THE UNIVERSITY OF HULL

SOCCER: PHYSICAL CHARACTERISTICS, PHYSICAL DEMANDS OF MATCH-PLAY AND EFFECTIVE PHYSICAL CONDITIONING

being a Thesis submitted for the Degree of PhD
at the University of Hull

by

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CHAPTER ONE: INTRODUCTION

1.1 Science and Football

Sport science was first incorporated into the preparation of soccer teams in the early 1970s. South American national teams were the pioneers in commonly using specialists in nutrition, psychology and physiology. However, despite huge sums of money within the game, British clubs have often less levels of sports science support than their European counterparts (Curry, 1997; Drawer and Fuller, 1999) and although recommendations were made for levels of sports science support provision for the 'Academy' system (Wilkinson, 1997) they do not appear to have been widely embraced, or implemented. This assumes greater significance, when the links between defective training regimen and/or inadequate fitness levels in the aetiology of injuries are considered (Ekstrand and Gillquist, 1983; Hawkins and Fuller, 1998, 1999; Hawkins et al., 2001). This is surprising considering the implications for clubs in terms of health and safety legislation (Fuller, 1995; Hawkins and Fuller, 1998; Drawer and Fuller, 1999; Hawkins and Fuller, 1999; Hawkins et al., 2001; Drawer and Fuller, 2002a). The UK sport science community have therefore had to make greater efforts to integrate the provision of scientific support to soccer teams. As a result, sport scientists have only recently begun to be employed at FA Premier League clubs as teams commence to a adopt a holistic approach in the quest for a competitive edge.

The inaugural World Congress of Science and Football (Liverpool, 1987) was the first attempt to bring scientists from all football codes together to establish common scientific threads. The Congress has become a quadrennial event and focuses on the application of sport science to the football codes, bringing academics and practitioners together (see Table 1). Initially, to embrace the sport science community, FIFA and many national governing bodies made extensions to their sports medicine department. However as Soccer Academies have realised the responsibility of nurturing talent from within, professional clubs have began to appoint their own specific scientific personnel (Jeffreys, 2002; Priestley et al., 2002).

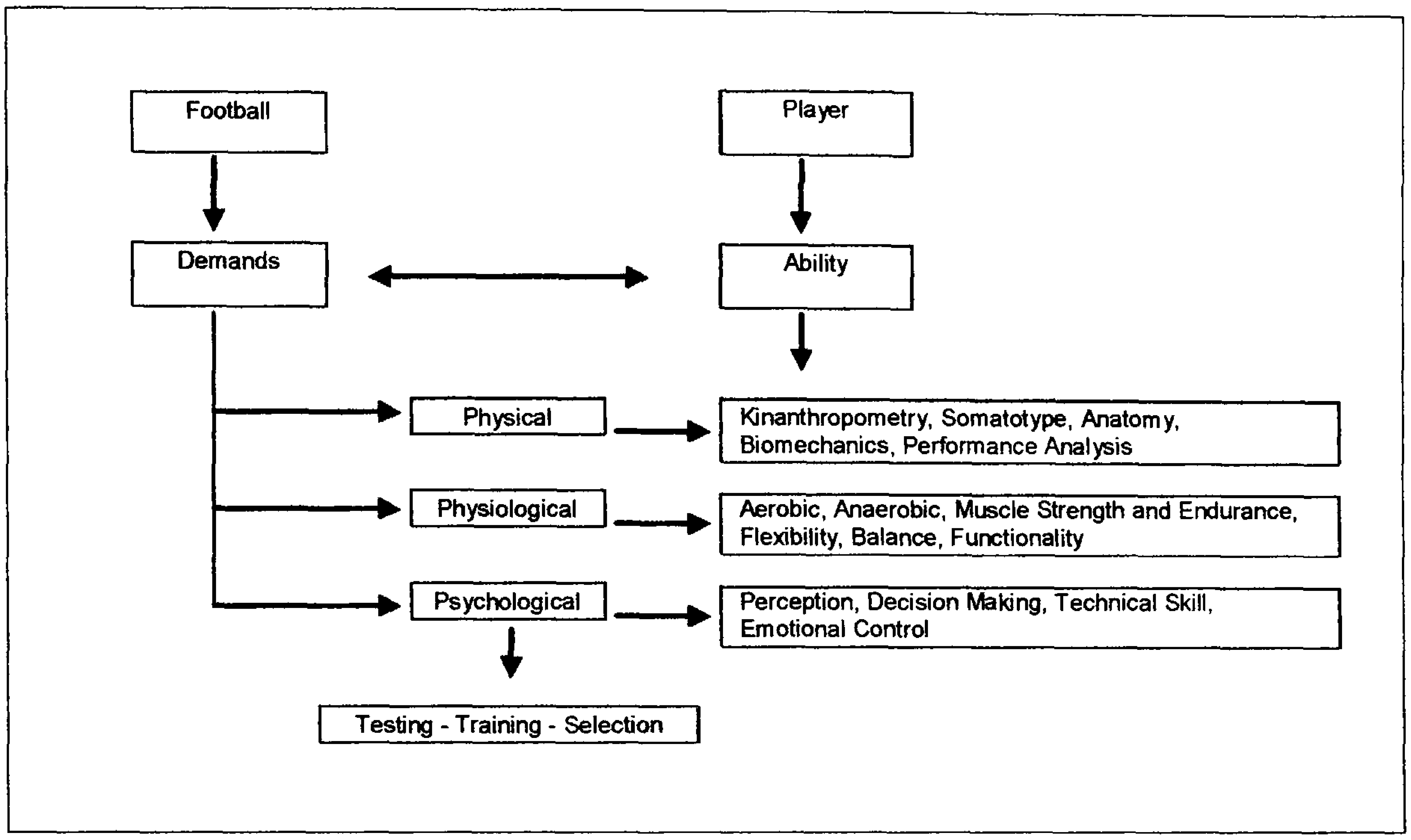
Table 1: Congress themes at First World Congress of Science and Football (Reilly, 2003b, p.2).

Clothing and footwear	Structuring football skills and practices
Football surfaces	Physiology of training and match-play
Biomechanics of kicking	Nutritional factors in football
Computer-aided match analysis	Playing in heat or cold
Team management	Football at altitude
Group dynamics in match-play	Coaching the problem player
Decision-making by referees	The injury-prone player
Soccer violence	Post-injury fitness testing
Pre-match stress and performance	Strain in adolescent footballers

1.2 Academic Study

Sport Science has already been a recognised academic programme of study in the UK for 30 years (1975-2005) with most emphasis placed on physiological, biomechanical, psychological and sociological disciplines. In an attempt to create sport scientists specific to Football (all codes), courses at undergraduate and postgraduate level have been formulated to cope with the increasing demand for specialists. The core disciplines have been maintained and made specific to Football and supplemented with areas such as performance analysis, ergonomics, skill acquisition and research. Reilly, 2003a suggested how the application of science impacts upon Football (Figure 1). Ultimately, the role of the scientist is to prepare the players optimally to cope with the demands of the game. Due to the hybrid nature of dynamic interactions in these sports, this becomes a complex process.

Figure 1: An ergonomics model of Football participation (modified from: Reilly, 2003b, p.4).



1.3 The PhD Research Programme

1.3.1 Introduction

Key performance indicators (KPIs) have been identified as determinants of successful performance (Hughes and Bartlett, 2002). Investigation of KPIs and greater understanding of their interaction should ultimately enhance performance. Various physical variables have been identified as KPIs in invasion sports such as soccer (e.g. Van Gool et al., 1988; Mangine et al., 1990; Tumilty, 1993a; Reilly, 1994c; Bangsbo, 1998b; Shephard, 1999; Hoff et al., 2002; Ostojic, 2002; Mohr et al., 2003; Reilly, 2003c). In this respect, many research investigations have been performed to detail several physical aspects of soccer. However, the evolution of the game commands a constant update of research areas (Drust et al., 1998; Miyagi et al., 1999; Rienzi et al., 2000; Strudwick et al., 2002). This research programme aims to detail an up-to-date analysis and provide a greater depth into the knowledge of the physical aspects of elite soccer performance. To accomplish this, the investigation seeks to examine three key objectives:

1. **What are the physical characteristics of elite soccer players?**

2. **What are the physical demands imposed upon elite players in match-play?**

3. **What are effective physical conditioning methods to prepare players?**

Investigation of the physical characteristics of modern day players and the specific physical demands of match-play provides a foundation of knowledge useful to establish effective soccer conditioning methods. In general, the knowledge gained from the research can be utilised to enhance the physical performance of soccer players. Overall, the combination of these research areas provides a greater depth of understanding and can be used in optimising player assessment, conditioning, selection and development. Researchers within the Science and Football domain have made several investigations into the physical aspects of performance, with many centering on the physical demands of match-play (e.g. Reilly and Thomas, 1976; Withers et al., 1982; Mayhew and Wenger, 1985; Drust et al., 1998; O'Donoghue, 1998; Krustrup and Bangsbo, 2001; Krustrup et al., 2002; O'Donoghue and Parker, 2002; Mohr et al., 2003). However, the physical demands of playing soccer at the highest level are continually evolving. These developments require a constant assessment and evaluation of the game to enable the preparation and condition of players to the highest possible standards (Drust et al., 1998; Miyagi et al., 1999; Rienzi et al., 2000; Strudwick et al., 2002). Surprisingly, there is only sparse scientific information available regarding the areas of physical characteristics and conditioning of soccer players.

1.3.2 Overall Purpose and Overview of Research Programme

The overall purpose of this thesis was to examine the physical aspects of high performance soccer. As such, four interrelated studies were designed to pursue this purpose. Each study was designed to overcome certain distinct methodological limitations of previous science and football (soccer) research and build upon existing research. The research designs for each of the four studies were methodologically different and progressed from previous research design incorporating data collected and analysed from text and internet sources, computerised video-analysis of interactive televised material and combined performance and laboratory assessments. In the following section the purpose of each study included in this thesis is provided and the rationale underpinning the selection of each research design is explained.

1.3.3 Study 1: Analysis of Age, Stature, Body Mass, BMI and Quality of Elite Soccer Players from four European Leagues

For many sports, there are specific physical characteristics that indicate suitability for, or potential to compete in that sport at the highest level. Various anthropometric characteristics of athletes have been shown to be reasonable predictors for participation at the highest level in sports such as swimming (Ackland et al., 1993), basketball, rugby league and American football (Norton and Olds, 2000). Surprisingly, there is no research available exploring these characteristics in soccer, particularly within the elite European soccer. It might well be that the recent changes in demands in soccer (Williams et al., 1999) have been accompanied by physical characteristic changes in soccer players that have been of greater magnitude than that of the normal population. This is an important issue because even small changes in these physical characteristics of players could result in a large reduction in the pool of people to draw from in the general population who have the suitable physical characteristics to be successful in soccer (Olds, 2001). Furthermore, the comparison of players in different leagues and in different positions might provide some valuable information regarding the different demands placed on soccer players in different leagues (Reilly et al., 2000a; Rienzi et al., 2000; Strudwick et al., 2002).

It is well documented that different positions in soccer constitute various different demands. Such findings suggest heterogeneity in physical characteristics that might be important for success in particular positions in soccer (Strudwick et al., 2002). The first aim of the present study was to investigate whether there are physical differences (age, stature, body mass, body mass index) between players in different positions in four European soccer leagues. This will also provide information into the diversity in playing style as well as the variation in what is being valued in soccer players in the various countries. This results in valuable information for the adaptation of different physical conditioning regimes as well as implications for talent identification (Fisher and Dean, 1998). The second aim of the present study was to assess the quality of the players of each of the four European leagues by surveying their international status, nationality and FIFA world ranking as well as participation in the FIFA World Cup 2002. This will offer information regarding the actual quality of international players within these leagues which, in turn, provides information about which league would be of the highest quality, differences in playing style and player selection. As the four leading European leagues were selected for analysis, the results provide beneficial information concerning the current status and possible future development of European soccer.

1.3.4 Study 2: The 'Bloomfield Movement Classification': Motion Analysis of Individual Soccer Players

In close relation with the investigation of the physical characteristics of elite level players, it was also aimed to identify the physical demands of performance. Computerised video-analysis was selected as the most appropriate platform to incorporate a study using the time-motion analysis methodology. This involves the notation of various subjectively or objectively chosen modes of motion which are digitally timed throughout the performance. To date, fewer than 8 modes of motion have often been chosen in time-motion investigation in soccer which arguably does not provide a sufficient degree of specificity to detail the physical demands. A high element of performance specificity must be established to elicit a high degree of transfer from competition into a training regime to optimise competitive performance (Henry, 1968; Barnett et al., 1973; Sale and MacDougall, 1981; Rosenbaum, 1987; Morrissey et al., 1995; Hill et al., 1998). The present study outlined a new approach to time-motion analysis through a method involving a greater depth of detail concerning modes of timed-motion, as well as other non-timed movements, directions, intensities, turning and 'On the Ball' categories. The aim of this study was to present a new methodology and establish reliability. The purpose was to provide a new method to perform a more detailed time-motion analysis study in soccer performance to be used in the third study of this thesis.

1.3.5 Study 3: Physical demands of outfield positions in FA Premier League soccer.

To elicit an enhancement in soccer performance, it is considered important to analyse the physical demands of match-play (Reilly and Thomas, 1976; Ali and Farrally, 1991a; Hughes, 2003). Time-motion analysis has been used to investigate these demands. However, many limitations exist with previous research, one of which being the range of classifications used in the collection of data. A high degree of performance specificity is desired to improve coaching practices such as physical conditioning (Barnett et al., 1973). To this end, a new time-motion analysis methodology was designed (see Study 2) and aimed at providing a new level of specificity of performance into the physical demands of high level soccer. Also, the majority of soccer-related time-motion analyses have reported macroscopically with total frequency, total duration or total distance covered providing a summary of the overall physical requirements of soccer. As soccer match-play is essentially an intermittent exercise (Bangsbo, 1994e), it is important to progress the knowledge of the physical nature of the sport and further provide a higher level of specific detail. The aims of the present study were to provide detail regarding intermittent patterns of Purposeful Movement (PM) and Recovery (R), performed by players of three different positions (defender, midfielder and striker), to investigate the reoccurrence of bouts of PM and R within selected time phases and finally provide time-motion analysis of the PM using the BMC.

