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SPORT AND EXERCISE PHYSIOLOGY

SCHOOL OF SPORT, P.E. AND RECREATION, U.W.I.C
THE EFFECT OF PROLONGED INTERMITTENT HIGH-INTENSITY EXERCISE ON THE PERFORMANCE OF SOCCER-SPECIFIC SKILLS
(DECLARATION FORM)
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ABSTRACT

The aim of the study was to examine the effect of accumulated fatigue, developed from the performance of prolonged intermittent high-intensity exercise, on the performance of soccer shooting and dribbling skill. Nine semi-professional soccer players volunteered to participate in the study. Their mean (± SD) age, body mass and height were 20.7 ± 1.4 years, 177.7 ± 6.1 cm and 73.5.1 ± 7.6 kg respectively. Participants completed a slalom dribble test and a Loughborough Soccer Shooting Test (LSST) prior to and directly following the performance of a 45 minute modified version of the Loughborough Intermittent Shuttle Test (LIST). The LIST was designed to simulate the minimum physical demands experienced by soccer players during competitive match-play. Performance of the soccer dribbling and shooting skill deteriorated by 4.2 ± 3.6 % (P < 0.05) and 31.61 ± 25.21% (P < 0.05) respectively, following the performance of the LIST. Mean heart rates (155 ± 11 bpm, 155 ± 13 bpm and 156 ± 12 bpm) and mean 15m sprint performance times (2.54 ± 0.15 s, 2.56 ± 0.14 s and 2.58 ± 0.14 s) remained unchanged across the performance of the three LIST activity bouts (P > 0.05). The results of the study demonstrate that soccer skill performance deteriorates after the completion of a prolonged intermittent high-intensity soccer-specific exercise, replicating the physiological demands of one half of soccer match-play. The findings demonstrate a need for trainers and coaches to include soccer-specific fatiguing exercises with skills training to aid players in coping with the demands of soccer match-play.
CHAPTER I

INTRODUCTION
1.1 An Overview of Fatigue in Soccer

Soccer is one of the most popular sports in the world, being played by men, women and children with a diverse range of playing abilities, performing at various levels of expertise. Stolen et al. (2005) described that the performance of soccer is dependent upon many factors, involving technical, tactical, mental and physiological areas.

The physiological aspects of soccer have been studied intensively in recent years, especially in elite male participants (Bangsbo, 1994; Bangsbo et al., 2006; Reilly et al., 1996). Described as a multi-sprint sport, soccer has been observed to encompass periods of high-intensity exercise with periods of lower-intensity exercise (Svensson & Drust, 2005), with phases of support running and recovery combined with short periods of sprinting (Nicholas et al., 2000). Additionally, players have been estimated to cover distances of 9 to 12km during a game (Mohr et al., 2005), performing 1000 - 1400 changes in playing actions (changing every 4 – 6 seconds), consisting mainly of short activities (Mohr et al., 2003a; Reilly and Thomas, 1976), including: tackling, jumping, acceleration and turning actions (Bangsbo, 1994).

The intermittent nature of soccer causes both the aerobic and anaerobic systems to be highly taxed during match-play. This is evident with mean heart rates of 85% of heart rate max (Bangsbo et al., 2006), and mean and maximum blood lactate levels of 5.23 and 11.63mM respectively (Smith et al., 1993), being reported. Edwards et al. (2003) asserted that ideally soccer players should be able to maintain the same level of performance throughout a game. However, during the 90-minute duration of a soccer match and particularly towards the end of play, Appriantono et al. (2006)
described that players will suffer from muscle fatigue, largely as a result of the repeated performance of the aforementioned intensive bursts of game activities.

The development of muscle fatigue has previously been found to be detrimental to performance, with Rhanama et al. (2003) emphasising that while players are able to continue to exercise, they do so at lower intensities, through having a reduced ability to perform maximally. In relation to top class soccer, studies have observed a decline in work rate and a decrease in the total distance covered (5%) between first and second halves of a game (Rhanama et al., 2003), as well as a reduced sprint performance (Krstrup et al., 2006). Additionally, sprint performance and the amount of high-intensity running was found to decline in the last 15 minutes of the game in both lower standard male (Mohr et al., 2003a) and elite female soccer players (Mohr et al., 2003b).

Ekblom (1994) explained that resistance to muscle fatigue is a key factor which determines the effectiveness of a player’s ability to continually perform efficient and precise movements within soccer. Lyons et al. (2006a) highlighted that the development of fatigue may be the determining factor of success and failure, the difference between winning and losing. In addition, soccer at the elite level is characterised not only by a player’s ability to perform repeated high intensity work but also the maintenance of an efficient performance of skills when in possession, such as passing, dribbling and shooting, especially towards the end of play (Mohr et al., 2003a; Rhanama et al., 2003).
Despite a plethora of fatigue related literature, an abundance of previous research relative to soccer has been focused on the effects of fatigue on physical performances, including repeated sprint ability and muscle force production (e.g. Appriantono et al., 2006; Balsom et al., 1992; Krstrup et al., 2006). Additionally, in spite of the acknowledged importance of fatigue in soccer, Lyons et al. (2006b) highlighted that ecologically sound studies investigating fatigue and its effects on soccer-specific skills are surprisingly rare.

Regardless of the paucity of studies within soccer, a number of investigations have focused on this aspect of performance within other team sports. Royal et al. (2006) observed a 43% ± 24% decrease in skill proficiency between pre-test and high-fatigue conditions in water polo. Additionally, Lyons et al. (2006a) reported a potential decrease in basketball passing accuracy following a short bout of high-intensity exercise.

While several investigations have assessed the effects of fatigue on the performance of soccer skills, several limitations are apparent. Studies have either utilised a very brief fatiguing protocol, where fatigue is localised and largely anaerobic in nature, and one which has not accurately replicated the physiological demands of match-play (Lyons et al., 2006b), or have utilised competitive match-play to induce fatigue, which causes large variability in the total work volume and intensity of exercise performed by players, and ultimately, the level of fatigue experienced (Rampinini et al., 2007a). McGregor et al. (1999) studied the effects of fluid ingestion on soccer-specific skills and observed a 5% deterioration in dribbling skill following a standardised 90 minute performance of the Loughborough Intermittent Shuttle Test.
(LIST), when no fluids were permitted. The study represents the limited volume of ecologically valid studies into the effects of prolonged soccer-specific exercise on soccer skill performance. However, the study provides no information on the impact of accumulated fatigue evident after the first half period on skill performance, as well as a neglect of its impact on essential soccer skills such as shooting (Lago, 2007).

1.2 Research Problem

Recognising limitations of current research, the study aims to examine the effect of accumulated fatigue, induced through the performance of a 45 minute intermittent high-intensity soccer-specific exercise protocol (Nicholas et al., 2000), simulating the physiological demands of one half of a soccer match, on the technical performance of shooting and dribbling skill. In addition, the study will relate to previous research with the aim of identifying whether the fatiguing protocol utilised, and the fatigue developed from its performance, influences sprint performance.

1.3 Null Hypotheses

The following hypotheses have been identified for the study:

\( H_{01} \): Sprint performance does not decrease during the 45 minute soccer-specific intermittent shuttle run test (LIST).

\( H_{02} \): The development of accumulated fatigue has no influence on the ability of players to perform the soccer-specific skills of shooting and dribbling, immediately post 45 minute soccer-specific shuttle run test (LIST).
CHAPTER II

REVIEW OF LITERATURE
2.1 Fatigue in Soccer

Fatigue is defined by McArdle et al. (1996, p.351) as “the decline in muscle tension capacity with repeated stimulation” (p. 351), whereas MacIntosh and Rassier (2002) present their definition which states that fatigue is; “a response that is less than the expected or anticipated contractile response, for a given stimulation” (p. 44).

Bangsbo et al. (2006) described that fatigue which occurs during soccer match-play is a multifaceted phenomenon, with many factors contributing to its cause. Fatigue or a reduction in performance was found to arise at different stages of a game: i) in the form of temporary fatigue which occurs during the game as a result of short periods of high-intensity exercise, ii) during the initial stages of the second half due to lower muscle temperatures compared to the first half (Mohr et al., 2004), and iii) towards the end of the game, resulting from repeated high-intensity or prolonged exercise (accumulated fatigue) (Mohr et al., 2005). However, Mohr et al. (2003a) inferred that it still remains unclear to what extent players experience fatigue during a competitive soccer game, Taylor et al. (2000) added that the determination of the onset of fatigue during a soccer match is especially difficult largely due to the random nature of play.
2.1.1 Mechanisms of Fatigue

The fundamental mechanisms of impaired performance due to fatigue caused by prolonged intermittent high-intensity exercise, still remain unclear. Bangsbo et al. (2006) highlighted that dehydration, hyperthermia and hypoglycaemia may contribute to the development of fatigue in the latter stages of a soccer game. However, such factors can be controlled to some extent using adequate hydration techniques (Guerra et al., 2004); the use of a high carbohydrate diet prior to (Balsom et al., 1999) or carbohydrate consumption during (Nicholas et al., 1995), soccer match-play.

