., Demir, M. and Akar, S. (2009). Effects of different **sport** surfaces on muscle performance. **Biology of Sport**, 26(3), 285-296.

Kerdok A.E., Biewener, A. A., McMahon T.A., Weyand, P.G. and Herr, H.M. (2002). Energetics and mechanics of human running on surfaces of different stiffnesses. **Journal of Applied Physiology**, 92, 469- 478.

Little, T. and Williams, A.G. (2005). Specificity of acceleration, maximum speed, and agility in professional soccer players. **Journal of Strength and Conditioning Research**, 19(1), 76-78.

Low, D.C. and Dixon, S.J. (2014). Understanding of the effect of changes to natural turf hardness on lower extremity loading. **Measurement and Control**, 47(7), 212-218.

McGhie, D. and Ettema, G. (2013). Biomechanical analysis of surface-athlete impacts on third-generation artificial turf. **American Journal of Sports Medicine**, 41, 177-185.

Poirier, L., Lozowski, E.P. and Thompson, R.I. (2011). Ice hardness in winter sport. **Cold Regions Science and Technology**, 67, 129-134.

Potthast, W., Verhelst, R., Hughes, M., Stone, K. and De Clercq, D. (2010). Soccer specific evaluation of player surface interaction on different soccer turf systems. **Sports Technology**, 3(1), 5-12.

Richie, D.H., DeVries, H.A. and Endo, C.K. (1993). Shin muscle activity and sports surfaces: an electromyographical study. **Journal of American Podiatric Medicine Association**, 83, 181-90.

Robinson, G. and O'Donoghue, P.G. (2008). Movement in World class tennis on clay and grass courts: a case study, In: (Hokelmann, A. and Brummond, M. (Eds.), **Performance Analysis of Sport VIII**, Aachen, Shaker, pp. 720-724.

Robinson, G., O'Donoghue, P. and Wooster, B. (2011). Path changes in the movement of English Premier League soccer players. **Journal of Sports Medicine and Physical Fitness**, 51, 220-226.

Rogers III, J.N. (1988). Impact absorption and traction characteristics of turf and soil surfaces. PhD. thesis. Pennsylvania State University. University Park, PA.

Sánchez-Sánchez, J., García-Unanue, J., Jiménez-Reyes, P., Gallardo, A. Burillo, P., Luis Felipe, J. and Gallardo, L. (2014). Influence of the mechanical properties of third-generation artificial turf systems on soccer players' physiological and physical performance and their perceptions. **PLoS One**, 9 (10): e111368.

Saunders, N., Twomey, D. and Otago, L. (2011). Clegg Hammer measures and human external loading forces: Is there a relationship? **International Journal of Sports Science Engineering**, 5(4), 231-236.

Stiles, V.H., James, I.T., Dixon, S.J. and Guisasola, I.N. (2009). Natural turf surfaces: The case for continued research. **Sports Medicine**, 39(1), 65-84.

Stiles, V. H., Guisasola, I. N., James, I. T. and Dixon, S. J. (2011). Biomechanical response to changes in natural turf during running and turning. **Journal of Applied Biomechanics**, 27(1), 54-63.

UEFA (2015). Regulations of the UEFA European Under-17 Championship 2015/2016. (Online) Retrieved August, 2015, from: http://www.uefa.com/MultimediaFiles/Download/Regulations/uefaorg/Regulations/02/25/83/36/2258336_DOWNLOAD.pdf.

Vissak, T. (2010). Recommendations for using the case study method in international business research. **The Qualitative Report**, 15(2), 370-388.

Ward, C.J. (1983). Amenity grass – drainage review. **A report of the Sports Council and Department of the Environment through NERC**, The Sports Turf Research Institute, Bingley, 112.

Zamparo, P., Perini, R., Orizio, C., Sacher, M. and Ferretti, G. (1992). The energy cost of walking or running on sand. **European Journal of Applied Physiology and Occupational Physiology**, 65, 183- 187.