1.3.6 Study 4: Effective conditioning for soccer match-play

The interaction of multiple dynamic physical activities often produces a hybrid of physiological and biomechanical stresses. Higher levels of soccer require increased levels of physical fitness through increased demands from high intensity activity (O'Donoghue et al., 2001; Strudwick and Reilly, 2001; Mohr et al., 2003). Therefore, increased ability to perform complex chains of movement skills (agility) in conjuncture with speed (both acceleration and deceleration) and quickness (overcoming inertia) are relative to high level performance (Withers et al., 1982; Bangsbo, 1992; Reilly, 1994a). This occurs through processes of motor learning and physical conditioning with the rules of specificity and overload as key underlying principles. In order to facilitate motor learning, practice should contain variability within each session in preference to the repeated rehearsal of a single skill (Fitts, 1964; Henry, 1968; Barnett et al., 1973; Carlson and Yaure, 1990; Vereijken, 1991; Whiting and Vereijken, 1993; Bangsbo and Peitersen, 2000; Williams, 2002). This may take the form of programmed and controlled (e.g. SAQ® conditioning) or random and semi-controlled (e.g. small-sided games) practice methods. Hoff et al., (2002) identified that both methods are credible for soccer conditioning. The main aim of this study was to investigate the efficacy of programmed and random motor learning and physical conditioning methods and investigate neurophysiological and performance adaptations. A second aim was to investigate the necessity of the use of specialised SAQ® equipment for the purposes of programmed conditioning.

CHAPTER TWO: REVIEW OF LITERATURE

2.1 The Assessment of Soccer Players

In order to produce successful performance in high-level soccer, it is critical to make regular assessments of multiple aspects of match-play. This involves the investigation of technical, tactical, psychological and physical/physiological elements of performance. The focus of this review of literature is to provide a detailed account and critical review of the physical and physiological findings of soccer-related studies. These studies have provided a considerable quantity of information surrounding a myriad of variables relative to physical fitness characteristics that are regarded as fundamental qualities for soccer performance. However, the quantification of the physical and physiological aspects of soccer, essentially an intermittent exercise activity, has proven to be a highly complex paradigm and several different approaches have been made to identify the energetic cost of match-play, as well as anthropometric, muscle function and energetic capacity of individual players of different positions. This information is subsequently amalgamated to optimise the physical and physiological status of the player through appropriate conditioning, nutrition and recovery regimes. However, the complexity of match-play complicates the achievement of ecological validity and consequently, several methodologies of soccer assessment potentially lack a degree of specificity. The following sections include details of, and limitations to, the previous studies performed in the domain of the assessment of soccer players.

2.2 Physical and Physiological Measurement

2.2.1 Biography and Anthropometry

Soccer players appear to have relative heterogeneity in terms of body size which may be influential in the selection of different teams, competitive levels and positions (Di

Salvo and Pigozzi, 1998; O'Donoghue et al., 2001; Strudwick et al., 2002). Some of the most important characteristics include age, stature (m), body mass (kg), body mass index ($kg.m^{-2}$), somatotype and body fat percentage (%). In this respect it is considered important to monitor the critical anthropometric variables, particularly in younger players, to ensure that an appropriate physical shape is formed to compete at specific competitive levels (Tumilty, 1998; Hansen et al., 1999; Norton and Olds, 2000; Reilly et al., 2000a; Reilly et al., 2000b; Williams and Reilly, 2000; Franks et al., 2002; Ostojic, 2002; Strudwick et al., 2002; Ostojic, 2003). To this end, it is particularly important to establish normative values for players of different positions. A summary of measurements reported in the literature is provided in Table 2.

Table 2: Mean±sd values for biographical, anthropometric and performance characteristics of professional and elite soccer players reported in the literature (Modified from: Reilly and Doran, 2003, p.23).

Source	Nationality	Level	N	Age (years)	Stature (cm)	Body Mass (kg)	BMI^ ($kg.m^{-2}$)	Body Fat (%)	Somatotype	VO_{2max}	CMJ* (cm)
Williams et al., (1973)	Scottish	Professional D1	-	-	174.6±9.0	69.4±2.1	22.77	-	-	-	-
Reilly et al, (1979)	English	Professional D1	-	-	176.0±1.1	73.2±1.5	23.63	-	-	-	-
White et al., (1988)	English	Professional D1	17	23.3±0.9	180.4±1.7	76.7±1.5	23.55	19.3±0.6	2.6-4.2-2.7	49.6±1.2	59.8±1.3
Faina et al., (1988)	Italian	Professional	27	26.0±4.8	177.2±4.5	74.4±5.8	23.69	-	-	58.9±6.1	43.5±4.9
Togari et al., (1988)	Japanese	National Squad	20	24.2±2.5	175.3±5.8	69.7±5.0	22.68	-	-	-	-
Rahkila et al., (1991)	Finnish	National Squad	105	15-28	180.4±8.0	76.0±1.3	23.35	-	-	-	-
Chin et al., (1992)	Hong Kong	Professional	24	26.3±4.2	173.4±4.6	67.7±5.0	22.52	7.3± ?	-	-	-
Puga et al., (1993)	Portuguese	National	21	27.6± ?	178.1± ?	73.8± ?	23.27	11± ?	-	-	-
Tíryakí et al., (1993)	Turkish	Professional D1	16	18-30	178.8±3.8	74.8±6.6	23.40	7.6±0.7	-	51.6±3.1	64.8±4.6
Tíryakí et al., (1993)	Turkish	Professional D2	16	18-30	177.7±3.4	69.6±4.1	22.04	7.1±0.4	-	51.1±2.0	54.1±5.7
Tíryakí et al., (1993)	Turkish	Professional D3	16	18-30	178.8±5.9	72.7±6.5	22.74	7.2±0.4	-	51.3±2.1	57.0±7.5
Bangsbo, (1994e)	Danish	Professional	65	24.0± ?	181.0± ?	77.1± ?	23.53	-	-	-	-
Bangsbo, (1994e)	Danish	Pro GK	5	27.4± ?	190.0±6.0	87.8±8.0	24.32	-	-	51.0±2.0	-
Bangsbo, (1994e)	Danish	Pro Centre Def	13	25.0± ?	189.0±4.0	87.5±2.5	24.50	-	-	56.0±3.5	-
Bangsbo, (1994e)	Danish	Pro Full-Back	12	23.8± ?	179.0±6.0	72.1±10.0	22.50	-	-	61.5±10.0	-
Bangsbo, (1994e)	Danish	Pro Midfielder	21	23.6± ?	177.0±6.0	74.0±8.0	23.62	-	-	62.6±4.0	-
Bangsbo, (1994e)	Danish	Pro Strikers	14	23.3± ?	178.0±7.0	73.9±3.1	23.32	-	-	60.0±3.7	-
Dunbar et al., (1995)	English	Professional PL	18	22.5±3.6	-	77.7±7.6	-	12.6±2.9	-	60.7±2.9	-

* CMJ - Counter Movement Jump ^BMI based on mean values of stature and body mass

Table 2: continued.

Source	Nationality	Level	N	Age (years)	Stature (cm)	Body Mass (kg)	BMI^ ($kg.m^{-2}$)	Body Fat (%)	Somatotype	VO_{2max}	CMJ (cm)
Mercer et al., (1995)	English	Professional D1	15	24.7±3.8	179.0±8.0	77.6±9.2	24.22	16.2±3.4	-	62.6±3.8	44.8±6.8
Raastad et al., (1997)	Norwegian	Professional	28	23.5±3.0	-	78.9±7.8	-	-	-	62.8±4.1	-
Bury et al., (1998)	Belgium	Professional D1	15	24.2±2.6	180.7±5.2	76.8±5.2	23.52	14.1±1.1	-	62.8±4.0	-
Di Salvo et al., (1998)	Italian	Professional	44	17.8±0.6	181.3±4.4	72.6±4.7	22.09	-	-	-	-
Rico-Sanz, (1998)	Puerto Rican	Olympic	8	17.0±2.0	169.8±6.5	63.4±3.1	21.99	7.6±3.1	-	69.2± ?	-
Rienzi et al., (1998a)	South American	Professional	110	26.1±4.0	177.0±6.0	76.4±7.0	24.39	10.6±2.6	2.0-5.3-2.2	-	-
Wisløff et al., (1998)	Norwegian	Professional D1	14	23.8±3.8	181.1±4.8	76.9±6.3	23.45	-	-	67.6±4.0	56.7±6.6
Wisløff et al., (1998)	Norwegian	Professional D1	15	23.8±3.9	180.8±4.9	76.8±7.4	23.49	-	-	59.9±4.1	53.1±4.0
Rico-Sanz et al., (1999a)	Swiss	Professional	17	17.5±1.0	177.3±5.3	69.4±6.4	22.08	-	-	-	-
Batterham et al., (1999)	English	Professional PL	9	18.1±0.6	181.0±6.0	70.5±5.0	21.52	-	-	-	-
Mujika et al., (2000)	Spanish	Professional	17	20.3±1.4	179.9±5.5	74.8±5.5	23.11	7.9±1.6	-	-	47.4±6.0
Aziz et al., (2000)	Singaporean	National	23	21.9±3.6	175.0±6.0	65.6±6.1	21.42	-	-	58.2±3.7	-
Rienzi et al., (2000)	South American	Professional	11	26.1±4.0	177.0±6.0	76.4±7.0	24.39	10.6±2.6	2.2-5.4-2.2	-	-
Sözen et al., (2000)	Turkish	Professional	83	25.5±4.0	177.8±5.5	73.6±8.5	23.28	-	-	-	-
Al-Hazzaa et al., (2001)	Saudi Arabian	Professional	154	25.2±3.3	177.2±5.9	73.1±6.8	23.28	12.3±2.7	-	56.8±4.8	-
Casajus, (2001)	Spanish	Professional	15	26.3±3.1	180.0±7.0	78.5±6.4	24.23	8.2±0.91	2.6-4.9-2.3	66.4±7.6	41.4±2.7
Cometti et al., (2001)	French	Professional D1	29	26.1±4.3	179.8±4.4	74.5±6.2	23.05	-	-	-	41.6±4.2
Cometti et al., (2001)	French	Professional D2	32	23.2±5.6	178.0±5.8	73.5±14.7	23.20	-	-	-	39.7±5.6
Helgerud et al., (2001)	Norwegian	Professional D1	19	18.1±0.8	181.3±5.6	72.2±11.1	21.97	-	-	64.3±3.9	54.7±3.8

Table 2: continued.

Source	Nationality	Level	N	Age (years)	Stature (cm)	Body Mass (kg)	BMI^ ($kg.m^{-2}$)	Body Fat (%)	Somatotype	VO_{2max}	CMJ (cm)
Craven et al., (2002)	English	Professional D1	14	23	181.0±6.0	80.1±9.2	24.45	-	-	-	-
Dowson et al., (2002)	New Zealand	National	21	Senior	178.0±6.8	78.9±6.0	24.90	17.4mm	-	60.5±2.6	48.0±4.6
Strudwick et al., (2002)	English	Professional PL	19	22.0±2.0	177.0±5.9	77.9±8.9	24.87	12.3±2.9	-	59.4±6.2	-
Carvalho et al., (2003)	Portuguese	Professional D2	74	-	176.9±5.88	76.7±5.46	24.51	-	-	-	-
	Portuguese	Pro GK	9	-	183.0±2.97	81.5±7.97	24.34	-	-	-	34.2±8.4
	Portuguese	Pro Centre Def	13	-	184.6±5.5	82.0±6.21	24.06	-	-	-	32.1±7.3
	Portuguese	Pro Full-Back	9	-	173.0±4.5	69.9±6.4	23.36	-	-	-	32.4±2.9
	Portuguese	Pro Centre Mid	17	-	176.1±7.9	74.3±7.0	23.96	-	-	-	35.5±6.2
	Portuguese	Pro Wide Mid	15	-	175.4±5.1	75.3±4.8	24.48	-	-	-	38.8±9.0
	Portuguese	Pro Strikers	11	-	180.0±10.7	78.9±8.6	24.35	-	-	-	35.3±5.2
Matkovic et al., (2003)	Croatian	National	57	23.2±3.5	180.6±5.6	77.6±5.7	23.79	14.9±3.5	-	-	-
	Croatian	National GK	7	-	182.9±4.3	80.1±5.1	23.94	20.2± ?	-	-	-
	Croatian	National Def	17	-	182.2±4.8	-	-	13.9± ?	-	-	-
	Croatian	National Mid	21	-	180.6±5.6	-	-	14.4± ?	-	-	-
	Croatian	National For	12	-	179.2±6.3	-	-	-	-	-	-
Wilson et al., (2004)	Northern Irish	Professional	34	26.0±5.8	173.0±8.2	76.2±5.1	25.46	-	-	-	-
	Northern Irish	Pro Defender	12	26.5±6.2	175.0±1.0	77.6±5.1	25.34	15.6±2.9	-	49.9±5.4	42.8±7.1
	Northern Irish	Pro Midfielder	10	26.7±6.1	175.0±1.0	76.6±4.8	25.01	16.0±2.2	-	51.6±7.8	47.0±9.6
	Northern Irish	Pro Striker	12	24.9±5.5	171.0±1.0	74.5±5.2	25.48	14.3±2.2	-	53.1±5.4	48.3±10

2.2.2 Muscle Function and Energetic Capacities

Muscular strength, power and endurance are considered important elements of physical fitness for soccer and necessitate assessment (Tumilty, 1998; Di Salvo et al., 2001; Reilly, 2001; Bangsbo and Michalsik, 2002; Strudwick et al., 2002). Typically, measurements are made for isokinetic and isometric strength, peak power, VO_{2max} and repeated high intensity exercise ability. A variety of tests are usually employed to assess the capacity of these qualities in both laboratory and field settings (Impellizzeri et al., 2005; Svensson and Drust, 2005). However, it is desired that a high degree of specificity is included in all tests to achieve ecological validity (Barnett et al., 1973; Young et al., 2001). In this respect, it has been discovered that the strength of the quadriceps, hamstrings and triceps surae groups is of particular importance when considering the fundamental requirement for specific skills such as kicking and tackling (Cabri et al., 1988; De Proft et al., 1988; Taiana et al., 1988; Trolle et al., 1993). Dynamometric tests provide high correlations with kicking performance and supply valuable information into the torque-velocity, joint-angle curves and the assessment of muscle strength deficits and imbalances (Östenberg and Roos, 2000; Cometti et al., 2001). In addition, the ability to generate greater force at a higher velocity improves peak power output and determines the capacity to accelerate as well as the ability to out-jump opponents when competing for the ball in the air. Usually, a vertical jump test such as a counter movement jump (CMJ) is utilised to produce a power output with differences reported between age groups, levels of ability and playing positions (see Table 2).