Byrne et al. (2004) highlighted that muscle damage, in the form of intracellular muscle structure and sarcolemma disruption, resulting from repeated and prolonged eccentric contractions during exercise (Exercise Induced Muscle Damage), can lead to an immediate and prolonged reduction in muscle function. Additionally, Byrne et al. (2004) suggested that an impairment of the excitation-contraction coupling process, through a reduced rate of calcium release from the sarcoplasmic reticulum may also contribute to fatigue development, through a loss of maximal and sub-maximal force generation.

Meeusen et al. (2006) speculated that performance impairment may arise as a consequence of central fatigue, with alterations to central nervous system functions, leading to a reduction in motor unit recruitment, and thereby affecting the physical and mental efficiency of the athlete. Possible causes include the accumulation of ammonia and an imbalance in the serotonin – dopamine ratio, causing an altered
cerebral metabolism and a state of lethargy respectively (Meeusen et al., 2006). Rhanama et al. (2003) expressed that ultimately the causes of reduced soccer match performance, whether a central or a peripheral phenomena, cannot be determined from existing data.

2.1.2 The Effect of Fatigue on Performance

Research has shown that the development of fatigue has a significant detrimental effect on soccer performance. Mohr et al. (2003a) observed that a player’s ability to perform high-intensity exercise, including repeated sprints and jumping, is reduced towards the end of the game for the players who play 90 minutes, occurring in both elite and non-elite populations. Rhanama et al. (2003) also observed a reduction in work rate, measured from a reduction in total distance covered in the second 45 minutes of the game compared to the first.

Mohr et al. (2005) observed that players also experience temporary fatigue during a game, finding that performance was reduced in terms of the amount of high-intensity running performed in the 5 minute period immediately after the most intense 5 minute interval recorded during the game. This indicates that the anaerobic energy system is also highly strained during intense phases of a game. The causes of temporary fatigue are thought to include; the short-term depletion of muscle creatine phosphate, accumulation of H+ ions (Bangsbo et al., 2006) and the accumulation of potassium causing electrical impulse disturbances in the muscle (Bangsbo et al., 1996).
In relation to prolonged intermittent exercise, Appriantono et al. (2006) observed a significantly slower ball velocity in a fatigued condition as result of reduced lower leg swing speed and poorer ball contact. Bangsbo (1994) presented that the major cause of this reduced strength performance, is a consequence of a decrease in the number of muscle fibres that can be recruited, with fibres that have already been recruited starting to fail.

Additionally, Rhanama et al. (2003) revealed that there is a progressive reduction in muscle strength as a consequence of muscle fatigue, with significant declines towards the end of a 90 minute soccer-specific intermittent exercise bout. Appriantono et al. (2006) illustrated that it can therefore be assumed that induced leg muscle fatigue can disturb maximal kicking performance and can lead to a less co-ordinated kicking motion. Furthermore, such declines in strength may have repercussions on the ability of players to successfully perform skills, ultimately leading to more errors (Rhanama et al., 2003).

2.1.3 The Effect of Fatigue on Skill Performance

In soccer, investigations examining the effect of fatigue on performance have largely focused on the physical and metabolic consequences of fatigue development (Bangsbo et al., 2006; Drust et al., 2000; Krstrup et al., 2006). While there is evidence that match related fatigue may lead to a decline in physical performance during a match, Impellizzeri (2007) argued that there are few studies examining if there is a decrease in technical skill involvement between the first and second halves.
Lyons *et al.* (2006b) demonstrated that high intensity localised muscle fatigue has a detrimental effect on soccer passing skills, observing a 3.25% decrease in proficiency, thus highlighting the role of anaerobic fatigue on skill performance. However, the brief fatiguing protocol used gives no insight into the effects of the prolonged performance of high-intensity intermittent exercise on soccer skill proficiency. Additionally, the type and duration of fatigue experienced through the performance of split squats was not comparable to that which is experienced in a game situation.

Godik *et al.* (1993) investigated the changing of kicking accuracy of soccer players depending on the type, values, aims and competitive loads of training. The authors observed that when training consisted of mostly aerobic activities (HR < 150 beats/min), shooting accuracy was maintained in junior players. Conversely, when the training load was increased, consisting mostly of anaerobic activities (HR = 180 – 190 beats/min), shooting accuracy decreased, supporting the conclusions of Lyons *et al.* (2006b). Despite investigating the influence of both aerobic and anaerobic type fatigue on skill performance, the findings have limited scope due to the nature of soccer match-play causing both the aerobic and anaerobic systems to be highly taxed simultaneously and intermittently.

McGregor *et al.* (1999) investigated the influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. The authors observed that skill performance in the form of dribbling was reduced (5%) in the non-fluid ingesting trial, after the completion of a 90 minute Intermittent Shuttle Test (LIST). The investigation and findings reported by McGregor *et al.* (1999) represent
the small volume of data and the general consensus on the influence of prolonged soccer-specific exercise on skill performance, despite not targeting the matter directly. However, the study only assessed the skill of dribbling, neglecting skills such as passing, shooting and tackling, and the various forms that each skill encompasses, which Reilly and Holmes (1983) argued are essential for successful performance.

2.2 Physiological Assessment of Soccer Players

The assessment of multiple sprint sports such as soccer has allowed research to focus on the creation of activity profiles and the development of sport-specific fitness tests (Siegler et al., 2006). Indeed, such observations and assessments have provided a valuable insight regarding the physiological and metabolic demands of competitive soccer, with several investigations monitoring heart rate response (Van Gool et al., 1988), blood metabolite changes (Krstrup et al., 2006) and estimated energy expenditure and oxygen consumption (Nicholas et al., 2000). This again emphasises the neglect of attention paid to the impact of accumulated fatigue on motor control and the performance of soccer-specific skills.

The use of real match-play analysis to highlight physiological and metabolic demands of competitive soccer has been of enormous benefit to research (Van Gool et al., 1988); however, utilising such a method introduces significant limitations. Bangsbo et al. (1991) highlighted that the total distance a player covers and the intensity profile of a match is dependent upon several factors, including: i) the quality of the opponents, ii) tactical considerations, iii) the importance of the game,
and iv) the score-line. Such factors may have a considerable influence on whether players are using their full physiological capacity during the game and thus, the level of fatigue experienced. Consequently, Svensson and Drust (2005) detailed how several researchers have devised both controlled laboratory and field based protocols that attempt to replicate the activity patterns observed in multiple sprint sports.

2.2.1 Laboratory Based Physiological Assessment

Abt et al. (1998) constructed an intermittent treadmill exercise protocol, which required players to run a total distance of 11.16km at varying intensities, for a duration of 60 minutes and 45 seconds. The authors declared that the run was similar in nature, distance and intensities to that experienced by players throughout a match. However, the test has limited ecological validity, as the exercise duration is not comparable to the time period of a soccer match, representing neither a full 90 minutes nor a 45 minute half.

Drust et al. (2000) developed a laboratory based protocol that also entailed subjects performing an intermittent exercise on a motorised treadmill. The exercise intensities utilised were deemed to be representative of the alternating pattern observed during a soccer match, utilising speeds of 6, 12, and 15 km·hr\(^{-1}\) for walking, jogging and cruising respectively. Additionally, the protocol closely replicated soccer in terms of duration, lasting for 46:11 minutes (two bouts). The protocol was also found to elicit physiological responses that are consistent with soccer math-play research, including heart rate response (Krustrup et al., 2006) and minute ventilation (Van Gool et al., 1988).
However, the use of a motorised treadmill minimises acceleration and deceleration movements, which are associated with additional energy costs and a higher level of fatigue experienced (Reilly, 1997), while Marriott et al. (1993) added that the treadmill is unable to truly simulate the intermittent nature of soccer. Additionally, Stolen et al. (2005) described that this change of pace is a critical skill within soccer; consequently, the neglect of such actions reduces the ecological validity of the protocols. Also, despite laboratory based protocols presenting a controlled environment, access to such facilities may be difficult for many soccer clubs, being both time consuming and expensive (Svensson & Drust, 2005).

2.2.2 Field Based Physiological Assessment

The use of field based protocols has become widespread due to a greater specificity and consequently greater ecological validity than laboratory testing. (Svensson & Drust, 2005). Rampinini et al. (2007b) developed a battery of field tests to examine indicators of match related physical performance in top level professional soccer players, consisting of a vertical jump test, a progressive running field test (300m) and a 40m repeated sprint ability test. Additionally, Wragg et al. (2000) developed a soccer-specific field test that examined the repeated sprint ability of soccer players and reported high reliability coefficients. However, despite such tests isolating individual components of match related performance they have a significant limitation in terms of ecological validity, with neither test representing the demands experienced during a competitive soccer match.
Nicholas *et al.* (1995) developed the prolonged intermittent, high intensity shuttle running test (PIHSRT), which consisted of fixed bouts of variable intensity running, followed by a combination of high and low speed intermittent running until volitional fatigue. Comparable to the PIHSRT, Nicholas *et al.* (2000) constructed a controlled, ‘free running’ field procedure known as the Loughborough Intermittent Shuttle Test (LIST), which simulates activity patterns common in soccer and is comparable to lab based protocols (Drust *et al.*, 2000).