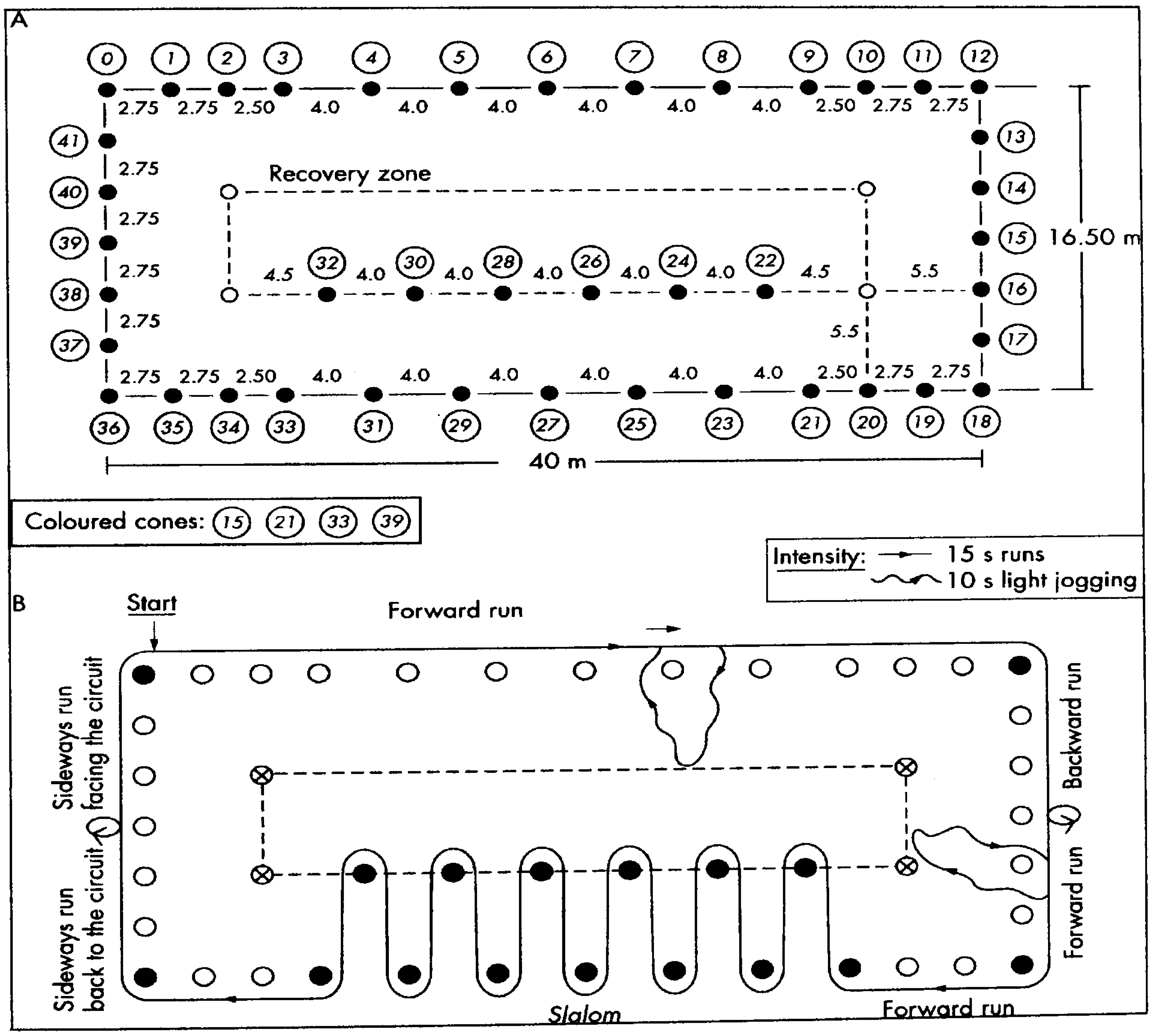
Other ecologically valid and reliable functional tests for soccer-specific physical fitness include time trials over short distances (<30m) (e.g. Mujika et al., 2000; Cometti et al., 2001; Di Salvo et al., 2001; Chamari et al., 2004; Polman et al., 2004), as well as measurements of flexibility and agility (e.g. Dunbar and Power, 1995; Buttifant et al., 2002; Arnason et al., 2004). In this respect, Wisløff et al., (2004) demonstrated a strong correlation between maximal muscle strength, vertical jump performance and 10-30m sprint times in well-trained male elite soccer players. However, soccer-specific endurance assessment has proven to be more problematic as a consequence of the randomised and intermittent nature of match-play. Henceforth, thorough investigation of the endurance (aerobic and repeated high intensity activity) roles of match-play is critical to develop soccer-specific tests of endurance.

2.2.3 Soccer-Specific Endurance

Due to the complexity of match-play, tests of soccer-specific endurance have proved more difficult to gain ecological validity. Although several protocols have been established and validated through various measurements both in field (e.g. Léger et al., 1988; Ramsbottom et al., 1988; Ekblom, 1989; Balsom, 1990; Nicholas et al., 2000; Wragg et al., 2000; Edwards and Clark, 2003; Kemi et al., 2003; Krustrup et al., 2003) and laboratory conditions (e.g. Nowacki et al., 1987; Nowacki, 1991; Nevill et al., 1996b; Williford et al., 1999; Drust et al., 2000b; Chamari et al., 2004), it is arguable if an ecologically valid test actually exists due to discretions in the analyses of the physical and physiological demands of match-play. These results, in turn, influence the design, assessment and subsequently the development of intermittent soccer-specific exercise protocols which, therefore, fundamentally lack validity. For example, a laboratory-based test (Drust et al., 2000b) incorporating intermittent exercise on a motorised treadmill designed on motion analyses of soccer match-play (Reilly and Thomas, 1976; Van Gool et al., 1988) has achieved validation through measurements of physiological parameters (oxygen uptake, heart rate, rectal temperature and sweat production) (Holmyard et al., 1988; Balsom and Ekblom, 1992; Drust et al., 2000a). However, as wide discrepancies exist between the physiological analyses of match-play parameters, ecological validation as a representation of the physical demands of match-play is therefore put into doubt. Furthermore, under laboratory conditions, key performance elements of match-play and specific soccer related movements have not been accounted for, for example any turning, twisting and unorthodox movements, as well as execution of technical skill and cognitive functioning (decision making) which also contribute to the energetic cost of soccer match-play (Bangsbo, 1994a; Reilly, 1997).

Alternatively, field-based tests such as the Multi-Stage Fitness Test (MSFT) provide valid assessment of VO_{2max} (Léger et al., 1988), though the forward linear movement repeated over 20m with 180° turnaround and accumulated speed is far removed from soccer-specific activity. In attempts to combat this, modifications of the MSFT have been performed to include an active recovery period (10s; 2x5m) between each 2x20m running bout (Yo-Yo Test) (Krustrup et al., 2003) and a pre-planned interaction of various modes of motion, running speeds and recoveries such as the Loughborough Intermittent Shuttle Test (LIST) (Nicholas et al., 2000). However, the Yo-Yo Test and LIST have made no major modifications to the forward linear movement repeated over 20m with 180° turnaround course or included any unorthodox (e.g. backwards and sideways) movement. In this respect, more soccer-specific field tests of endurance have been forwarded firstly by Ekblom, (1989) and extended by Bangsbo and Lindquist, (1992). With regard to the latter, the Intermittent Endurance Test (Figure 2) provides indicators of VO_{2max} and incorporates a variety of levels of intensity, modes of motion and movement patterns similar to soccer. Strong relationships were discovered between distance covered in match-play and test performance as well as post-test and post-match levels of blood lactate. However, both these parameters have been shown to be inaccurate measurements of match-play which also put into doubt the ecological validity of this test. Furthermore, the test has been shown to correlate only with the lowest velocity associated with VO_{2max} and actually provides a poor estimate of VO_{2max} (Chamari et al., 2004).

Figure 2: The Intermittent Endurance Test (Bangsbo and Lindquist, 1992).



2.2.4 Repeated High Intensity Exercise Ability

Repeated high intensity exercise, such as sprinting or jumping is also a central concept of physical fitness for soccer match-play (Yamanaka et al., 1988; Balsom and Ekblom, 1992; Balsom et al., 1999; Nicholas et al., 1999; Aziz et al., 2000; Mujika et al., 2000; Rienzi et al., 2000; Wragg et al., 2000; Mohr et al., 2003; Rahnama et al., 2003). Although the energy for soccer performance is supplied primarily by the aerobic system, the anaerobic contributions to match-play are considered critical to the match outcome (Reilly, 1997; Wragg et al., 2000). Various field tests have been developed to assess repeated sprint ability (e.g. Tumilty et al., 1988; Dawson et al., 1993; Fitzsimmons et al., 1993; Bogdanis et al., 1996; Wadley and Le Rossignol, 1998; Aziz et al., 2000; Wragg et al., 2000; Bishop et al., 2001; Thomas et al., 2002; Rahnama et al., 2003). Each test is characterised by a short (20-40m) forward linear course, with a range of repetitions (6-18) and rates of recovery (15-25s). Validity has been ascertained by each test through physiological measurements of soccer performance and criterion validity from established anaerobic tests such as the Wingate Test (e.g. Thomas et al., 2002). However, this may actually be an inappropriate form of validation when observing measurements of metabolism between continuous, intermittent high-low intensity and intermittent maximal intensity exercise (Balsom and Ekblom, 1992; Gaitanos et al., 1993; Balsom et al., 1994b). More specific to soccer, The Bangsbo Sprint Test incorporates a random right and left turn component to improve ecological validity (Bangsbo, 1994a). Laboratory tests have also been formulated such as the Maximal Anaerobic Running Test (MART) (Rusko et al., 1993) performed on a motorised treadmill test and experiences similar issues of validity as the soccer-specific endurance test proposed by Drust et al., (2000b).

2.2.5 Summary of Physical and Physiological Measurement

It is critical to perform physical and physiological measurements of soccer players to make an assessment of their fitness capacity to perform at the highest level (Nettleton and Briggs, 1980; Wadley and Le Rossignol, 1998; Reilly et al., 2000a; Reilly, 2001; Castagna et al., 2002a; Thomas et al., 2002; Reilly and Doran, 2003). In this respect, body size, shape and composition provide the basis of functionality to perform the game (e.g. 'suitable' stature (m), body mass (kg) and body fat percentage) and requires kinanthropometric measurement. Previous studies indicate that heterogeneity exists between players and therefore it is important to establish normative values for elite players of different positions to provide support for selection and talent identification of younger players (Fisher and Dean, 1998; Helsen et al., 2000; Williams and Reilly, 2000; Franks et al., 2002; Strudwick et al., 2002; Baxter et al., 2003; Helsen et al., 2005; Vaeyens et al., 2005).

Other examples of soccer-specific assessment have provided different levels of validity as a result of the physical and physiological demands of randomised intermittent exercise. Anaerobic muscle functions appear to be relatively valid and reliable, with strong correlations existing between vertical jump, muscle strength and 10-30m sprint speeds (Wisløff et al., 2004). In addition, dynamometry provides a suitable assessment of the strength and function of important lower body muscle groups (Cometti et al., 2001). In contrast, measurements of VO_{2max} and repeated high intensity intermittent exercise essentially lack ecological validity and appear to require a higher degree of specificity regarding match-play to make a useful assessment of match-play capacity. To this end, some attempts have been made to make more specific tests such as the Intermittent Treadmill Test, Loughborough Intermittent Shuttle Test and Yo-Yo Test (Drust et al., 1999; Nicholas et al., 2000; Krustrup et al., 2003). However, the movements involved are arguably far removed from those of soccer match-play activity and few attempts have been made to incorporate specific distances, motions, movements, turns, directions and intensities into assessments that could be accepted as more suitable for analysing match-play capacity (Ekblom, 1989; Bangsbo and Lindquist, 1992; Bangsbo, 1994e). However, more stringent analyses of physical and physiological match-play requirements regarding these variables would provide better knowledge to design more ecologically valid tests for soccer-specific endurance and repeated high intensity exercise.

2.3 Physical Characteristics and Quality of Soccer Players

2.3.1 Foreign Players in Domestic Competition

European soccer has seen many changes over the last two decades (1985-2005) including modification in European Union employment laws such as the 1995 Bosman ruling (Blanpain and Inston, 1996; Maguire and Stead, 1996; Morris et al., 1996; Maguire and Pearton, 2000; McArdle, 2000), sharp increases in revenues (Williams, 1994; Boon et al., 1998; Boon et al., 2000), the introduction of the UEFA Champions League, improved levels of sport science support including the physical conditioning of players and enhanced nutritional practices (e.g. Gerisch et al., 1988; Shephard, 1990; Kirkendall, 1993; Ekblom and Williams, 1994; Hargreaves, 1994; Maughan and Leiper, 1994; Davies et al., 1995; Bangsbo, 1999; Drawer and Fuller, 1999; Bangsbo, 2000a, b; Mujika et al., 2000; Reilly and Williams, 2003; Polman et al., 2004). Some of the consequences associated with these changes have been rapid increases in player salaries and transfer fees, faster match-play, a higher volume of competitive games for the top players (Williams et al., 1999) and an increase in cross-boundary movement of players (Maguire and Stead, 1996; Maguire and Pearton, 2000). With regard to the latter, there were only eleven foreign (non-UK and EIRE) players in the starting line-ups for the first fixtures of the 1992/93 FA Premier League season, a figure that has risen to 101 for the 2002/03 season. In total the number of foreign players in the FA Premier League has risen from 37 in the 1992/93 season to 220 for the 2002/03 season (Rollin and Rollin, 2002). Due to this evolution and multi-cultural mix of players, variations in the physical characteristics of players may be expected and provide an insight as to which desirable physical characteristics are sought within various teams. In this respect, if there exists a trend for strikers to be tall in stature for several teams in the same league, it may be suggested that these teams aim to use the striker as a 'target' for the midfielders and defenders to reach with an aerial pass (Bangsbo and Peitersen, 2000; Hawkins, 2002; Bangsbo and Peitersen, 2004).