The LIST involved participants running between two lines placed 20m apart, with the running speed being determined by using a percentage of the individuals VO$_2$ max. Lasting for a sub-total of 15 minutes, the protocol was repeated 5 times with 3 minutes recovery between each period, followed by a period of open-ended intermittent shuttle running designed to fatigue participants within 10 minutes.

In addition to the time period of exercise being comparable to the duration of soccer match-play, the activity pattern of the LIST was found to elicit physiological and metabolic responses similar to those observed during soccer (Nicholas *et al.*, 2000). These included the mean total distance covered by a player (Bangsbo *et al.*, 1991), heart rate response to exercise (Bangsbo, 1994) and blood lactate levels (Krstrup *et al.*, 2006; Smith *et al.*, 1993). Additionally, the activity profile of the LIST, in terms of time spent at each exercise intensity, is consistent with the activity patterns and intensities exhibited during a soccer match (Reilly and Thomas, 1976). Therefore, the LIST test details how it is possible to control the workload with a valid protocol as opposed to using an actual match, in addition to maintaining movement actions of...
soccer including sprinting, acceleration, deceleration and turning, that are not possible when utilising lab protocols (treadmill running).

Rienzi et al. (2000) argued that the LIST requires players to work for longer periods of time at moderate and high intensity activities, identifying that cruising and sprinting only constitute to 4% of the exercise pattern observed rather than the 22.3% illustrated by Nicholas et al. (2000). A significant limitation of the LIST is that it omits the utility movements of soccer, including jumping, backwards and sideways running and the performance of game skills. Such a factor has implications on the physiological and metabolic responses that occur (Nicholas et al., 2000), with Drust et al. (2000) identifying that the LIST may have a reduced energy demand. However, the inclusion of these movements would make the assessment of the physiological responses to soccer considerably more difficult under controlled conditions (Drust et al., 2000).

Due to its significant ecological validity the LIST has been implemented in a wide range of studies (Table 1 and 2). Several investigations have not utilised the LIST as a test of fitness or the physical performance of soccer players, instead researchers have chosen to utilise it as a method to induce a fatigued state similar to that which is evident after the first half or at the end of a soccer match (Table 2). The LIST has been adapted in numerous ways including a reduction in the number of 15-minute activity blocks used as well as the use of non-individualised walking, jogging and cruising speeds (Edwards et al., 2003). Such modifications reduce the overall testing time as a result of the investigators being able to test multiple participants within one
testing session, whilst having a greater applicability for coaches and trainers at the non-elite level (Seigler et al., 2006).
<table>
<thead>
<tr>
<th>Study</th>
<th>Focus Area</th>
<th>Protocol Adaptations</th>
<th>Sprint Performance</th>
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<tr>
<td></td>
<td></td>
<td>- Non – individualised running speeds</td>
<td></td>
</tr>
<tr>
<td>Edwards, Macfadyen and Clark (2003)</td>
<td>Test performance indicators from a single soccer-specific fitness test differentiate between highly trained and recreationally active soccer players</td>
<td>Part A:</td>
<td>20m sprint performance was reduced as the exercise progressed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- VO₂max estimation using PSRT to determine running speeds</td>
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<td>- Non-individualised running speeds</td>
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<td>- Reduction in the number of activity blocks (3)</td>
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<tr>
<td>Siegler, Gaskill, and Ruby (2003)</td>
<td>Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training protocol.</td>
<td>Part A:</td>
<td>Not Reported</td>
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<tr>
<td></td>
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<td>- Reduction in the number of activity blocks (3)</td>
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**PSRT** – Progressive Shuttle Run Test.
### Table 2. Investigations utilising the Loughborough Intermittent Shuttle Test as a fatiguing protocol

<table>
<thead>
<tr>
<th>Study</th>
<th>Focus Area</th>
<th>Protocol Adaptations</th>
<th>Sprint Performance</th>
</tr>
</thead>
</table>
| McGregor, Nicholas, Lakomy and Williams (1999) | The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill | Part A:  
- VO\(_2\)\text{max} estimation using PSRT to determine running speeds  
- Increase in number of activity blocks (6) | 15m sprint performance was reduced as the exercise progressed |
| Morris, Nevill, Thompson, Collie & Williams (2003) | The influence of a 6.5% carbohydrate-electrolyte solution on performance of a prolonged intermittent high-intensity running at 30\(^\circ\)C | Part A:  
- 4 min rest period between 15 minute exercise blocks  
- VO\(_2\)\text{max} estimation using MSRT to determine running speeds  
Part B:  
- 60 s sprinting followed by 60s rest until volitional exhaustion | 15m sprint performance was reduced as the exercise progressed especially in the 3\textsuperscript{rd} 15 minute activity block |
| Sunderland and Nevill (2005) | High-intensity intermittent running and field hockey skill performance in the heat | Part A:  
- Increase in number of activity blocks (6+) | Not reported |
| Morris, Nevill, Boobis, Macdonald, & Williams (2005) | Muscle metabolism, temperature, and function during prolonged, intermittent, high-Intensity running in air temperatures of 33\(^\circ\)C and 17\(^\circ\)C | Part A:  
- VO\(_2\)\text{max} estimation using PSRT to determine running speeds  
- Activity blocks repeated until volitional exhaustion | 15m sprint time increased as exercise progressed |

**MSRT** - Multi-stage Shuttle Run Test  
**PSRT** – Progressive Shuttle Run Test.
2.3 Skill Assessment in Soccer

All sports require the application of skill in one form or another, while team games such as soccer demand a combination of skills including cognitive, intellectual, perceptual and motor orientated skills (Davies, 1998), being performed simultaneously in a rapidly changing environment (Bate, 1996). Davis et al. (2005) described how the concept of and the term skill is defined in several ways, depending on what sporting element it has been used in conjunction with. However, Knapp (1977, cited in Davis et al., 2005) provided the following definition of skill which is particularly useful for the current study and highlights the characteristics of a skilled performance: “Skill is the learned ability to bring about pre-determined results with maximum certainty, often with minimum outlay of time or energy or both” (p. 280).

Reilly & Holmes (1983) explained the significance of acquiring skill, and describe how physiological attributes such as endurance, anaerobic power and muscular strength are insufficient to lead to a successful performance in elite level soccer, unless allied to and co-ordinated with fundamental soccer skills. Additionally, a superior skill level can often compensate for deficiencies in physical performance through a dictation of the pace and strategy of play (Reilly & Holmes, 1983). Ultimately, at elite level, skill in the ability to execute a successful pass, dribble with pace and control, or shoot at goal with accuracy, will determine the outcome of a game (Godik et al., 1993; Hughes & Bartlett, 2002).
Ali et al. (2007a) described that although there are some closed skills during soccer (set-pieces), the majority of play involves open skill. Soccer demands a range of basic open skills, including, trapping, dribbling, controlling and passing the ball (McGregor et al., 2007). Additionally, while soccer involves a multiplicity of skills, Reilly & Holmes (1983) described that the most frequently utilised actions of passing, dribbling and controlling are the fundamental skills that are essential for retaining possession and are precursors for the completion of a skilled performance, regardless of playing position or skill level. Additionally, the action of shooting is considered to be an even more crucial skill, with Ali et al. (2007a) highlighting that the fundamental principle of soccer is to score more goals than the opposing team.

The value of these fundamental soccer skills is highlighted by their inclusion within the discipline of talent identification. Reilly et al. (2000) utilised tests for passing, shooting, controlling and dribbling which had previously been identified by Reilly and Holmes (1983) as principal components in the assessment of skilled play. Reilly et al. (2000) observed that the dribbling test was able to discriminate between players of varying ability, with elite players performing significantly better than non-elite players. Additionally, the shooting test was able to differentiate between skill levels, but predictably only in strikers (Reilly et al., 2000). Finally, Vaeyens et al. (2006) reported that dribbling and shooting skills were two of the most discriminating factors when comparing elite and non-elite players.
Tests that provide data concerning the current skill level of players have many performance related advantages with Bangsbo (1994) suggesting that skills tests are relevant and resemble the conditions during a match. Van Rossum and Wijbenga (1993) described the following values that measuring aspects of soccer technique may have:

- Provides objective feedback about present performance levels of players and with repeated administration detail performance changes
- Indicates any strengths and weaknesses of players
- Allows the setting of goals for the refinement of specific practices
- Stimulates or motivates players (intra-individual and inter-individual competitiveness)
- To study the effect of a training programme

The assessment of soccer-specific skills such as passing, shooting and dribbling has largely been hindered by the lack of research into the area of soccer skill performance, more specifically, this has resulted in a lack of valid and reliable skills tests. Furthermore, Ali et al. (2007a) expressed that while several skills tests that are specific to soccer have been developed in research, many have yet to be validated and consequently have limited applicability as research tools. An additional and significant problem that contributes to this lack of developmental research is the difficulty in assessing skill performance in a reliable way (McGregor et al., 2007).
Davies (1998) illustrated that many researchers have attempted to devise tests that can assess a player’s skill level in soccer. However, of the numerous early studies, such as that proposed by Zelenka et al. (1967) and Kuhn (1978), most were “unacceptable from a scientific point of view, as there was no information about their objectivity, reliability and validity” (Van Rossum and Wijbenga, 1993, p. 313) (Table 3).
Table 3. Examples of early Soccer-Specific Skills tests that did not report reliability and validity values