2.3.2 Style of Play

An issue that could have a bearing on player characteristics is the style of play adopted by a country and their respective domestic league clubs (e.g. Lewis and Hughes, 1988; Ali and Farrally, 1990; Reilly et al., 1991; Yamanaka et al., 1993; Kuper, 1994; Bangsbo and Pietersen, 2000; Ensum et al., 2002; Taylor et al., 2002; Taylor and Williams, 2002; Yamanaka et al., 2002; Reilly, 2003b; Bloomfield et al., 2004c). This is nicely formulated in the statement *'It is because it is just as much of a clash of cultural approaches, which dictate the way teams play, as it is a battle of tactics. For it is impossible to implant the mentality of one country into another, whether it's to do with playing or training'* (Breitner, 1994, p.258). The English game, in this respect, is said to be characterised by a more forthright, fast and physical approach (Hawkins and Fuller, 1999; Croucher, 2002; O'Donoghue, 2003) whereas soccer in the Italian Serie A is perceived to adopt a more cautious, methodical, defensive and technical approach (Castagna and D'Ottavio, 1999; Roi et al., 2005). In close relation, Yamanaka et al. (1993) contrasted the playing patterns of international teams of the British Isles (England, Ireland, Scotland), South America (Argentina, Brazil, Uruguay) and Europe (Italy, the Netherlands, West Germany) during the 1990 World Cup. Teams from the British Isles were indeed found to use a more direct style than their European counterparts while South American teams performed significantly fewer dribbles in the attacking third of the field and fewer runs in the middle third, than European teams. Furthermore, the English style of playing is said to level out the work rate, that is, all outfield players are expected to put in the same amount of physical effort (Reilly, 2003b). Differences in physical characteristics would therefore contribute to various levels of energy expenditure within match-play. The diversity in playing style as well as the variation in what is being valued in soccer players in the various countries, results in the adaptation of differences in training regimes as well as presenting implications for talent identification (Fisher and Dean, 1998; Helsen et al., 2000; Reilly et al., 2000a; Williams and Reilly, 2000; Franks et al., 2002; Helsen et al., 2005; Vaeyens et al., 2005). Consequently, differences in anthropometrics between players in different leagues as well as differences between players in different positions would be expected. Currently, little research evidence is available on these issues.

2.3.3 Quality of Player

It is often debated as to which league in Europe contains the highest quality players, with the premier divisions in England, Germany, Italy and Spain being widely regarded as the leading four. Some evidence to support this is that teams from these divisions have won 34 out of 47 European Champions' Cups, 29 out of 39 European Cup Winners' Cups and 34 out of 44 UEFA Cups (www.uefa.com) by the end of the 2002/03 season. Due to different perceptions and a wide variability of playing traits, there are many subjective methods of determining the quality of a player. However, the pinnacle of international soccer is regarded as the FIFA World Cup competition (www.fifa.com). To this end, after the qualifying procedure, individual selection for participation in this competition is regarded as a significant personal achievement (Bangsbo, 1998a; Hillis, 1998). Furthermore, FIFA develop a ranking system of international teams based on the results of international matches played over a period of eight years. Therefore, it may be assumed that teams that have been ranked highly by FIFA must contain a high level of quality players.

Consequently, the league that contains the highest number of international players from highly ranked nations is arguably the league of the highest quality. Subsequently, the details of these players, such as physical characteristics may be useful in identifying and developing talent (Fisher and Dean, 1998; Helsen et al., 2000; Reilly et al., 2000a; Williams and Reilly, 2000; Franks et al., 2002; Helsen et al., 2005; Vaeyens et al., 2005).

2.3.4 Age

Professional careers in soccer appear to approximate to 15 years in duration with players often introduced to first team soccer in their late teenage years and, with exception to career ending injury, their final season usually played in the mid-thirties (Drawer and Fuller, 2002b). Top European soccer teams have an extensive screening programme for the selection of young athletes who show potential to be nurtured and become high level players (e.g. Brewer et al., 1992). In terms of skill, several taxonomies have been created to identify what constitutes potential (Poulton, 1957; Fleishman, 1975; Ackerman, 1988). Interestingly, it appears that birth-date has an influence on talent identification with significantly more elite professional players born in the first quarter of the 'soccer calendar year' than the final quarter (Barnsley et al., 1992; Brewer et al., 1992; Verhulst, 1992; Dudink, 1994; Brewer et al., 1995; Hansen et al., 1999; Musch and Hay, 1999; Helsen et al., 2000; Simmons and Paull, 2001; Glamser and Vincent, 2004; Helsen et al., 2005; Vaeyens et al., 2005). To this end, Dudink (1994) reported a ratio of 1.6:1 for professional English soccer players born from September to February as compared to those born from March to August. More recently, Glamser and Vincent, (2004) discovered almost 70% of 147 of the most talented boys in the United States Olympic Development Program were born between January and June (selection from 1st January). In fact, these players were three times as likely to have a birthday in the first quarter of the year as in the last, and were over five times as likely to have a January birthday as a December birthday. The study supports the conclusion that the relative age effect is a major factor in the selection of elite soccer players around the world, the impact of which is so great as to suggest that some modification of selection systems are required (Glamser and Vincent, 2004). Similar results have been discovered in ice hockey (Barnsley and Thompson, 1988; Boucher and Mutimer, 1994), American Football (Glamser and Marciani, 1992), baseball (Thompson et al., 1991), cricket and netball (O'Donoghue et al., 2004). Helsen et al., (2000) examined this phenomenon with youth soccer players and related the higher drop-out rates of those born in the final months of the 'soccer calendar year' with physical precocity as a result of less physical maturation. Also, as a consequence, the older players had more exposure to hours spent in practice often producing superior skill levels (Helsen et al., 2000; Helsen et al., 2005; Vaeyens et al., 2005).

2.3.5 Desirable Physical Characteristics

It is suggested that the typical soccer players have a 2-5-2 (two-five-two) somatotype indicating a trend toward mesomorphy and regarded as a valuable body-shape for activities like tackling, jumping, shooting and acceleration (Rienzi et al., 1998b; Rienzi et al., 2000). Proportional muscle mass (MM) has been determined using data collected from stature (cm), thigh circumference corrected for the front thigh skinfold thickness (cm), uncorrected forearm circumference (cm) and lower limb circumference corrected for the medial gastrocnemius skinfold thickness (cm) (Martin et al., 1990). This was later revisited and updated using variables of stature (cm), modified upper thigh girth, corrected gastrocnemius girth and corrected arm girth (Doupe et al., 1997). However, although proven reliable, this equation may still represent an overestimate of MM (Cattrysse et al., 2002) when compared to previous findings (Matiegka, 1921; Drinkwater and Ross, 1980). Furthermore, it is well documented that playing in different positions constitutes different performance demands. For example, forward players and centre backs are significantly more engaged in situations where they have to jump or are required to head the ball whereas defenders tend to make more tackles (Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo, 1994a; Di Salvo and Pigozzi, 1998; Wells and Reilly, 2002). Such findings suggest further evidence for heterogeneity in physical and physiological characteristics that might be important for success in particular positions in soccer (Ekblom, 1986; Mangine et al., 1990; Tumilty, 1993a; Bangsbo, 1994e, 1998b; Reilly et al., 2000a; Dowson et al., 2002; Ostojic, 2002; Strudwick et al., 2002). Table 2 (pp. 22 - 24) provides a summary of reported values of age (years), stature (cm), body mass (kg), body fat (%), somatotype, VO_{2max} and counter-movement jump (CMJ) in the literature. Absence of idyllic physique is not in itself a barrier to success, though having a taller stature, for example, may make an individual more suitable for specific positions such as goal-keeper, centre-half, or 'target' striker (Reilly et al., 2000a). In addition, specific physiological characteristics are sought of players from different positions. In particular, higher VO_{2max} values for midfield players have been reported in comparison to other outfield players (Smaros, 1980; Bangsbo and Lindquist, 1992; Chin et al., 1992; Davis et al., 1992; Williford et al., 1999; Al-Hazzaa et al., 2001; Reilly, 2003c). The main possible explanation for these observed differences being the increased distances covered during match-play by midfield players in comparison to players in other positions (Reilly and Thomas, 1976; Ekblom, 1986; Yamanaka et al., 1989; Bangsbo et al., 1991; Bangsbo, 1992; Rienzi et al., 2000).

2.3.6 Evolution of Physique

It appears that the physique of high level soccer players, particularly body mass, has considerably evolved over the last three decades (Williams et al., 1973; Bangsbo, 1994e; Di Salvo and Pigozzi, 1998; Strudwick et al., 2002). However, Norton and Olds (1996) reported that generally soccer players did not differ in their size and shape from the general population except for goalkeepers. The stature (m) and body mass (kg) of players in the highest division in England (Reilly and Thomas, 1979; White et al., 1988) have also been reported as similar to that of the general population (Peebles and Norris, 1998). Likewise, similar results have been obtained for Italian professionals (Faina et al., 1988). However, the recent changes in the physical demands in soccer (O'Donoghue et al., 2001; Bangsbo and Michalsik, 2002; Reilly, 2003c; Mohr et al., 2004) have been accompanied by changes in the physical characteristics of soccer players that have been of greater magnitude than that of the normal population (Peebles and Norris, 1998). This is an important issue because even small changes in these physical characteristics of players could result in a large reduction in the pool of people in the general population who have the suitable physical characteristics to be successful in soccer. Similar results have been found in rugby union (Olds, 2001). However, a word of caution is required as Matkovic (2005) recently acclaimed that morphological characteristics of Croatian National players did not significantly deviate from that of the average male population of the same age in Croatia although this may only serve to highlight differences between the general populations.

2.3.7 Nationality

It is well known that differences exist between the physical characteristics of nationalities (Peebles and Norris, 1998). Table 3 includes values of physical characteristics from seven different geographical zones based on reports in the literature. Eastern Asian and South American players appear to have the lowest values in terms of stature and body mass (Togari et al., 1988; Chin et al., 1992; Rico-Sanz, 1998; Rienzi et al., 1998a; Aziz et al., 2000; Rienzi et al., 2000). Similar values for stature exist between players from Southern and Central Europe (Williams et al., 1973; Reilly and Thomas, 1979; Faina et al., 1988; White et al., 1988; Puga et al., 1993; Tíryakí et al., 1993; Dunbar and Power, 1995; Mercer et al., 1995; Bury et al., 1998; Di Salvo and Pigozzi, 1998; Batterham et al., 1999; Mujika et al., 2000; Sözen et al., 2000; Carvalho et al., 2003; Matkovic et al., 2003; Wilson and O'Donoghue, 2004), Oceania (Dowson et al., 2002), Central Asia (Al-Hazzaa et al., 2001) with Northern European soccer players having the tallest stature amongst all the reported literature (Bangsbo, 1994e; Raastad et al., 1997; Wisløff et al., 1998; Helgerud et al., 2001). Greater variability exists within the body mass of players with Eastern Asian players having the least mass (67.7kg) and Oceanic players the most (78.9kg). However, similar values for BMI exist throughout all the geographical zones supporting evidence to suggest homogeneity amongst soccer players with regard to this factor.

Table 3: Summary of mean±sd values of physical characteristics from seven different geographical zones based on reports in the literature (See Table 2, pp. 22 - 24).

Geographical Zone	Stature (cm)	Body mass (kg)	BMI ($kg.m^{-2}$)
South American	174.6±4.0	72.1±7.1	23.6±1.4
Eastern Asia	174.6±1.0	67.7±2.1	22.2±0.7
Central Asia	177.2±5.9	73.1±6.8	23.3± ?
Southern Europe	178.7±1.0	74.0±2.8	23.2±0.8
Central Europe	178.2±3.0	75.3±3.2	23.7±1.1
Northern Europe	180.9±0.0	76.3±2.2	23.2±0.7
Oceania	178.0±6.8	78.9±6.0	24.9± ?

South America - Puerto Rico, other countries not declared in literature
Eastern Asia - Japan, Hong Kong, Singapore
Central Asia - Saudi-Arabia
Southern Europe - Spain, Portugal, Turkey, Croatia, Italy, Switzerland
Central Europe - England, Northern Ireland, Scotland, Belgium, France
Northern Europe - Denmark, Finland, Norway
Oceania - New Zealand

2.3.8 Positional differences

Previously, only four studies have reported the physical characteristics of soccer players of different positions (Bangsbo, 1994e; Carvalho et al., 2003; Matkovic et al., 2003; Wilson and O'Donoghue, 2004). In each study, a mean±sd of 57.5±14.8 soccer players were assessed which, when separated by playing position places constraints on the validity and reliability of the values. Table 4 provides the total number of subjects by each position in these studies. However, the results of these studies would suggest there are differences between each position (See Table 2, pp. 22-24) and in this respect, it is necessary to question the value of the mean figures used in several studies that do not account for positional differences. In addition, due to the multi-cultural squads in European club soccer, the blend of different nationalities, ethnicities, and racial origins creates many unique mixes. As a consequence, there exists variation in separate squads' anthropometric data which must be viewed with some caution.

Table 4: Number of soccer players assessed in four anthropometric studies incorporating position as a variable.

Source	GK	Defender	Midfield	Striker	Total
Bangsbo et al., (1994)	5	25	21	14	65
Carvalho et al., (2003)	9	22	32	11	74
Matkovic et al., (2003)	7	17	21	12	57
Wilson et al., (2004)	0	12	10	12	34
Total (mean±sd)	5.3±3.3	19±4.9	21±7.8	12.3±1.1	57.5±14.8

2.3.9 Summary of Physical Characteristics and Quality of Soccer Players

There have been many changes in English soccer since the introduction of the FA Premier League in August 1992. Notably, there have been increases in the volume of games played in a season, in squad sizes, in the number of foreign players and, in the context of this thesis some differences have been observed in stature (m), body mass (kg), body mass index ($kg.m^{-2}$) (BMI), body fat % and VO_{2max} values. The style of play adapted by teams within a given league may be reflected in the physical characteristics of the players both in terms of body size and fitness (see Bangsbo and Pietersen, 2000; Ensum et al., 2002; Taylor et al., 2002; Taylor and Williams, 2002; Yamanaka et al., 2002; Reilly, 2003b; Bloomfield et al., 2004c). Due to a season-of-birth bias, those born early in the soccer year seem to have an advantage to make it to an elite level through greater physical maturation and accumulated practice hours (Barnsley et al., 1992; Brewer et al., 1992; Verhulst, 1992; Dudink, 1994; Brewer et al., 1995; Hansen et al., 1999; Musch and Hay, 1999; Helsen et al., 2000; Simmons and Paull, 2001; Glamser and Vincent, 2004; Helsen et al., 2005; Vaeyens et al., 2005). This suggests that physical precocity is an important consideration in talent identification and certain desirable characteristics are essential. In this respect, differences have been identified in anthropometric characteristics of players of different nationality and playing position (Bangsbo, 1994e; Carvalho et al., 2003; Matkovic et al., 2003; Wilson and O'Donoghue, 2004). However, many of the studies that have reported physical characteristics of players, especially players of different positions, have assessed relatively few participants. Therefore, there is a need for further investigations using larger sample sizes of elite players to establish normative values of players of different positions. Such information can be useful in talent identification and development (Fisher and Dean, 1998; Helsen et al., 2000; Reilly et al., 2000a; Williams and Reilly, 2000; Franks et al., 2002).

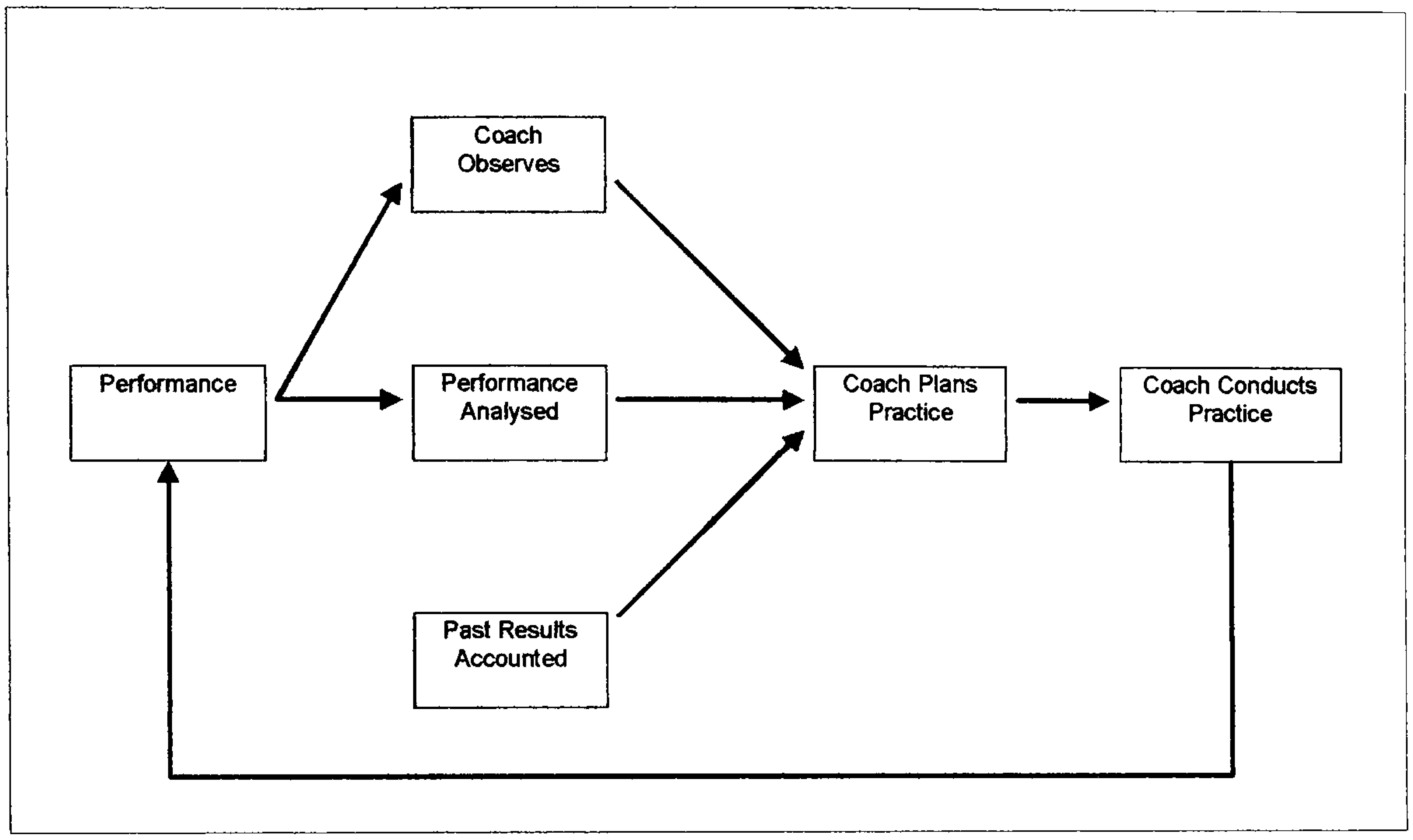
2.4 Physical Demands of Soccer

2.4.1 Notational Analysis

A wide range of studies have been performed to determine the demands of competition soccer (e.g Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo et al., 1991; Rienzi et al., 2000). Through different methods of notational analysis (a method for annotating the detail of match-play), assessments have been made into the performance of the team or of the individual players. This is necessary as it has been identified that international soccer coaches were able to recall only 30% of key performance factors that determined successful performance in one match, hence illustrating the limitation of the human memory system to store all the relevant information absorbed over a significant period of time (Franks and Miller, 1986). The same study also found that less than 45% of post-game assessment was correct based on a 45min period of match-play. The main advantage of notational analysis is that it offers a non-intrusive, objective method of analysing performance. In turn, this provides important data in the observational, analytical and planning phases of the coaching process (Figure 3) (Franks, 1997).

In terms of the analysis of individual players, the quantification of physical exertion is of particular interest. Several studies since have been performed in soccer to investigate the physical demands of match-play for different levels of competition and different positions (e.g Reilly and Thomas, 1976; Withers et al., 1982; Van Gool et al., 1988; Bangsbo et al., 1991; Rienzi et al., 2000; Mohr et al., 2003).. A range of notational analysis methodologies have been adopted to study the phenomenon with the most prominent being the use of time-motion analysis.

Figure 3: A schematic diagram of the coaching process (Franks, 1997).



2.4.2 Time-Motion Analysis

Analysis of match-play through use of timing devices is a methodology which has been used to assess the physical demands of individuals (Hughes, 2003). In addition, it is a useful method to support evidence gained from physiological studies. Some of the earliest investigations made using this method were performed in English soccer using various techniques such as making scale drawings of the pitch to calculate the total distances players travelled during matches (Winterbottom, 1959; Wade, 1962a; Zelenka et al., 1967; Vinnai, 1973). As a result, crude measures of energy expended can be extrapolated (Reilly and Thomas, 1976). Other studies have investigated the durations of various modes of motion (time-motion analysis) with the first studies again completed in English soccer (Brookes and Knowles, 1974; Reilly and Thomas, 1976). Motion modalities can be classified and recorded according to type, intensity (or quality), duration (or distance), and frequency (Bangsbo, 1992; Reilly, 1994a). This is recognised as a useful, non-invasive, method that provides valuable information into the physical exertion of a player with the results regarded as being highly valuable to coaches and managers (Ali and Farrally, 1991a). Several authors have performed time-motion analyses in a wide variety of multiple-sprint invasion sports including soccer (e.g. Reilly and Thomas, 1976; Withers et al., 1982; Mayhew and Wenger, 1985; Ohashi et al., 1988; Rohde and Espersen, 1988; Yamanaka et al., 1988; Yamanaka et al., 1989; Bangsbo et al., 1991; Ogushi et al., 1991; Ohashi et al., 1991; Shephard, 1991; Drust et al., 1998; O'Donoghue, 1998; Castagna and D'Ottavio, 1999; Miyagi et al., 1999; Rienzi et al., 2000; D'Ottavio and Castagna, 2001a; O'Donoghue and Parker, 2002; Mohr et al., 2003), netball (Steele and Chad, 1991, 1992; Borrie et al., 1995), rugby union (Docherty et al., 1988; Deutsch et al., 1998) and rugby league (Meir et al., 1993). Some of these investigations have also reported the characteristics of specific positions within these sports and physiological demands (e.g. Van Gool et al., 1988; Bangsbo et al., 1991; Drust et al., 1998; Mohr et al., 2003; Thatcher and Batterham, 2004) and others have detailed the demands of the referee or assistant referee (e.g. Krustrup and Bangsbo, 2001; D'Ottavio and Castagna, 2002; Krustrup et al., 2002). These data can then be related and applied to the construction of research paradigms and utilised in areas of applied sport science such as physical preparation (e.g. Thatcher and Batterham, 2004). However, due to the rapid evolution of sport in general and soccer in particular, it is critical to perform continuous research in order to re-assess the demands of the modern game (Drust et al., 1998; Miyagi et al., 1999; Rienzi et al., 2000; Strudwick et al., 2002).

As the game of soccer has evolved, the methods of analysing performance have also developed, although perhaps not at the same rate. On review of the current studies available, there appear to be large discrepancies between values for total distances covered by players and modes of motion for reasons that appear mainly due to methodological differences.

2.4.3 Total Distance Covered

Table 5 provides a summary of different methodologies used in studies of time-motion analysis to detail total distance covered. Methods have evolved from the simple use of hand notation for tracking players' movements on scale plans of pitches (e.g. Winterbottom, 1959), to the current utilisation of video recordings and computerised analyses (e.g. Borrie et al., 2002). As a consequence, a wide range of distances has been reported with Winterbottom (1959) providing a total match value of 3.36km which is a significantly less distance than that of Strudwick and Reilly (2002) who report a mean total distance of 11.26km. Although it is accepted that the physical demands of soccer have evolved, it is unlikely that the demands have increased this significantly but rather the evolution of the time-motion analysis methodology has provided more accurate results. To this end, computerised video-analysis is accepted as the most effective methodology in modern-day time-motion analysis to analyse movement, evaluate techniques and tactics and to compile detailed statistical analysis (Hughes, 2003).

Table 5: Mean and range of distances covered in match-play and methodologies employed.

Source	Nationality	Level	M	N	Method	Total Distance (km)
Winterbottom, (1959)	English	English	-	8	Hand notation using scale plan of pitch	3.361
Wade, (1962b)	English	English	-	-	-	1.6 - 5.486
Zelenka et al., (1967)	Italian	Italian	1	1	-	11.5
Togari, (1967)	Japanese	Professional	-	-	Hand notation using scale plan of pitch	8-12
Ohta et al., (1969)	Japanese	Professional	-	-	Hand notation using scale plan of pitch	8-12
Agnevik, (1970)	Swedish	Professional D1~	-	11	-	10.2
Vinnai, (1973)	Russian	-	-	-	-	17
Saltin, (1973)	Swedish	Professional	3	9	Cine-film	10.9
Brookes et al., (1974)	English	English	4	40	Hand notation - subjective estimates	4.886 (4.070 - 7.030)
Whitehead, (1975)	English	Professional D1-D2	-	8	Hand notation - subjective estimates	11.5
Reilly and Thomas, (1976)	English	Professional D1	51	40	Tape Recorder - individual stride lengths	8.680 (7.069 - 10.921)
Smaros, (1980)	-	-	-	7	TV cameras (2)	7.1
Withers et al., (1982)	Australian	National	-	20	Video recordings and mean stride lengths	11.527±1.96
Ekblom, (1986)	Swedish	Professional D1-D4	48	10	Hand notation.	9.8
Ekblom, (1986)	German	Professional D2	12	10	Hand notation.	9.8
Ohashi et al., (1988)	Japanese	National & League	2	4	Trigonometry (2 cameras).	9.845 (9.03 - 10.87)
Ohashi et al., (1988)	Japanese	National & League	-	-	Trigonometry.	9.971
Van Gool et al., (1988)	Belgian	University	1	7	Video recordings and translation	10.245
Bangsbo et al., (1991)	Danish	Professional D1-D2	34	14	Video cameras (24)	10.8 (9.49 - 12.93)
Ohashi et al., (1991)	Japanese	National & League	-	50	Trigonometry	11.529

Table 5: continued.

Source	Nationality	Level	M	N	Method	Total Distance (km)
Miyagi et al., (1999)	Yugoslavian	National	4	1	Trigonometry	10.460±0.591
Rienzi et al., (2000)	S. American	National	-	17	Video - stride frequency estimation.	8.638±1.158
Rienzi et al., (2000)	English	Professional PL*	-	6	Video - stride frequency estimation.	10.104±0.703
Strudwick et al., (2001)	English	Professional PL*	-	24	Video - stride frequency estimation	11.264
D'Ottavia et al., (2001a)	Italian	Elite Referees	96	33	Trigonometry	11.469±0.983
Krustrup et al., (2001)	Danish	Referees	43	27	Computerised video-analysis	10.07±0.13
Krustrup et al., (2002)	Danish	Assistant Referees	22	15	Computerised video-analysis	7.28 (5.78 - 8.16)
Mohr et al., (2003)	Italian	Professional SA^	7	18	Computerised video-analysis	10.86±0.18
Mohr et al., (2003)	Danish	Professional	7	24	Computerised video-analysis	10.33±0.26

M - Number of matches used in the investigation

N - Number of players used in the investigation

~ D1 - Division One

* PL - FA Premier League

^ SA - Italian Serie A

2.4.3.1 Distance Covered - Positional Differences

In addition to the identification of differences in the physique of soccer players of different positions, it appears that differences also exist in the physical demands of match-play for each position. In terms of distance covered, the greatest overall distances are covered by midfield players who act as links between defence and attack (e.g. Reilly and Thomas, 1976; Ekblom, 1986; Bangsbo et al., 1991; Drust et al., 1998; Rienzi et al., 2000; Strudwick and Reilly, 2001; Mohr et al., 2003). Bangsbo et al., (1991), in this respect, reported that elite Danish defenders (10.1km) and strikers (10.5km) covered approximately the same distance, but this was significantly less than that covered by the midfield players (11.5km). The increased distance covered by midfielders is also significantly correlated (r=0.89; n=8) with higher VO_{2max} values for these players in comparison to other outfield players (Reilly and Thomas, 1976; Smodlaka, 1978; Smaros, 1980; Ekblom, 1986; White et al., 1988; Tumilty, 1993a; Bangsbo, 1994e, a, 1997; Aziz et al., 2000; Castagna and D'Ottavio, 2001; Castagna et al., 2002a; Edwards and Clark, 2002). Table 6 provides a summary of findings for distance covered for different positions.

2.4.3.2 Limitations to Total Distance Covered

Primarily, measurement of distances covered by players is an area which is adversely affected by methodological differences (See Table 5, pp. 47 - 48). It is therefore critical to identify the sources of variability from methodological issues ranging from a lack of standardised approaches (e.g. level of competition and environmental conditions) and analysis of data. Furthermore, the method makes a general assumption that energy is expended only when the player travels to a new location on the pitch. This is an important issue as this provides an underestimation of total energy expenditure (Reilly, 1997). Several high intensity movements are performed in soccer match-play without obvious changes of location on the pitch, for example a vertical jump. In addition, other parameters such as agility (acceleration, deceleration, changing direction), contact, and 'on-the-ball' activity also contribute to physical energy expenditure (Reilly, 1997). It is therefore more useful to investigate the movements made which accumulate to cover the total energy expenditure in order to reproduce them in practice scenarios and attempt to optimise performance. To this end, attempts have been made to classify various modes of motion which also provided considerable differences in the approaches (See Table 6).