<table>
<thead>
<tr>
<th>Authors</th>
<th>Test</th>
<th>Protocol</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| Zelenka et al. (1967) | Specific Function Test | Participants negotiate an obstacle course consisting of dribbling and shooting tasks | - Inclusion of athletic obstacles is irrelevant to soccer match play (Ali et al., 2007a)  
- No Control group |
| Khun (1978, In. Van Rossum and Wijbenga, 1993) | Soccer Specific skills tests | Participants completed the following tests:  
- Goal Kicking for Accuracy  
- Passing for Accuracy (30 and 40m)  
- Slalom Dribbling  
- Juggling  
- Circuit task – dribbling and a goal kick | - Goal Kicking for Accuracy – Adaptation required  
- Passing for Accuracy – too easy  
- Slalom Dribbling – too easy  
- Circuit task – measures technique and fitness (should be abandoned) (Van Rossum and Wijbenga, 1993) |
Only a few early studies (Reilly and Holmes, 1983; Van Rossum and Wijbenga, 1993) obtained preliminary data regarding the validity and reliability of soccer skills tests (Table 4). Van Rossum and Wijbenga (1993) assessed Kuhn’s (1978) soccer-specific test and reported that it had had several drawbacks (Table 3). Subsequently, Van Rossum and Wijbenga (1993) developed an adapted version of Kuhn’s (1978) protocol (Table 4) and concluded the soccer skills tests were now able to indicate proficiency of fundamental soccer techniques, discriminating between players within a team, between teams and at different age levels. Conversely, the established reliability and validity values for the shooting and dribbling tests developed by Reilly and Holmes (1983) (Table 4), have lead to them being used successfully as part of a multi-dimensional model in the field of talent identification (Vayens et al., 2006; Reilly et al., 2000).
<table>
<thead>
<tr>
<th>Authors</th>
<th>Test</th>
<th>Protocol</th>
<th>Reliability</th>
<th>Validity</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reilly and Holmes (1983)</td>
<td>Slalom Dribble Test</td>
<td>Participants negotiate a set obstacle course in a zig-zag fashion with completion time representing skill proficiency</td>
<td>$r = 0.95$</td>
<td>$r = 0.60 – 0.70$</td>
<td>None Identified</td>
</tr>
<tr>
<td>Reilly and Holmes (1983)</td>
<td>Shooting Test</td>
<td>Participants shoot at a soccer goal that was separated into various scoring zones, from a stationary position.</td>
<td>$r = 0.81$</td>
<td>$r = 0.60 – 0.70$</td>
<td>Passing or shooting from a static position could make the test an execution of technique rather than skill (Ali et al., 2007a)</td>
</tr>
</tbody>
</table>
| Van Rossum and Wijbenga (1993) | Adapted version of Khun’s (1978) test battery | Participants completed the following tests:  
- Ground Passing for Accuracy  
- Air Passing for Accuracy  
- Slalom Dribbling  
- Ball Juggling | $r = 0.62 – 0.88$ | Not Reported | Passing Accuracy Tests - Passing or shooting from a static position could make the test an execution of technique rather than skill. (Ali et al., 2007a) |
| Ali et al. (2007a)           | Loughborough Soccer Passing Test (LSPT) | Requires participants to complete 16 passes as quickly as possible, with time penalties for inaccurate passes | $r = 0.65 – 0.83$ | High logical, construct and ecological validity | None Identified                                                              |
| Ali et al. (2007a)           | Loughborough Soccer Shooting Test (LSST) | Requires participants to pass, control and shoot the ball to targets on a full sized goal | $r = 0.51 – 0.68$ | High logical, construct and ecological validity | High ecological validity (use of speed check radar to measure shot speed and real size plywood goalkeeper) may reduced repeatability of test (Ali et al., 2007a) |
Bosco and Gustafson (1983) argued that such skills tests may be high in reliability, but they do not accurately reflect skill in a real game scenario. Davies (1998) added by expressing that although the execution of a soccer skill such as passing, dribbling or shooting is part of a skilled performance, it is the player’s ability to make accurate and correct decisions about the timing, force and direction of the action, as determined by the demands of the situation, that determines their level of skill and the achievement of a successful performance. However, this is very difficult to mimic within a standard testing protocol due to the numerous external factors that contribute to successful and accurate decision making for skill performance during a soccer match (Elferink-Gemser et al., 2004; Williams, 2000).

Furthermore, Ali et al. (2007a) argued that tests which involve a subject performing an action from a static position such as that required in tests devised by several researchers (Reilly & Holmes, 1983; Zelenka et al., 1967), is actually an assessment of “technique” rather than “skill”. Ali et al. (2007a) continued by identifying that; “The specific feature of a skilled movement is where the player has a learned ability to select and perform the correct technique as determined by the demands of the situation” (p.1470). Subsequently, Ali et al. (2007a) devised skills tests that assess the multi-faceted aspects of soccer skill, namely the Loughborough Soccer Passing Test (LSPT) and the Loughborough Soccer Shooting Test (LSST) (Table 4). Ali et al. (2007a) concluded that both tests were reliable methods of assessing soccer skill performance (Table 3). The tests displayed good ecological validity (Lyons et al., 2006b); in addition to elite players performing significantly better than non-elite players during the LSPT, and a general trend (non significant) for elite players to
perform better than non elite during the LSST, which supports the construct validity of the tests.
CHAPTER III

METHOD
3.1 Participants

The study was conducted with 9 male semi-professional soccer players (age 20.7 ± 1.4 years, stature 177.7 ± 6.1 cm, body mass 73.5.1 ± 7.6 kg), playing in the MacWhirter Welsh Division 2 League for UWIC Football club. The participants were from a range of outfield playing positions and were involved in regular training and match-play. Goalkeepers were not included in the study as the testing carried out was not specific to their role in a game. All players voluntarily participated in the study and gave informed consent (Appendix A), being notified of the nature and demands of the study as well as their right to withdraw at any time (Appendix B). Participants also completed health questionnaires in order to ascertain their current health status (Appendix C).

3.2 Experimental Design

All testing was completed at the National Indoor Athletic Centre (NIAC) at the University of Wales Institute, Cardiff (UWIC), or, on the adjacent Astroturf soccer pitch. The experimental design required all participants to complete a slalom dribble test (Reilly & Holmes, 1983) and the Loughborough Soccer Shooting Test (LSST, Ali et al., 2007a) prior to and after the performance of the Loughborough Intermittent Shuttle Test (LIST, Nicholas et al., 2000).
3.3 Skill Assessment

3.3.1 General Apparatus

All soccer balls utilised during both the shooting and dribbling assessments were FIFA approved ERREA (Size 5) Garra match balls.

3.3.2 Slalom dribble

The slalom dribble test (Reilly & Holmes, 1983) assesses total body movement, requiring participants to dribble around a set obstacle course as quickly as possible, plastic cones were used as the obstacles (Figure 1). Two parallel lines were initially drawn as reference guides 4.57m apart with intervals of 1.83m being marked along each line. Diagonal connections of alternate marks measuring 4.88m in length were then made, with five cones being placed at the end of each connection and a sixth being placed 7.32m from the final cone and 9.14m from the starting line. On the starters command the subjects dribbled the ball from behind the start line to the right of the first cone and then alternately around the outside of the remaining 5 cones in a zig-zag path. The subject stopped and left the ball at the sixth cone before travelling in a straight line across the finish line (Figure 1).

The subjects were accustomed to the course prior to testing, first through a demonstration by the tester and secondly through the performance of 2 trial runs. The time taken to negotiate the obstacle course was measured and recorded using **Smart Speed timing** gates (Fusion Sport, Brisbane, Australia). The subjects were required to perform the slalom dribble twice, with a rest of 1 minute between trails, with the mean time of both trails representing the subjects’ score.
Figure 1. A schematic representation of the slalom dribble test

(Reilly and Holmes, 1983)
3.3.3 Loughborough Soccer Shooting Test

Shooting accuracy was assessed using the Loughborough Soccer Shooting Test (Ali et al., 2007a). All boundary lines of test were marked on the floor using 5 cm grey tape. A square “shooting zone” measuring 8.5 x 8.5m was marked with the nearest line being 16.5m from the goal line. Four standard cones were placed on each corner of the shooting zone and a standard gymnasium bench was placed on the middle of the far side of the zone to act as a rebound board (Figure 2).
Figure 2. A schematic representation of the Loughborough Soccer Shooting Test

(Ali et al., 2007a)
3.3.3.1 The Goal

A full size soccer goal measuring 2.44 x 7.32m was split into various scoring zones and was marked using 5cm grey tape and luminous orange rope measuring 1cm in diameter (Figure 2). The study did not utilise the life-size goalkeeper made of plywood and the SpeedChek sports radar to measure shot speed as detailed by Ali et al. (2007a). Ali et al. (2007a) argue that the use of the static goalkeeper enhances ecological validity; consequently the method utilised in the present study may lack the advantages of its use. However, the authors do acknowledge that introducing high ecological validity could have reduced the reliability of the test. Furthermore, the authors reported a low correlation ($r = 0.36$) between shot speed and points scored suggesting that there is no relationship between shot speed and shooting accuracy and that the two factors are independent, negating the use of measuring shot speed.