Table 6: Mean and range of distances covered in match-play by players of different positions.

Source	Nationality	Level	M	N	Position	Mean Total Distance (km)
Whitehead, (1975)	English	Professional D1~	-	1	Defender	11.472
				1	Midfielder	13.827
		Professional D2	-	1	Defender	10.826
				1	Midfielder	11.184
		Amateur	-	1	Defender	9.679
				1	Midfielder	9.084
Reilly and Thomas, (1976)	English	Professional D1	51	7	Central Defenders	7.759±0.521
				8	Full backs	8.245±0.816
				11	Midfielders	9.805±0.787
				14	Strikers	8.397±0.710
Withers et al., (1982)	Australian	National	-	5	Central Defenders	10.169±1.460
				5	Full backs	11.980±1.873
				5	Midfielders	12.194±2.366
				5	Strikers	11.766±0.949
Van Gool et al., (1988)	Belgian	University	1	2	Defenders	9.902±0.255
				3	Midfielders	10.710±0.416
				2	Strikers	10.246±0.141
Bangsbo et al., (1991)	Danish	Professional D1-D2	34	4	Defenders	10.1
				7	Midfielders	11.4
				3	Strikers	10.5

Table 6: continued.

Source	Nationality	Level	M	N	Position	Mean Total Distance (km)
Rienzi et al., (2000)	S. American	National and	-	9	Defenders	8.696±0.976
	and English	Professional PL*		10	Midfielders	9.826±1.031
				4	Strikers	7.736±0.929
Mohr et al., (2003)	Italian and	Professional SA^	7	11	Defenders	9.74±0.22
	Danish	and Professional		9	Full Backs	10.98±0.23
				13	Midfielders	11.00±0.21
				9	Strikers	10.48±0.30

M - Number of matches used in the investigation

N - Number of players used in the investigation

~ D1 - Division One

* PL - FA Premier League

^ SA - Italian Serie A

2.4.4 Modes of Motion

The analysis of motion can be performed through two distinct methodologies. In biomechanics, fine and discrete movements are assessed through cinematographic analysis involving computerised frame-by-frame analysis of isolated movements providing accurate and detailed biomechanical results (Winter, 1979). Alternatively, gross and continuous movements are recorded through notational analysis which provides a wider overview of performance (Hughes and Franks, 2004). Although not as detailed as cinematographic analysis, the use of video and computerised notational analysis techniques enhances the manipulation and presentation of data as it is able to process large amounts of data quickly and easily allowing for detailed statistical analyses to be compiled on the performance or player (e.g. Ohashi et al., 1988; Treadwell, 1988; Hughes et al., 1989; Gerisch and Reichelt, 1993; Borrie et al., 1995; Olsen and Larson, 1997; Pollard and Reep, 1997; Rienzi et al., 2000; Reilly, 2001; Nevill et al., 2002a; Hodges et al., 2003; Hughes, 2003).

Through time-motion analyses, the randomised pattern of exercise in multiple-sprint invasion sports such as soccer has been identified as intermittent. It has been reported that between 1000-1200 discrete movement changes (incorporating rapid and frequent changes in pace and direction) occur within soccer match-play, with the mean duration being 4.5-6s per movement (Reilly and Thomas, 1976). This is comprised of frequent alternations of 'motion' activities such as standing, walking, jogging, cruising or running, sprinting, as well as backwards and sideways movements which are all, to some extent, measurable through notation (e.g. Reilly and Thomas, 1976; Withers et al., 1982; Mayhew and Wenger, 1985; Yamanaka et al., 1988; Yamanaka et al., 1989; Bangsbo et al., 1991; Drust et al., 1998; O'Donoghue, 1998; Miyagi et al., 1999; Rienzi et al., 2000; Mohr et al., 2003). An overview of the methodologies employed is provided in Table 7.

Table 7: Methodological review of time-motion analysis studies in soccer.

Classification Method	Examples of Studies	Motion Classifications
Subjective Description	Reilly & Thomas (1976) Mayhew & Wenger, (1985)* Rienzi et al., (2000)^ O'Donoghue et al., (2001)**	Standing* Walking (+ sideways/backwards) Jogging (+ sideways/backwards^) Running/Cruising Sprinting Shuffling** 'On the Ball' Activity**
Arbitrary Speed Classification	Bangsbo et al., (1991) Krustrup et al., (2001) Krustrup et al., (2002) Mohr et al., (2003)	Standing - 0 $km{\cdot}h^{-1}$ Walking - 6 $km{\cdot}h^{-1}$ Low-speed jogging - 8 $km{\cdot}h^{-1}$ Low-speed running - 12 $km{\cdot}h^{-1}$ Backward running - 12 $km{\cdot}h^{-1}$ High to moderate-speed running - 15$km{\cdot}h^{-1}$ High-speed running - 18 $km{\cdot}h^{-1}$ Sprint running - 30 $km{\cdot}h^{-1}$
Basic Speed Classification	Ohashi, et al., (1988) Van Gool et al., (1988)	Speed ranges, from 0-1m s^{-1} to 9-10 m s^{-1} in increments of 1m s^{-1}.
Individual Mean Stride Lengths	Reilly & Thomas, (1976)	Walking: 0.64 (0.966) Jogging: 0.90 (0.962) Cruising: 1.13 (0.915) Sprinting: 1.24 (0.971) Sideways: - Backing: 0.60 (0.915)
	Withers et al., (1982)	Walking: 0.82 (0.981) Jogging: 1.36 (0.979) Cruising: 1.75 (0.745) Sprinting: 1.76 (0.815) Sideways: 1.25 (0.904) Backing: 0.78 (0.982)

(Figures in parentheses represent reliability & objectivity coefficient values)

Key: */^/** - Classifications introduced in the respective study

2.4.4.1 Modes of Motion - Positional Differences

The most frequently cited mean values in the literature are those from Reilly and Thomas (1976) (walking 24.8%, jogging 36.8%, cruising 20.5%, sprinting 11.2% and backing 6.7%) which were applicable for a mean±sd total distance covered of 8.68±1.011km. However, these generic values lack information concerning positional specificity as the different playing positions appear to experience different levels of exertion. For example, the greater distances covered by midfield players are mainly due to their engagement in low speed running more frequently, and for longer duration (e.g. Bangsbo et al., 1991) and standing still for significantly less time than the other outfield players (O'Donoghue, 1998). In addition, Reilly and Thomas (1976) reported that defenders and strikers covered more distance in walking and sprinting and less in jogging and cruising. Also, the midfield players covered more distance in jogging and cruising and less in walking and sprinting. Strikers, on the other hand, have been found to perform the most all out sprints, followed by midfielders and defenders (e.g. Bangsbo et al., 1991). In addition, it is well documented that playing in different positions constitute different playing performance demands within the game. For example, strikers and centre backs are significantly more engaged in situations where they have to jump or are required to head the ball whereas defenders tend to make more tackles (Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo, 1994a; Di Salvo and Pigozzi, 1998; Wells and Reilly, 2002). Overall, the data seem to indicate that different positions within the game of soccer require different physical and physiological demands. Tables 8 (distance) and 9 (time) provide a summary of findings for time-motion analysis studies performed in soccer with position or level included as a dependent variable.

Table 8: Mean and range of distances covered in match-play by players of different positions and levels.

Source	N	Pos/Level	Walk (%)	Jog (%)	Run (%)	Sprint (%)	Other (%)
Whitehead, (1975)	1	e-Defender	22.6	30.9	24.0	22.6	-
	1	e-Midfielder	36.5	33.3	16.5	13.7	-
	1	s-Defender	38.7	27.4	19.2	14.7	-
	1	s-Midfielder	43.9	37.4	9.8	9.0	-
	1	a-Defender	42.4	26.6	18.8	12.2	-
	1	a-Midfielder	47.4	37.4	10.4	10.0	-
Reilly and Thomas, (1976)	40	e-All	24.8	36.8	20.5	11.2	6.7
	7	e-Defenders	27.8	35.2	19.2	9.5	8.1
	8	e-Full backs	22.9	37.5	20.6	10.7	8.4
	11	e-Midfielders	20.7	41.2	22.0	10.8	5.2
	14	e-Strikers	27.5	33.0	20.9	12.7	5.9
Withers et al., (1982)	20	e-All	26.3	44.6	13.1	5.8	10.3
	5	e-Defenders	23.7	45.0	14.5	7.9	8.9
	5	e-Full backs	30.3	37.9	12.5	3.9	15.3
	5	e-Midfielders	21.9	49.9	15.1	5.3	7.8
	5	e-Strikers	29.8	44.4	10.0	5.8	10.1
Rienzi et al., (2000)	23	e-All	31.7	44.1	10.5	4.3	9.4
	9	e-Defenders	32.0	46.0	8.3	2.7	11.0
	10	e-Midfielders	25.4	50.6	11.5	3.3	9.2
	4	e-Strikers	39.2	34.0	11.7	7.3	7.8

Key: e - elite; s - semi-pro; a - amateur

Table 9: Mean and range of time spent in modes of motion in match-play by players of different positions and levels.

Source	N	Pos/Level	Stand (%)	Walk (%)	Jog (%)	Run (%)	Sprint (%)	Other (%)
Mayhew et al., (1985)	3	Midfield	2.3	46.4	38.0	11.3	-	2.0
Ohashi et al., (1988)	4	Elite	-	61.0	35.1	3.5	0.4	-
Yamanaka et al., (1988)	10	Elite	4.3	55.4	32.7	5.7	1.9	-
	19	Professional	4.7	46.9	36.9	6.7	4.7	-
	20	College	7.0	47.6	34.9	7.9	2.6	-
Treadwell, (1988)	-	-	-	69.5	-	28.2	0.6	1.5
Ali and Farrally, (1991a)	21	University	7.0	56.0	30.0	4.0	3.0	-
Bangsbo et al., (1991)	14	All	10.4	27.9	21.5	36.3	2.2	1.6
	4	Defenders	13.3	29.7	22.5	30.0	3.1	1.3
	7	Midfielders	8.2	26.6	21.6	38.8	2.5	1.4
	3	Strikers	11.0	29.0	20.1	36.8	0.5	2.1
O'Donoghue et al., (2001)	24	Elite Pro	12.3	47.4	27.9	3.1	-	9.2
	24	Semi-Pro	16.1	47.6	25.9	3.1	-	7.3
	24	Amateur	16.1	47.0	25.2	4.7	-	7.1
Mohr et al., (2003)	18	Top Class	19.5±0.7	41.8±0.9	16.7±0.9	16.8±0.3	1.4±0.1	3.7±0.3
	24	Moderate	18.4±1.5	43.6±0.8	19.1±0.9	15.1±0.3	0.9±0.1	2.9±0.2

(Note: Wide variations observed between studies due to methodological difference, movement classification interpretation and/or analysis of data)

2.4.4.2 Limitations to Modes of Motion

Wide variations also occur within the methodologies employed in this type of time-motion research (See Table 7, p. 54), the major issue to address being the choice of motion classifications. Usually, this has been done subjectively although attempts have been made to quantify classifications objectively (e.g. Ohashi et al., 1988; Van Gool et al., 1988). Nevertheless, it is arguable that the motion classification systems used in previous time-motion investigation do not encompass a complete profile of motion and performance demands placed upon soccer players to provide a high enough degree of specificity to detail the physical demands of soccer (Barnett et al., 1973; Sale and MacDougall, 1981; Morrissey et al., 1995). To date, fewer than 8 modes of motion have often been chosen which, when considering the stochastic and dynamic nature of soccer specific movements, is far removed from supplying a full movement repertoire. Consequently, areas of sport science such as physiology, psychology, nutrition and biochemistry are also limited in their progress without this specific detail. Since the Reilly and Thomas (1976) study, motion classification systems have developed to include jumping (Mayhew and Wenger, 1985) and running has been classified as low, moderate or high speed (Bangsbo et al., 1991). More recently, shuffling and match-play ('on the ball') activity classifications have been included in the analysis (O'Donoghue, 1998). Moreover, despite these advancements, these classifications continue to provide only crude measurements of physical exertion due to the high frequency of alternations in activities. To produce higher degrees of specificity, a complete set of movement categories, directions, intensities, turns and playing activity is desired in order to gain a thorough understanding and evaluation of the physical performance requirements. With this knowledge it therefore becomes possible to objectively design physical conditioning and assessment protocols that are highly specific to performance and therefore optimises the physical functioning of the players.