3.3.3.2 Role of the Investigators

Two investigators were used during the test and were located at positions “A” and “B” in Figure 2. The role of investigator A was to initially instruct the player to move to either the left or the right cone and then to ensure that the shot was taken within the marked shooting area. Secondly investigator A had to observe the shot to determine the points scored, in addition to recording all relevant information. The role of Investigator B was to time the movement of the player from the initial call from investigator A to the time when they passed the finish line.
3.3.3.3 Procedure for the LSST

The test began with the ball being placed on the marked circle located in the centre of the shooting zone. The participant’s initial position was to stand facing away from goal towards the bench, within playing distance of the ball. After the call of investigator A, the player was required to sprint to the cone he had been directed to move to, touch the top of it, and then return to the ball in the centre of the square. After playing a rebound pass off the bench, the player then controlled the ball if necessary, turned, and shot at the goal within the shooting area. The player was required to follow the shot by sprinting between two cones positioned 5.5m away from and directly in front of the goal. Each participant performed a single trail consisting of 10 shots, with a rest period of 30 seconds between each shot sequence. There were 10 trial orders that were randomly selected for each player.

3.3.3.4 Scoring the LSST

The scoring areas marked out within the goal reflect the optimal placement of a shot to beat an opposing keeper (Ali et al., 2007a). Ali et al. (2007a) identified that a player with a greater shooting ability will be able to shoot with either foot; therefore, of the 10 shots being performed for each trial, five were performed using the right foot and five with the left. The performance score achieved was the total cumulative points scored from all the shots on target. Any shots that were taken from outside the designated shooting zone or took more than 8.5 seconds to complete were discounted. The time taken to complete each shot sequence was measured using a Casio Digital stopwatch (HS-30W-1V, Casio Electronics Co, Ltd, London, UK). The score
achieved for each shot sequence was recorded manually using a LSST score sheet (Appendix D).

### 3.4 Fatiguing Protocol

All participants performed a modified version of part A of the LIST (Nicholas et al., 2000) as used previously by Edwards et al. (2003), in NIAC at UWIC, under standard environmental conditions. Participants were required to run between two lines, 20m apart, at various speeds. The running and walking speeds during each 20m of the test were dictated by a combination of a verbal countdown to an audio signal (to assist pace judgment), pre-recorded onto a compact disc. The speeds used to represent walking; jogging and cruising were not individualised (Edwards et al., 2003) and were not based on percentage estimates of preliminary participant Vo2max measurements (Drust et al., 2000).

The speeds chosen for each activity pattern were comparable to those used by Drust et al. (2000) and were as follows: walking 5 km·h⁻¹, jogging 9 km·h⁻¹, cruising 14 km·h⁻¹ with sprinting being the maximal running speed of each participant. Activity speeds were based upon the speeds observed by Van Gool et al. (1988) for each specific movement type during soccer match-play. Edawrds et al. (2003) illustrate that this protocol reflects the different application of the procedure as a single and automated soccer-specific fitness test for multiple testing at one time (Edawrds et al., 2003). 15m sprint times performed during the LIST were measured and recorded in one direction using Smart Speed timing gates (Fusion Sport, Brisbane, Australia).
The exercise protocol utilised consisted of 15 minute activity blocks. The activity blocks were identical to the model used by Nicholas et al. (2000) and consisted of a set pattern of intermittent running and walking. The pattern of exercise was intermittent high (sprint and cruise) and low (jog and walk) intensity activity, with the sequence being as follows:

- 3 x 20m at a walking pace of 5 km·h⁻¹
- 1 x 15m at maximal running speed
- 4s recovery
- 3 x 20m at a running speed of 9 km·h⁻¹
- 3 x 20m at a running speed of 14 km·h⁻¹

This pattern of exercise, lasting for 90 seconds, was repeated ten times forming a 15 minute block which was then followed by a rest period of 3 minutes. Although the activity blocks consisted of a set pattern identical to the model used by Nicholas et al. (2000), the number of identical activity blocks was reduced from 5 to 3 to represent the first half of a soccer match (Drust et al., 2000; Edawrds et al., 2003). The 4 second recovery period that followed the maximal sprint activity was used to accommodate for the variations in maximal running speed. Backwards and sideways movements and actions with the ball were not included in the study because of the technical impracticalities when using the LIST (Drust et al., 2000).
Figure 3. A schematic representation of the activity pattern performed during the Loughborough Intermittent Shuttle Test (Edwards et al., 2003)

3.5 Experimental Protocol

The participants visited the testing site on two separate occasions, participating in two testing sessions. Two days prior to the first testing session, each player was given pre-test instructions for diet, exercise and clothing for both testing sessions, to ensure participants could exercise maximally and safely.

3.5.1 Preliminary Measurements and Familiarisation

Preliminary data was obtained with all participants reporting to NIAC at UWIC for the first session of testing. The session required participants to firstly complete the slalom dribble test (Reilly & Holmes, 1983) followed by the LSST (Ali et al., 2007a). A standardised warm-up, consisting of jogging, stretching and striding, was performed by each participant for 15 minutes. Prior to each skills test participants
were given an opportunity to accustom themselves to the protocols. Participants performed two trials of the slalom dribble test and one trial of the Loughborough Soccer Shooting Test. The participants then performed the LIST test (Nicholas et al., 2000) for 15 minutes in order to familiarise themselves with the required running speeds and experimental procedures.

3.5.2 Main Trial

All participants then performed the second test session; however, due to time and facility constraints they did so on different occasions in groups of three. Three of the nine participants were randomly selected to report to NIAC at UWIC for the second testing session. Prior to testing, participants were asked to abstain from consuming large amounts of beverages or food. All experiments were arranged so that each individual performed the skills tests at the same time of day to control for circadian influences (Sunderland and Nevill, 2005). Height was measured without shoes to the nearest 0.1cm at a mid inspiration using a fixed stadiometer (Holtain, LTD, Crymych, Pembrokeshire, Wales, UK). Body mass was measured to the nearest 0.1kg, in light athletic apparel and without shoes, on a Seca digital electronic scale (Model 770, SECA, Vogel & Halke, Hamburg, Germany). A standardised warm-up, consisting of jogging, stretching and striding, was then performed by each participant for 15 minutes.
Participants then performed 45 minutes (three 15 minute activity blocks) of the LIST. During each trial the investigators ensured that the participants performed the exercise correctly by placing at least one foot on or over the lines marking the 20m distance. During the LIST protocol and soccer skills tests, participants were verbally encouraged to perform maximally. Directly after the LIST had finished, participants repeated both the slalom dribble test and the LSST. Heart rates were monitored and recorded throughout the performance of the LIST using Polar heart rate monitors (Polar Electro Oy, Pfressorintie 5, Finland). A standardised 10 minute cool-down followed the testing sessions.

3.6 Statistical Analysis

One-way repeated measures ANOVA’s were used to analyse mean 15m sprint times and heart rates during the 45 minutes LIST exercise. Post-hoc Bonferroni tests were performed to identify where any differences that were found lay. The assumption of sphericity was explored in order to ensure that the repeated measures demonstrated homogeneity of variance. Paired sample t – tests were used to analyse the data obtained from the soccer-specific skills tests performed pre and post LIST. A comparison was also made between LSST trials, with any points excluded as consequence of not achieving performance time criteria being included for pre and post LIST trials.
A comparison was then made between the frequencies (pre and post LIST) with which players scored 5, 3, 2 and 1 points during the LSST trials. However, the statistics needed to analyse the differences in these frequencies is beyond the scope of the current study and requires complex statistical procedures with;

“Variables representing proportions or frequencies requiring root or arcsine-root transformation before you give them the usual repeated-measures analysis. The more exact approach is to use binomial or Poisson regression” (Hopkins, 1997).