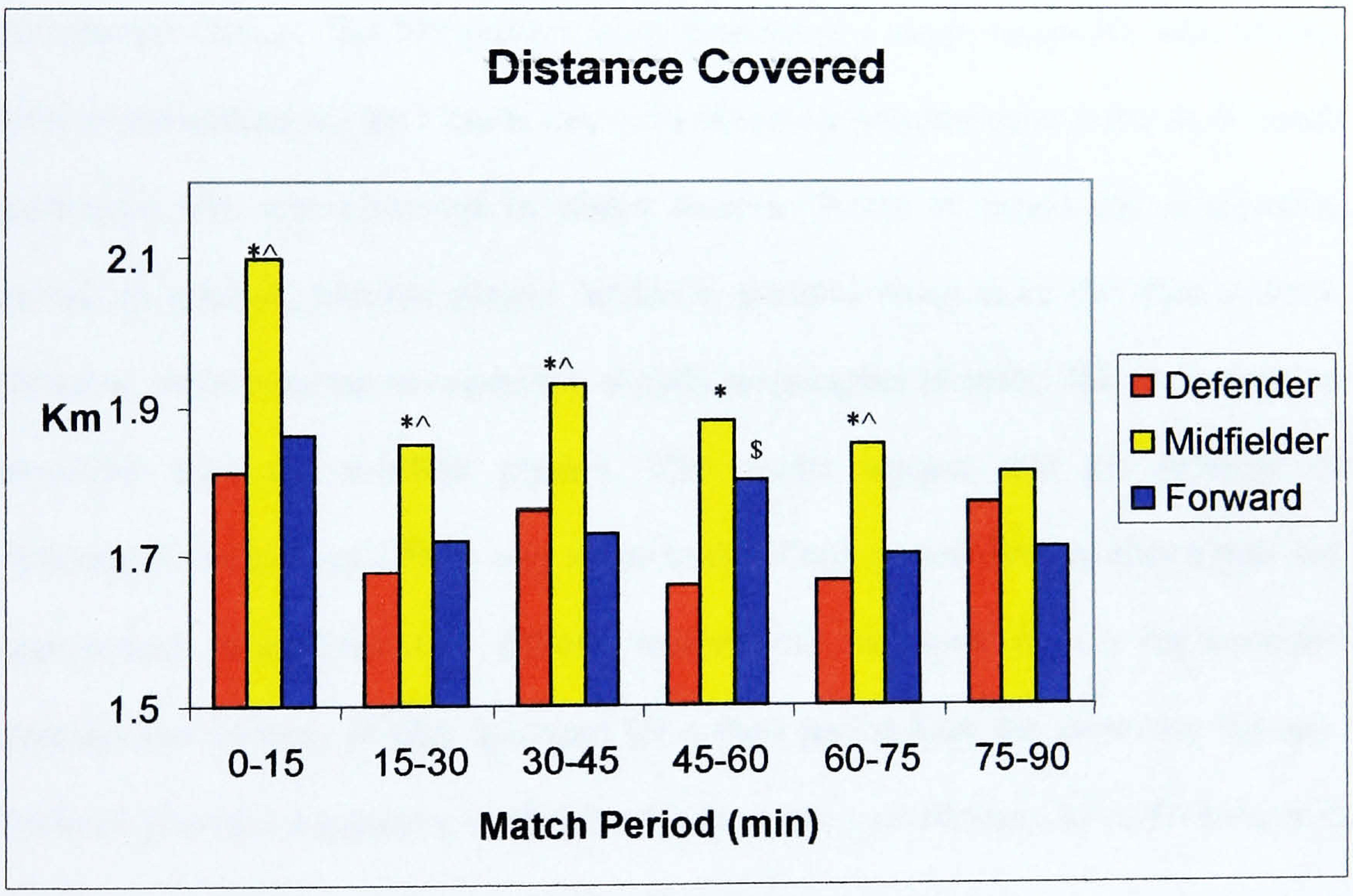
Furthermore, the reporting of time-motion analyses usually includes values concerning totals, percentages, frequencies and means which is of limited profit and provides simply a macroscopic view on the physical demands in soccer. Recently, a programmed exercise protocol for netball based on the mean duration of high intensity activity and low to moderate intensity proved to be ineffective in enhancing match-play specific physical fitness (O'Donoghue and Cassidy, 2002). To this end, a full range of high intensity 'bursts' and low to moderate intensity 'recoveries' are sought to design physical conditioning programmes that are specific to soccer match-play (O'Donoghue and King, 2003). Consequently, ratio scales have been adapted to present data based on levels of intensity (O'Donoghue, 2003). This is more useful as it provides information on a range of frequencies and durations of motion. In the case of soccer, it has been found that most 'bursts' of high intensity activity are less than 4s in duration with subsequent 'recoveries' usually ranging between 12-90s (O'Donoghue, 2003). Midfielders appear to perform significantly more 'bursts' of 4-6s in duration and more 'recoveries' of 2-4s, 4-6s and 8-12s than other outfield players (O'Donoghue, 2003).

2.4.5 Different Stages of Match-Play

A FA Premier League soccer match consists of two halves of a continual 45mins with typically 1-5mins of time added for stoppages in play due to injury at the end of each half determined by the first official. The halves are separated by a 15min rest period. Match-play is made up of intermittent and inconsistent periods of 'ball in play' and 'ball out of play' with players constantly performing physical effort of varying intensity. Soccer match-play has been described as stochastic, acyclical and intermittent with uniqueness through its variability and unpredictability (Nicholas et al., 2000; Wragg et al., 2000). As a result, effort is not evenly distributed across the ~90mins due to factors such as tactics and formation (e.g. Grehaigne et al., 1999; Bangsbo and

Peitersen, 2002, 2004), level and type of competition (e.g. Hillis, 1998; Rienzi et al., 2000; O'Donoghue et al., 2001), location and importance of match (e.g. Nevill et al., 1996a; Yin and Zheng, 1998; Nevill et al., 2002b; Waters and Lovell, 2002; Bray et al., 2003; Neave and Wolfson, 2003), weather and pitch conditions, refereeing decisions (e.g. red and yellow cards) (Nevill et al., 2002c), equipment (e.g. Carre et al., 2002), competition tachycardia and anxiety (e.g. Reilly and Walsh, 1981; MacLaren et al., 1988; Pizzi and Castagna, 2002; Helsen and Bultynck, 2004) and motivation and score-line (O'Donoghue and Tenga, 2001; Bloomfield et al., 2004c, d). However, it may be assumed that effort will be highest at the beginning of a match and will reduce throughout primarily due to fatigue (e.g. Tumilty, 1991; Marriott et al., 1993; Reilly, 1997; Rebelo et al., 1998; Rico-Sanz et al., 1999a; Mohr et al., 2003; Rahnama et al., 2003). Several studies have demonstrated a decreased distance covered, and hence a decreased physical output, during the 2nd half of elite level matches compared with the 1st half. Reilly and Thomas (1976) reported a decrement in 75% of their subjects whereas others provide values of 465m (Van Gool et al., 1988), 405m (Ohashi et al., 1988), ~300m (Bangsbo et al., 1991), 164m (Miyagi et al., 1999), 141m (Rienzi et al., 2000), 716m (Strudwick and Reilly, 2001) and 160m (Mohr et al., 2003). Although a consistent decline is observed a high degree of variance exists through the different time motion analysis methodologies employed as well as the different elite competitions and competitions assessed. Bangsbo et al., (1991) provide detail within match-play through reporting distance covered in 5min consecutive match periods. It appears that the furthest distances are covered in the opening 15mins followed by a noticeable reduction in the next 10mins and a slight incline through to the end of the first half. The second half commences with a brief increase in physical effort proceeded by a decreased but relatively level effort for the majority of the half with a small increase again through the final 10mins (Figure 4). Significant differences exist between first and second half periods 1-3 (0-15min), 7 (30-35min) and 9 (40-45min). Time-motion analyses suggest distance is covered in approximately 80-90% of low to moderate intensity activities and the remaining 10-20% performing high intensity activities (HIA) which has been estimated to total 7mins (Saltin, 1973; Reilly and Thomas, 1976; Withers et al., 1982; Mayhew and Wenger, 1985; Yamanaka et al., 1988; Bangsbo et al., 1991; Ohashi et al., 1991; Shephard, 1991; Bangsbo, 1994e; O'Donoghue, 1998; Rienzi et al., 2000; Bangsbo and Michalsik, 2002). Ali and Farrally (1991) relate the reduction in distance covered with decreases in the high intensity activity performed and evidence has been provided to support this, with reductions in both high intensity running and sprinting motions across six consecutive 15min match periods (Mohr et al., 2003).

Figure 4: Distance covered according to 15min match period (Bangsbo et al., 1991).



Key: * - difference between defenders and midfielders ($p<0.05$).

^ - difference between defenders and forwards ($p<0.05$).

$ - difference between midfielders and forwards ($p<0.05$).

2.4.6 Significant Events within Match-Play

One significant event in soccer is the scoring of a goal which consequently alters the score-line of the match. As a result, it may be suggested that levels of motivation and physical exertion may alter. O'Donoghue and Tenga (2001) were the first to investigate this phenomenon and found that players perform significantly more exercise when they are ahead in match-play. Subsequently, Bloomfield et al., (2004b) compared the intensity of play in FA Premier League midfielders and strikers according to the score-line status (level, ahead or behind) of the match. The activity of 232 players was observed and coded for intensity of play using a 2-category classification of motion ('Purposeful Movement' (PM) and 'Rest' (R)) over six 15min match periods (0-15; 15-30; 30-45; 45-60; 60-75; 75-90). PM was defined as any purposeful and deliberate movement made by the player reliably interpreted to influence play with R consisting of all other movement. The 141 players who experienced a single score-line state (ahead, level or behind) during the 15mins they were observed were included in the study. Each participant was also classified by match location (home or away) and observation period. In general, midfield players tended to perform much more PM than strikers. However, strikers appeared to perform slightly more higher intensity PM when ahead in score-line than the midfield players. The results suggest that the findings of O'Donoghue and Tenga (2001) only relate to the 10min period directly after a goal has been scored. Bloomfield et al., (2004b) indicate that increased effort is not sustained although the intensity of play increases for a short period after the score-line changes. Table 10 provides a summary of findings for the exercise performed by midfielders and strikers in the FA Premier League in three different score-line states.

Table 10: Summary of analysis of % PM (mean±sd) (Bloomfield et al., 2004d).

Score-line	Striker	Midfield	All
Ahead	(n=19) 31.5±6.2	(n=25) 32.6±6.6	(n=44) 32.1±6.4
Behind	(n=28) 30.3±6.2	(n=15) 33.5±8.5	(n=43) 31.4±7.1
Level	(n=35) 30.9±7.1	(n=19) 35.6±6.1	(n=54) 32.6±7.1
Any	(n=82) 30.8±6.5	(n=59) 33.8±7.0	(n=141) 32.1±6.9

Other significant events such as substitutions, the distribution of red and yellow cards as well as the tactics employed are also worthy of future scientific research in this field and, in turn, should provide further specific detail surrounding the physical demands of soccer match-play.

2.4.7 Summary of Physical Demands of Soccer

Notational analysis provides a non-intrusive and objective method of analysis of performance (Hughes, 2003). In this respect, the use of time-motion analysis provides information as to the physical demands of match-play. Through technological advances, the methodology has developed from pen and paper analyses (Winterbottom, 1959) to more reliable and sophisticated computerised video-analysis (Ali and Farrally, 1991a). The main findings of these analyses are the total, mean±sd or percentage values for distances covered or time spent in various modes of motion. Major limitations exist with these findings as distance travelled is considered an underestimation of the physical demands of match-play through the assumption that energy is only expended when a player changes location on the pitch. In addition, often fewer than 8 modes of motion have been chosen for time-motion analysis. In contrast, a high degree of specificity is sought to reproduce the physical and physiological demands of match-play for practice situations (Barnett et al., 1973; Hill et al., 1998) and current classifications negate energy expended in high intensity non-travelling movements, unorthodox movements, turns, directions, intensities or 'on-the-ball' activity. Also, the macroscopic reporting of time-motion analyses is far removed from providing information concerning the specificity of the physical demands of 'bursts' of activity within match-play and the interaction of motions (O'Donoghue and Cassidy, 2002; O'Donoghue and King, 2003; Bloomfield et al., 2005a).

Furthermore, differences have been reported in the physical demands of players of different positions though many studies have observed relatively few subjects (e.g. Withers et al., 1982; Bangsbo et al., 1991; Miyagi et al., 1999; Rienzi et al., 2000). Also, physical effort appears to be unevenly distributed throughout the course of a match (e.g. Bangsbo et al., 1991; Rebelo et al., 1998; Mohr et al., 2003; Bloomfield et al., 2004d; Mohr et al., 2004). This has usually been associated with fatigue although it also seems that significant match events such as the scoring of a goal (and perhaps its timing) has an effect on the physical demands of match-play (O'Donoghue and Tenga, 2001; Bloomfield et al., 2004c, d).

2.5 Bioenergetics of Soccer

2.5.1 Pattern of Exercise

Due to the irregular intermittent nature of randomised periods of exercise and recovery varying in frequency, intensity and duration, soccer has been classified bioenergetically as a multiple-sprint sport (Balsom et al., 1999). This pattern of exercise produces a hybrid of physiological stresses and requires the utilisation of each bioenergetic system (Åstrand et al., 1960; Ekblom et al., 1971; Brooks et al., 1990; Hamilton et al., 1991; Balsom and Ekblom, 1992; Balsom et al., 1992a, b; Gaitanos et al., 1993; Balsom, 1995; Tabata et al., 1996; Bangsbo, 1997; Reilly, 1997; Tabata et al., 1997; Hargreaves et al., 1998; Drust et al., 1999; Aziz et al., 2000; Drust et al., 2000b; Vuorimaa et al., 2000; Rahnama et al., 2003). The (aerobic) ability to consume a high maximum volume of oxygen (VO_{2max}), the capacity to perform brief (<6s) maximal intensity exercise (anaerobic) and repeated bouts of high intensity (anaerobic, glycolytic and aerobic) exercise over a prolonged period of time are regarded as pre-requisite physical fitness variables to successful soccer performance (Ekblom, 1986; Dawson et al., 1993; Dunbar and Power, 1995; Helgerud et al., 2001; Castagna et al., 2002a; Dunbar, 2002; Edwards and Clark, 2002; Hoff et al., 2002; Stratton, 2003). Mean heart rates during match-play correspond to approximately 80% of HR_{max} and 70% of VO_{2max} (Bangsbo, 1994a) which appears to remain at a steady-rate value indicating a predominance on energy production from aerobic pathways in an intermittent exercise pattern (Reilly, 1997). Reilly (1997) also describes the high:low intensity activity ratio interval nature of soccer as 1s:7s in terms of duration which has developed into a more specific work-rate ratio of 1s:16s:3s (high:low:rest) (Rienzi et al., 2000; Strudwick et al., 2002). More recently, Drust et al., (2000) discovered a mean number of 19 sprints within match-play which occurred every 4-5min and Strudwick and Reilly (2002) observed a change in activity every 3.5s, a bout of high-intensity activity every 60s, and a maximal effort every 4mins. However, these are general findings based on mean values and are far removed from the high level of specificity required to identify the pattern of match-play. In this respect, O'Donoghue and Cassidy (2002) reported that a programmed exercise protocol of intermittent exercise (netball) based on mean 'bursts' of high intensity activity and 'recoveries' of low to moderate intensity based on time-motion analysis proved to be ineffective in enhancing match-play specific physical fitness. To this end, a full range of 'bursts' and 'recoveries' in intermittent type sports are sought to design physical conditioning programmes that are specific to match-play (O'Donoghue and King, 2003). Consequently, ratio scales have been adapted to present data based on levels of intensity (O'Donoghue, 2003). This approach is also adopted in a study of repeated sprint activity (minimum 3 sprints with a mean recovery less than 21s between sprints) in international level field hockey, a sport with close relations to the physiological demands of soccer (Aziz et al., 2000). Repeated sprint activity was observed on 17 occasions with a mean±sd of 4±1 sprints per bout with 95% of recovery in active motion (Spencer et al., 2004). However, positional differences remain unidentified. In terms of anaerobic exercise, Bangsbo (1997) identified a total of almost 7min of high intensity activity during elite soccer matches with the most intensive exercises identified as <5s in duration and ≥100%VO_{2max} (Balsom et al., 1999). In match-play, the energy supply continuously oscillates between fuelling contractile activity during intensive exercise, and restoring homeostasis during intervening recovery (active and passive). However, the various degrees and combinations of energy system utilisation and replenishment by each player create unique complexities when employing physiological parameters to assess energy expenditure. In contrast, the physiological measurement of endurance events or strength and power exercise is more obvious due to singular energy system usage. Therefore, the investigation of energy expenditure in soccer is a highly complex process and should not be simply considered as a single discrete physiological parameter but rather the result of a combination of several ecologically valid and reliable physical and physiological measurements. To this end, it is surprising that no studies have been performed to quantify the range of patterns of exercise in soccer.