All data are presented as the mean ± standard deviation (SD) from the mean and are based on a sample of nine participants unless otherwise stated. The significance level was set at $P < 0.05$. All statistical analysis was calculated using SPSS 12.0, with graphical data being calculated using Microsoft Excel and SPSS 12.0.
CHAPTER IV

RESULTS
4.1 Heart Rate

The mean heart rates achieved during the performance of the first, second and third activity bouts of the LIST were 155 ± 11 bpm, 155 ± 13 bpm and 156 ± 12 bpm, respectively, corresponding to 78.0 ± 5.3%, 77.7 ± 6.4% and 78.2 ± 6.1% of predicted maximum heart rate. The mean heart rate response over the three activity bouts for the nine participants was averaged at 5 second intervals and is shown in figure 4. A one-way repeated measures ANOVA reported that the average heart rates for the nine participants was not significantly different between the first, second and third activity bouts of the LIST ($P > 0.05$).
Figure 4. A trace of the mean heart rate response for all participants during the performance of the first, second and third activity bouts of the LIST.
4.2 Sprint Performance

Mean sprint times for each LIST bout was calculated using the mean of the 10 sprint times recorded for each participant. The mean 15m sprint times for the first, second and last 15 minute activity bouts were 2.54 ± 0.15 s, 2.56 ± 0.14 s and 2.58 ± 0.14 s, respectively. Despite a visual analysis of the mean times taken to complete the 15m sprint suggesting a slight increase in sprint times, a comparison of the three exercise bouts revealed that there was no significant difference in sprint performance as exercise progressed (P > 0.05). In addition, there was no trend for sprint times to differ during each bout of activity (Figure 5).
Figure 5. Average time taken to complete the 15-m sprints for all participants during the performance of the three Loughborough Intermittent Shuttle Test activity bouts.
4.3 Skill Performance

4.3.1 Slalom Dribbling Times

A comparison of mean dribbling skill performance time’s recorded pre and post exercise, showed that there was a significant increase in the time taken to complete the slalom dribble test following the performance of the three 15-minute LIST activity bouts ($P < 0.05$). The results of the paired t-test substantiate the claim that there is a significant decline in dribbling skill performance (4.2 ± 3.6%) as a consequence of the 45 minute LIST performance. Figure 6 presents the means and standard deviations for the slalom dribble times performed pre-and-post LIST.

![Figure 6. Mean Slalom Dribble performance times from pre-LIST and post-LIST trials](image-url)
4.3.2 Loughborough Soccer Shooting Test Scores

An examination of descriptive data indicates that the mean point scores of the participants for pre and post LIST Loughborough Soccer Shooting test trials were 20.56 ± 6.7 points and 13 ± 3.0 points, respectively (Figure 7). A statistical analysis of the LSST trials revealed that there was a significant decrease (31.61 ± 25.21%) in mean points scored following the performance of the LIST ($P < 0.05$).

![Figure 7. Mean points scored for the Loughborough Soccer Shooting Test completed pre- and-post LIST performance](image-url)
Further analysis of the pre and post exercise LSST trials was then performed with the inclusion of any points that were excluded from an individual’s total scores (achieved for pre and post LIST trials), as a consequence of not achieving the 8.5 second performance criteria for a specific shot sequence. No significant difference was observed between the mean points scored for the pre and post LSST trials despite a mean decrease of 18.67 ± 24.71% for total points scored ($P > 0.05$, Figure 8).

![Image of bar chart showing mean points scored for pre- and post LIST performance.](image)

**Figure 8.** Mean Loughborough Soccer Shooting Test point scores for pre- and-post LIST performance, with the inclusion of points omitted as a consequence of not achieving the 8.5s performance criteria
An additional comparison was also made between the frequencies with which the participants scored points from each scoring zone, with the means and standard deviations being presented in table 5. Such a comparison was performed with a view that the number of high scoring shots (5 and 3 points) may have decreased as consequence of performing the 45 minute LIST, providing additional evidence to verify the reduction in shooting accuracy. An examination of the descriptive data reveals a 47.4% reduction in the number of shots that achieved a five point’s score and a 71.4% decrease in the number of shots that achieved a three point’s score during the LSST from pre-to-post LIST performances. Such a large decrease in the number of 5 and 3 point scores achieved may further emphasise the influence of accumulated fatigue on soccer shooting skill performance.

Table 5. Mean frequency of point score locations during the LSST, pre and post LIST performance

<table>
<thead>
<tr>
<th>Points Score</th>
<th>Pre LIST</th>
<th>Post LIST</th>
<th>Percentage Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>21</td>
<td>9.6</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>20</td>
<td>-20.1</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>2</td>
<td>-71.4</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>10</td>
<td>-47.4</td>
</tr>
</tbody>
</table>
CHAPTER V

DISCUSSION
5.1 Introduction

To date the effect of fatigue developed during the first half of a soccer match on skill performance has not been examined. However, the major finding in the present study that 45 minutes of intermittent high-intensity shuttle running (LIST) resulted in significant decreases in both soccer dribbling and shooting skill performance may go some way to rectifying the paucity of research in this area. The following text initially discusses the physiological responses of the individuals to the LIST, before examining the major findings of the study and identifying possible mechanisms for its cause. Following this, practical implications of the findings and limitations of the study are then identified.

5.2 Hear Rate and Distance Covered

The total distance covered during the 45 minute LIST (6,000m) is comparable with those previously reported during the first half of competitive soccer match-play (Reilly & Thomas, 1976; Bangsbo et al., 1991; Mohr et al., 2003a). Conversely, the mean heart rates during the LIST activity bouts are considerably lower than those reported during competitive soccer match-play (Bangsbo, 1994; Van Gool et al., 1988) and similar studies using the LIST on comparable populations (Edwards et al., 2003). However, they are within the range of mean values (143 – 185 beats·min⁻¹) reported by Ali and Farally (1991). The lower mean heart rates may imply that the fatiguing protocol was not sufficiently demanding in order to replicate the physiological responses observed in a soccer match, although, the exercise intensities
used in the current study are comparable to those used in a similar protocol by Drust, *et al.* (2000).

### 5.3 Repeated Sprint Performance

Sprint performance across the three activity bouts of the LIST exercise in the present study remained unchanged (*P* >0.05), allowing the acceptance of Hypothesis H₀₁. The maintenance of sprint performance during the LIST is consistent with the findings reported by Edwards *et al.* (2003), who observed that 20m sprint times remained unchanged across three LIST activity bouts, for both academy scholars (n = 13) and recreational players (n = 10). Additionally, McGregor *et al.* (1999) reported that 15m sprint performance had been maintained through the performance of first three LIST activity bouts, using semi-professional soccer players (n = 9). Finally, despite sprint performance being significantly reduced after intense periods of play, sprint performance was found to be recovered at the end of the first half during competitive match-play (Mohr *et al.*, 2005).

Oliver *et al.* (2008) described that the ability of the participants to maintain sprint performance during the intermittent exercise test implies the absence of fatigue. However, it is likely that participants would have an altered sprint mechanics as the LIST progressed in order to maintain sprint performance (Oliver *et al.*, 2008). This has also been highlighted by Ratel *et al.* (2006) who reported that despite reductions in mean power and force output, 13 male adults were able to maintain 10 second repeated sprint performance (interspersed by 3 minute recovery bouts), through a reduced stride rate and an increased stride length during later sprints. The
maintenance of sprint performance in the present study may therefore be a consequence of an altered sprint mechanics, demonstrated through a reduced stride rate and an increased stride length.

5.4 Soccer Skill Performance

The major findings of the present study was that prolonged intermittent high-intensity shuttle running, through the performance of the 45 minute LIST, resulted in a significant decrease in both soccer dribbling (4.2 ± 3.6 %) and shooting (31.61 ± 25.21%) skill performance ($P < 0.05$). Thus, hypothesis $H_02$ can be rejected. During the performance of the LSST it must be noted that any shots not performed within the time limit were not added to the total performance score. However, if all scoring shots, regardless of time taken, were included in the score total, the decrease in shot accuracy would be considerably less (18.67 ± 24.71%, Figure 8). Thus, Ali et al. (2007b) described that participants sacrificed speed of movement in order to maintain accuracy, which is known as the speed-accuracy trade-off. Ali et al. (2007b) continue by suggesting that its occurrence is a consequence of gross motor aspects of sprinting and force development being compromised. It is also of note that should the shot performance criteria be ignored, no significant difference would have been observed between the pre and post exercise LSST trials.

The relative lack of published information on fatigue development and skill performance during soccer, in particular after the first half period, makes an extensive comparison between findings of the current study with other studies very difficult. However, in support of the current findings, McGregor et al. (1999)
observed a 5% decrease in soccer dribbling skill performance within a non-fluid ingesting trial, following the performance of six LIST activity bouts, representing full match duration. Additionally, Ali et al. (2007b) reported a significant decrease in soccer shooting skill performance again following a 90 minute performance of the LIST, for the placebo trial. However a greater comparison can be made with, as well as provide support for the findings of Rampinini et al. (2007a) who observed a significant decrease in skill performance between the first and second halves of competitive soccer match-play. Consequently, these findings suggest there is a potential decrement in a player’s technical proficiency for successfully completing soccer skills as a consequence of match-related fatigue, developed during the first half period.

5.5 Mechanisms of Fatigue

Lyons et al. (2006b) described that attempting to ascertain the underlying mechanisms for the reduced skill performance is difficult, while the “identification of a definitive mechanism appears unrealistic”. In spite of this, an abundance of research has speculated on primary mechanisms of fatigue and its influence on skill performance.

Jordet et al. (2007) advocated that glycogen depletion of individual muscle fibres appears to be the most logical explanation for this phenomenon, which is supported by the frequent association made in research (Bangsbo et al., 1992; Bangsbo et al., 2006). An early study by Saltin (1973) observed that glycogen depleted soccer players covered less ground during the match and at a slower average speed than control players. Krstrup et al. (2006) reported that half of the muscle fibres
obtained through a biopsy of the vastus lateralis, were almost empty or were fully
depleted of glycogen after the performance of a soccer match, which the authors
concluded, may have contributed to the reduced sprint performance towards the end
of play. Conversely, Jacobs et al. (1982) highlights that muscle glycogen stores are
not always depleted during a soccer game, reporting that glycogen concentrations
after a match were (200 mmol·kg⁻¹) above the critical threshold of 175 mmol·kg⁻¹
which has previously been suggested as the level below which the anaerobic
component of performance is inhibited (Jacobs, 1981).

Similarly, a contrast in findings is also evident within studies that have investigated
the influence of carbohydrate-electrolyte ingestion on soccer skill performance.
Reilly (1997) indicated that the energy provided in glucose drinks delays fatigue due
partly by saving muscle glycogen stores. Despite this, Zeederberg et al. (1996)
observed that the ingestion of a carbohydrate-electrolyte solution had no measurable
benefits on motor skill proficiencies of soccer players during competitive match-play,
in a cool environment. In opposition, Ostojic and Mazic (2002) detailed the
significant benefits of ingesting carbohydrate-electrolyte solution during competitive
match-play after observing a significantly improved soccer dribbling performance
post match. In addition, Ali et al. (2007b) observed that ingesting a carbohydrate-
electrolyte solution during a 90 minute LIST allowed participants to better maintain
both soccer skill (shooting) and sprint performance, when muscle glycogen stores
had previously been depleted. Thus, fatigue at the end of soccer games may be
caused by glycogen depletion of individual muscle fibres.
In addition to muscle energy stores, Hypoglycemia has also been suggested as a possible contributor to deterioration in performance during a soccer match. The findings of the aforementioned studies investigating the ingestion of carbohydrate-electrolyte solutions provide support that the maintenance of blood glucose delays fatigue and allows the maintenance of soccer skill and sprint performance towards the end of play (Ali et al., 2007b; Ostojic and Mazic, 2002). Welsh et al. (2002) proposed that low blood glucose levels may cause central fatigue by influencing neuromuscular and/or central nervous system function, resulting in a decreased motor skill performance, feelings of lethargy and decreased arousal through greater serotonin release and an increased perception of fatigue. This may in part explain the increase in slalom dribbling times and the decrease in shooting accuracy in the present study, although, the possible effects of low plasma glucose concentrations on cognitive function and skill performance remains to be clarified.

However, Kirkendall (1993) observed that the use of a glucose polymer pre-match had no significant influence on total distance covered during the first half of the soccer match when compared to the placebo ingesting trial. Additionally, McGregor et al. (1999) observed no difference in blood glucose concentrations between rest and exercise and concluded that hypoglycaemia was not the cause of the deterioration in soccer dribbling skill performance following a 90 minute LIST. Finally, Bangsbo (1994) highlighted that hypoglycaemia in soccer occurs very rarely, with the liver efficiently regulating blood glucose throughout match-play. Therefore the contribution that a reduced muscle glycogen concentration and blood glucose concentrations in the present study where only a 45 minute LIST protocol was used,
is likely to be limited. However, as a consequence of the study lacking muscle
glycogen and blood glucose concentration data, this assumption lacks certainty.

Reilly (1997) identified that dehydration and hyperthermia have also been suggested
as contributors to fatigue and reductions in performance, with soccer players being
reported to lose up to 3 litres of fluid during match-play. Hoffman et al. (1994)
expands by identifying that only a 2% loss in body mass can increase core
temperature and lead to added cardiovascular strain, as well as impair mental
functioning and endurance performance, ultimately having a negative impact on skill
maintenance (McGregor et al., 1999). Despite fluid consumption being self-
regulated in the current study, the contribution of dehydration to the reduction in
skill performance is unlikely. Morris et al. (2005) identified a mean reduction in
body mass of 1.9% following the performance of 196.6 ± 14.6 minutes of the LIST
under moderate conditions, which is considerably longer than the 45 minutes
performed in the present study. In a more comparable study, Morris et al. (2003)
identified body mass losses of only 0.7 – 1.3% for the three LIST activity bouts
performed, with the demands of the exercise being far greater than the present study,
due to exercise being performed at a temperature of 30°C. Krstrup et al. (2006)
reported that a 1% drop in body mass had no effect on core or muscle temperature,
thus, it appears fluid loss may not be an important component in our observation.

Oliver et al. (2008) proposed that reductions in physical performances may arise as a
consequence of muscle damage induced through the performance of the soccer-
specific intermittent exercise. Damage is caused predominantly to type II muscle
fibres as a consequence of repeated eccentric exercises, which were performed
during the fatiguing protocol in the form of sprinting, acceleration and deceleration movements (Byrne et al., 2004; Thompson et al., 1999). Thompson et al. (1999) identified a marked increase in both muscle soreness and markers of muscle damage after the LIST. Furthermore, Brocket et al. (1997) observed that eccentric exercise leads to changes in the sense of joint position and sense of force production, and postulate that these changes can attributed to muscle damage in the form of disturbances to muscle receptors, muscle spindles and tendon organs. Alterations to neuromuscular co-ordination may in part explain, and appears the most likely cause of the increase in slalom dribbling times and particularly the decreases in shooting accuracy (Table 5), with the ball velocity and trajectory being significantly influenced by joint position and point of contact with the soccer ball (Kellis & Katis, 2007).

Despite the lack of deterioration in sprint performance in the present study implying the absence of fatigue, and negating any explanations proposed previously, the use of a relatively short sprinting distance (15m) may mask the development of fatigue which lead to the deterioration in soccer skill performance. Balsom et al. (1992) previously identified that during the performance of fifteen 40m sprints with 60 seconds rest, sprint performance over 15m was maintained despite observing a significant decrease in end running speeds. Maintenance of sprint performance is attributed to the rapid replenishment of ATP and PCr during the 60 rest periods, which are the central contributors to energy production and ultimately force generation needed to accelerate the body forward (Balsom et al., 1992). Consequently, the 80s sub-maximal exercise performed between sprints allowed for
a more complete recovery of the force generating capacity of the muscle, leading to a maintained 15m sprint performance across the three LIST activity bouts.

The lack of tangible reductions in physical performance levels may also indicate that fatigue is cognitive in nature. The negative effect induced by the repetitive nature of the skills tests; habituation phenomena and the contribution of central fatigue arising over time could have brought about the deterioration in skill performance (Davranche & Audiffren, 2004). Reilly (1996) observed that during competitive soccer matches, the number of goals scored increases towards the end of the game, and speculated that mental fatigue leading to lapses in concentration, technical errors and deterioration in skills, may be the cause of this trend. Supporting this, Greig et al. (2007) observed a significant impairment of motor system efficiency, demonstrated through deterioration in response accuracy to a computer based vigilance task, after the performance of a 90 minute laboratory-based soccer-specific protocol. However, Greig et al. (2007) also reported that response accuracy improved significantly during the first 30 minutes of exercise and was maintained for the following 15 minutes, signifying that mental fatigue may not develop during the first half of a soccer match. Additionally, it has been argued that deterioration in mental performance related to soccer-specific decision making is only evident in less-skilled players (Marriott et al., 1993).
Ultimately, in the present study, the use of semi-professional population and a soccer-specific protocol that omits utility movements such as dribbling the ball which are associated with additional physiological (Reilly & Ball, 1984) and cognitive stresses, the contribution of mental and metabolic fatigue to the deterioration in soccer skill performance remains ambiguous.

5.6 Practical Implications

The results of the study demonstrated a potential decrease in soccer shooting and dribbling skill following a prolonged bout of high intensity, intermittent exercise, providing some support that the development of fatigue is often accompanied by a decline in skill performance (Lyons et al., 2006b; Mohr et al., 2003a). Such findings will be most beneficial to fitness, skills and general coaches of soccer teams, whose players are required to repeatedly perform shooting and dribbling skills efficiently and successfully during prolonged intermittent high intensity exercise, and in which an error in performance can ultimately determine the outcome of a game (Lyons et al., 2006b). Fitness coaches may need to adapt strength and conditioning programs with such influences of fatigue in mind. More specifically, such programs could perhaps incorporate soccer-specific or fatiguing exercises with the aim of mimicking match-play conditions within a training ground environment, with the overall aim of aiding players in generating a greater capacity to cope with the demands of competitive match-play (Lyons et al., 2006b).
5.7 Limitations of the Research

Despite using a sound methodological testing procedure, the undergraduate nature of the present study, may have lead to several limitations influencing research findings. Firstly, while the sample used within the present study was representative of semi-professional soccer players, the findings can only be generalised to soccer players of the same age and level of ability. Furthermore, the small sample size used in the study also limits the generality of any findings, despite being consistent with previous research investigating the relationship between fatigue and skill performance (McGregor et al., 1999; Sunderland and Nevill, 2005). Additionally, although subjects were instructed not to participate in any strenuous physical activity or consume alcohol 24hrs prior to the pre-arranged testing sessions, the researcher could not fully ensure that this assumption was met.

Limitations of the present study are largely concerned with the neglect of attention in determining the extent of fatigue experienced during the LIST. The use of a rating of perceived exertion scale and a muscle soreness perception scale (Thompson et al., 1999) would have allowed for the researcher to formulate a greater understanding of the site and perceived level of fatigue experienced from the LIST performance. More specifically using muscle soreness perception scale may have aided the researcher in clarifying whether subjects experienced a delayed onset of muscle soreness (DOMS), ultimately allowing the influence that muscle damage may have had on skill performance to be further understood (Thompson et al., 1999). However, their use would have required a substantial and time consuming follow-up protocol.
with DOMS occurring for up to 3 days after the exercise performance (Thompson et al., 1999).

Additionally, the measurement of blood lactates, blood glucose levels and muscle glycogen stores pre-during and post LIST would have allowed for further clarification of the influence of the change in metabolic processes to the LIST on soccer skill performances (McGregor et al., 1999; Ostojic & Mazic, 2002). However, the use of such invasive techniques is beyond the scope of the study, requiring extensive facilities, equipment and experience in order to ensure the safety of participants. Consequently, such practices have been omitted in other research into fatigue and skill performance, using comparable populations as the present study (Lyons et al., 2006b).
CHAPTER VI

CONCLUSION
6.1 Major Findings

The results of the study demonstrate that despite a maintenance of sprint performance, there is a significant decrease in soccer skill proficiency following the performance of a prolonged intermittent high-intensity exercise, replicating the demands of one half of a soccer match.

The reduction in skill performance when fatigued may have significant implications for competitive match-play performance, particularly in relation to detriments in shooting accuracy, as the ability of a team to score goals is the ultimate determinant of success (Lago, 2006). Ultimately, the exact mechanism of fatigue development during a game, or after the first half period and the subsequent decrement in performance remains to be elucidated. However, it is unlikely to be due to low muscle glycogen, hypoglycaemia dehydration or hyperthermia as skill performance declined after only 45 minutes.

Future ecologically sound studies into the effects of soccer-specific fatigue development on soccer skill performance should concentrate on utilising a wider range of soccer skills; using tests that are able demonstrate both high reliability and high ecological validity. Additionally, future research should aim to clarify the nature, level and site of fatigue in order to reveal the mechanisms of performance deteriorations during soccer matches and ultimately, their direct influences on skill performance.


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glycogen and diet in elite soccer players. *European Journal of Applied

penalty mark in soccer: The roles of stress, skill, and fatigue for kick

Kellis, E., & Katis, A. (2007). Biomechanical characteristics and determinants of


APPENDIX A
Informed Consent Form

Project Title: The effect of fatigue on the performance of soccer specific skills; shooting and dribbling

Lead Researcher: Keeron Stone
Contact Details: Email: K.J.Stone@uwic.ac.uk Tel: 07811143415

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

Name (Print):

Contact Telephone:

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 attend two sessions to complete the project.
- As part of the study I will have personal data recorded (height, weight, age, sex) as well as being required to complete soccer specific skills tests and a prolonged intermittent shuttle test (LIST).
- The test results will only be used for the purpose of the dissertation. 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.

Signature of Participant: …………………………………………………

Date: …………………………………………………………………..
APPENDIX B
Dear Participant,

I’m currently carrying out an investigation that aims to examine the effect of accumulated fatigue, induced through the completion of the Loughborough Intermittent Shuttle test (LIST) designed to simulate a soccer match, on the performance of the soccer specific skills of dribbling and shooting.

Prior to participating in the study, you as the subject must provide informed consent, acknowledging that; i) you have been informed of the test procedures, ii) are participating voluntarily and iii) you know that you can withdraw at any point, for any reason, without disadvantage.

Selection criteria

You have been selected to participate in the study, due to your current participation in semi-professional competitive football. Additionally, your skill level, athletic ability and the fact that you are accustomed to the type and levels of fatigued experienced during a competitive soccer match, allows any potential health/illness problems whilst performing the LIST to be minimised. Any findings of the current study may be beneficial in terms of providing you with an insight to your current fitness status, identifying strengths and weaknesses of performance, with a view to the development specific practices.

Testing protocol

If you should agree to participate in this study, you will be required to attend two sessions to complete the project. All testing will be performed at the National Indoor Athletics Centre (NIAC) at University of Wales in Cardiff (U.W.I.C) or on the adjacent Astroturf soccer pitch. Two days prior to the first testing session you will be given pre-test instructions for diet, exercise and clothing for both testing sessions. Prior to testing, you will be asked to abstain from consuming large amounts of beverages or food.

The first testing session will initially involve you completing informed consent forms and pre-test health screening questionnaires, lasting approximately 10 minutes. Your height and weight will then be measured, with the height measurement requiring you to remove your shoes and the weight measurement requiring you to wear light athletic clothing (shorts and t-shirt). During this session you will then be asked to complete the slalom dribble test, which requires a ball to be dribbled around a set obstacle course in the quickest possible time. In addition, you will also perform the shooting accuracy test (Loughborough Soccer Shooting Test), requiring you to shoot at marked targets within a full size goal from a set distance.

The second testing session requires you to perform a Modified version of the Loughborough Intermittent Shuttle Test (LIST). The LIST comprises of a set activity
pattern that replicates the demands observed during competitive soccer match-play. The activity pattern consists of intermittent high (sprint and cruise), medium (jog) and low intensity (walk) activity being performed in repeated shuttles over a 20m distance, with the order and total number of shuttles for each pattern being as follows:

- Walking – 3 shuttles (60m)
- Maximal Sprint – 1 shuttle (15m)
- Jogging – 3 shuttles (60m)
- Cruising – 3 shuttles (60m)

This activity pattern lasts for a total of 90 seconds and will be repeated 10 times to represent one activity block lasting 15 minutes. You will undertake three activity blocks to represent a 45 minute first half period. Directly after the LIST has been completed you will be required to repeat the slalom dribble and shooting accuracy tests in order to determine whether fatigue has an influence over skill performance.

Confidentiality

As a participant in the study, any information recorded will remain confidential, and your name will not be written anywhere within the investigation write-up. Additionally, during the research process, only I and my dissertation supervisor (Jon Oliver) will have access to any results recorded. The pre-test health screening questionnaires are designed for your safety, and are used in order to assess if you are fit and capable of completing the testing protocols.

Potential Risks

In order to ensure your safety during the investigation and testing sessions several methods will be implemented. Your heart rate will be monitored throughout the performance of the LIST using Polar heart rate monitors, to ensure that you are not exercising at a dangerous level. Additionally, to limit the possibility of injury a full and comprehensive 15 minute warm-up will be imposed prior to any physical activity or testing, as well as the inclusion of a warm down post test.

Should any incidences arise where you sustain an injury or feel unwell, the test will be stopped immediately and qualified first aider personnel will be on hand to treat you. In addition, a phone will be on hand to contact the emergency services should you require it.

Finally, I remind you that you are free to withdraw from the study for any reason at all, at any point, without disadvantage.

If you have any questions about the research process please contact me on 07811143415 or my supervisor Jon Oliver (J.L.Oliver@uwic.ac.uk).
APPENDIX C
Physical Activity Readiness Questionnaire (PAR-Q)

Participants Name: ………………………………………

Please circle the answers to the following questions:

Do you have asthma or any breathing problems?  YES / NO

Has your doctor ever said that you have a heart condition? YES / NO

Do you ever feel pain in your chest? YES / NO

Do you ever feel faint or have spells of dizziness? YES / NO

Has your doctor ever said you have a joint problem (also back problem) such as arthritis that has been aggravated by exercise or could be made worse by exercise? YES / NO

Has your doctor ever told that you have high blood pressure? YES / NO

Are you currently taking any medication of which the instructor should be made aware? YES / NO

If so, what? …………………………………………………………………………………

Is there any other reason why you should not participate in a fitness test? YES / NO

Are you unaccustomed to vigorous exercise? YES / NO

Have you performed any form of physical activity in the last 24 hours? YES/ NO

IF YOU HAVE ANSWERED YES TO ONE OR MORE QUESTIONS, please add details below. Similarly, if there are any situations which will prevent you from exercising write them here (or let us know if they arise through the experiment)

If your situation changes regarding your responses to these questions, please notify the appropriate research member.

Signed (participant): ………………………………….

Signed (Investigator): ……………………………….

Date:……………………………….
APPENDIX D
**Loughborough Soccer Shooting Test score sheet**

**Player No.: …………**

**Right Foot:**

<table>
<thead>
<tr>
<th>Shot No.</th>
<th>Score</th>
<th>Inside Shooting area</th>
<th>Within 8.5 seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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Sub Total:

**Left foot:**

<table>
<thead>
<tr>
<th>Shot No.</th>
<th>Score</th>
<th>Inside Shooting area</th>
<th>Within 8.5 seconds</th>
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</tbody>
</table>

Sub Total:

**Total Score: ____**