2.5.2 Multiple Repeated Sprint Activity

Several investigations have been made to distinguish the physiological and metabolic effects of intermittent exercise (Åstrand et al., 1960; Ekblom et al., 1971; Brooks et al., 1990; Hamilton et al., 1991; Ballor and Volovsek, 1992; Balsom and Ekblom, 1992; Balsom et al., 1992a, b; Balsom et al., 1993; Gaitanos et al., 1993; Balsom et al., 1994a; Balsom, 1995; Tabata et al., 1996; Bangsbo, 1997; Reilly, 1997; Tabata et al., 1997; Hargreaves et al., 1998; Drust et al., 1999; Aziz et al., 2000; Drust et al., 2000b; Nicholas et al., 2000; Vuorimaa et al., 2000; Rahnama et al., 2003). Usually, protocols include regular repeated bouts of fixed, short duration high-intensity efforts, interspersed with fixed periods of static recovery (e.g. Balsom, 1995). However, physiological responses to intermittent exercise have been shown to be sensitive to alterations in exercise to rest ratios (Christensen et al., 1960a; Ballor and Volovsek, 1992; Balsom et al., 1992b; Balsom, 1995; Vuorimaa et al., 2000). Therefore, although the information gained from these studies is of limited value in soccer due to the misrepresentation of the exercise patterns of match-play, it still provides a valuable insight into the various demands of intermittent exercise.

2.5.3 Summary of Bioenergetics of Soccer

Due to the irregular intermittent nature of randomised periods of exercise and recovery varying in frequency, intensity and duration, soccer has been classified bioenergetically as a multiple-sprint sport (Balsom et al., 1999). This pattern of exercise produces a hybrid of physiological stresses and requires the utilisation of each bioenergetic system to various extents (e.g. Balsom, 1995; Bangsbo, 1997; Reilly, 1997; Hargreaves et al., 1998; Drust et al., 1999; Aziz et al., 2000; Drust et al., 2000b; Rahnama et al., 2003). Heart rate values from match-play indicate a predominance on aerobic energy production, though total high intensity activity amounts to almost 7min with the most intensive exercises identified as <5s in duration and $\geq 100\% VO_{2max}$ (Balsom et al., 1999). In match-play, the energy supply continuously oscillates between fuelling contractile activity during intensive exercise, and restoring homeostasis during intervening recovery. However, the various degrees and combinations of energy system utilisation and replenishment by each player create unique complexities when employing physiological parameters to assess energy expenditure. This hybrid makes physiological assessment difficult to quantify. However, these assessments would be facilitated if the range of patterns (duration and intensity) of the physical demands of exercise in soccer was identified through time-motion analysis.

2.6 Physiological Demands of Soccer

Several invasive methods have been utilised to quantify the physiological demands and energy expenditure of match-play through procedures including heart-rate monitoring (e.g. Van Gool et al., 1983; Ali and Farrally, 1991b; Dip et al., 1993; Drust and Reilly, 1995; Florida-James and Reilly, 1995; Impellizzeri et al., 2005), oxygen consumption (e.g. Ogushi et al., 1991; Miyagi et al., 1995) blood analysis (Tumilty et al., 1988; Bangsbo, 1990; Bangsbo et al., 1991; Miyagi et al., 1995; Castagna et al., 2002b), metabolism (e.g. Bangsbo, 1994e, a; Ekblom and Williams, 1994; Hargreaves, 1994), body temperature (e.g. Ekblom et al., 1971; Rico-Sanz et al., 1996; Mohr et al., 2004), muscle glycogen levels (e.g. Jacobs et al., 1982; Kirkendall, 1991, 1993; Hargreaves, 1994; Balsom et al., 1999; Rico-Sanz et al., 1999a; Rico-Sanz et al., 1999b) and levels of hydration (e.g. Miles et al., 1992; Maughan and Leiper, 1994; Davies et al., 1995; Rico-Sanz et al., 1996; Burke and Hawley, 1997; Reilly, 2002). However, due to the complex nature of soccer match-play, it has proven difficult to provide accurate measurements and several limitations exist within the methodologies. In conjunction with data provided by studies of the physical demands, physiological data may also influence the nutritional, conditioning and recovery strategies of players (e.g. Gerisch et al., 1988; Shephard, 1990; Kirkendall, 1993; Ekblom and Williams, 1994; Hargreaves, 1994; Maughan and Leiper, 1994; Davies et al., 1995; Bangsbo, 1999; Drawer and Fuller, 1999; Bangsbo, 2000a, b; Maguire and Pearton, 2000; Mujika et al., 2000; Reilly and Williams, 2003; Polman et al., 2004).

2.6.1 Heart Rate

Measurements of heart rate during soccer match-play have been taken to assist in the assessment of the physiological demands of soccer (e.g. Impellizzeri et al., 2005). The method is also widely accepted as a useful practice for monitoring intensity of play

(Van Gool et al., 1983; Barnsley and Thompson, 1988; Van Gool et al., 1988; Ali and Farrally, 1991b; Dip et al., 1993; Helgerud et al., 2001; Hoff et al., 2002; Achten and Jeukendrup, 2003b; Carling and Le Gall, 2004; Scott, 2004). A summary of measurements taken during practice, friendly and competitive matches and from a diverse range of competition levels are presented in Table 11. The mean values reported during match-play appear to correspond to approximately 70% of VO_{2max} (Bangsbo, 1994a) and 80% of HR_{max} which appear to remain as a steady-rate value indicating a predominance of energy production from aerobic pathways which relate closely to total distance covered (Dip et al., 1993; D'Ottavio and Castagna, 2001b; Krustrup and Bangsbo, 2001; Krustrup et al., 2002; Foster et al., 2003; Thatcher and Batterham, 2004).

Table 11: Summary of heart rates during practice, friendly and competitive matches from a diverse range of competition levels.

Source	Details	N	Position/Time phase	Mean Heart Rate ($b \cdot min^{-1}$)
Seliger, (1968b)	Model 10min match	-	-	160
Seliger, (1968a)	Sample 10min match	-	-	165
Agnevik, (1970)	Swedish match	-	-	175
Van Gool et al., (1983)	Belgian University Match	50	Central Defenders	155.3±11.4
		71	Full Backs	154.5±16.0
		58	Midfielders	169.7±9.2
		53	Strikers	171.1±13.5
Reilly, (1986)	English League – friendly matches	-	-	157
Rohde and Espersen, (1988)	Danish Division One Players, Training matches	-	-	74% HR_{max} (68% of match).
	RHR = ~60 $b \cdot min^{-1}$; No HR_{max} data			91% HR_{max} (4% of match).
	Danish Division One Players, Competitive matches	-	-	77% HR_{max} (68% of match).
	RHR = ~60 $b \cdot min^{-1}$; No HR_{max} data			91% HR_{max} (26% of match).
Van Gool et al., (1988)	Belgian University Match	7	1st Half	169 (86.7% HR_{max})
			2nd Half	165 (84.7% HR_{max})
Ali and Farrally, (1991b)	University friendly match	-	University	169
Ogushi et al., (1991)	University friendly match	2	Player 1 & 2	160 (80%HR_{max}) & 161 (83% HR_{max})
Tumilty, (1993a)	Australian International U17	16	-	173 (87% HR_{max})
Florida-James et al., (1995)	Competitive match	-	-	161
Bangsbo, (1994a)	Competitive match	-	-	171

However, values taken during intermittent exercise may be elevated in a manner disproportionate to oxygen uptake (Tumilty, 1993b; Balsom et al., 1994a; Balsom et al., 1994b; Lothian and Farrally, 1995; Tabata et al., 1997; Drust et al., 2000b). As a consequence, contrary to the underestimation provided by measuring distance covered, heart rate data collected from match-play represents an overestimation of physical exertion. This is an important issue considering the unknown magnitude of overestimation which appears to be a complex issue to resolve (Bangsbo, 1994a). Considering the frequency, duration and range of motion and movements performed including accelerating, decelerating, turning and jumping and the cardiovascular drift of sustained exercise (Shephard, 1992), the infinite combination of possible effects suggests the magnitude of the overestimation is extremely difficult, if not impossible, to quantify. This is exacerbated when considering the psychological stressors such as arousal and positive and negative induced competition anxiety often causing tachycardic effects (e.g. Reilly and Walsh, 1981; MacLaren et al., 1988; Pizzi and Castagna, 2002; Helsen and Bultynck, 2004). Furthermore, estimations of mean heart rates result in a major loss of valuable information, due to the superficiality of analysis. It negates the relative individual physical fitness status of players to be considered in the estimation, and/or the correlation of both of these factors with the specific individual workloads responsible for eliciting the physiological responses.

2.6.2 Body Temperature

Rectal temperature measurements taken at mid-point and post-match in soccer have been used to provide an indication of energy expenditure in match-play. Ekblom, (1986) suggested a relative oxygen yield of 80% or more of individual VO_{2max} using the relationship between rectal temperature and continuous exercise. However, though body temperature has been shown to be related to relative energy consumption during intermittent exercise in temperate climates (Åstrand et al., 1960), intermittent exercises have also been proven to elicit higher temperatures than continuous exercise at the same level of oxygen consumption (Christensen et al., 1960b; Ekblom et al., 1971; Balsom, 1995). Although recently, Drust et al., (2000b) found contrasting evidence to suggest that there was no significant difference in the rectal temperature values between soccer specific intermittent and continuous treadmill protocols. In this respect, the lack of evidence suggests this is yet to be established as a reliable method of assessing energy expenditure. Table 12 provides a summary of the findings of Ekblom (1986).

Table 12: Measurements of rectal temperature (T°C) made during soccer match-play (Ekblom, 1986).

Level of Play	Temperature (°C)
Swedish Division 1	39.5 ± 0.3
Swedish Division 2	39.2 ± 0.4
Swedish Division 3	39.0 ± 0.4
Swedish Division 4	39.1 ± 0.4
In conditions of 20°C (air temperature), 7.2% recorded temperatures >40°C	

2.6.3 VO_2

A relatively high VO_{2max} is considered to be an important factor in soccer performance as a strong relationship ($r = 0.89$) exists with total distance covered in match-play as well as an influence upon the frequency of sprints and the ability to resist deterioration in sprint performance (Smaros, 1980; Dawson et al., 1993; Reilly, 1994b, 1997; Wadley and Le Rossignol, 1998; Aziz et al., 2000; Helgerud et al., 2001; Hoff et al., 2002; Achten and Jeukendrup, 2003b). Periods of high intensity activity (HIA) and active recovery account for the majority of energy expenditure through elevated demands of the cardiovascular system and increases in blood lactate concentration (Ekblom, 1986; Tumilty et al., 1988; Bangsbo, 1990; Bangsbo et al., 1991; Bangsbo, 1994a; Miyagi et al., 1995; Reilly, 1997; Drust et al., 2000b; Castagna et al., 2002b;

Ebine et al., 2002; Foster et al., 2003). Van Gool et al., (1988) report mean heart rates for the first and second half which have been converted to a VO_2 of 51.1 and 46.2 ml•kg^{-1}min^{-1} respectively (Bangsbo, 1994a). However, it has been established that heart rate values provide an overestimation of energy expenditure and therefore these values of VO_2 are unlikely to be a true reflection of aerobic energy requirements through the HR-VO_2 regression calculation (Reilly, 1997). Direct measurements provide more accuracy although the method is limited due to the inhibition of full involvement in match-play (Kawakami et al., 1992; Reilly, 1997). As a consequence, wide levels of VO_{2max} and estimated total energy expenditure (Kcal) have been reported in the literature and are provided in Table 13.

Table 13: Oxygen uptakes and estimated energy expenditure during friendly and competitive matches.

Source	Protocol	Oxygen Uptake ($ml \cdot kg^{-1} min^{-1}$)	Total Energy Expenditure (Kcal)
Yamaoka, (1965)	Direct Measurement	-	693
Covell et al., (1965)	-	-	468-954
Durnin and Passmore, (1967)	Direct Measurement	-	450-1080
Seliger, (1968a)	Direct measurement: Elite Czech, Model 10min game	3.18	1240
Seliger, (1968b)	Direct measurement: Elite Czech, Sample 10min game	35.5	1180
Van Gool et al., (1988)	$HR\text{-}VO_2$ regression analysis: Belgian University Match	42.9 - 63.4	-
Ogushi et al., (1991)	$HR\text{-}VO_2$ regression analysis: University Friendly Match	47 – 49	-
	Direct Measurement: University Friendly Match	35-38	-
Shephard, (1992)	Equations based on steady aerobic activity: Based on 75% VO_{2max}, (61 $ml \cdot kg^{-1} min^{-1}$) body mass 76kg	72.8	1205 - 1565

2.6.4 Blood Analysis

2.6.4.1 Levels of Lactate

Wide variations of blood lactate concentrations during match-play have also been witnessed with peak values at times higher than 12mmol•l^{-1} at elite levels (Ekblom, 1986; Bangsbo et al., 1991; Miyagi et al., 1995; Reilly, 1997). However, only slight differences have been established between first and second half concentrations at elite levels with a typical reduction of <2mmol•l^{-1} from samples taken at the end of each half. However, the activity in the 5min period prior to sampling is considered important and is difficult to standardise (e.g. Carli et al., 1986; Gerisch et al., 1988; MacLaren et al., 1988; Rohde and Espersen, 1988; Bangsbo et al., 1991; Tumilty, 1993b). In addition, due to lower levels of high intensity activity in the second half, aerobic metabolism may also facilitate a higher rate of removal from the blood thus rendering skewed results. Consequently, analysis of blood lactate during match-play appears to be an inefficient method of quantifying total energy expenditure (Mohr et al., 2005) A summary of findings is presented in Table 14.

2.6.4.2 Levels of Ammonia, Hypoxanthine and Uric Acid

Evidence suggests that concentrations of the body's waste products increase during soccer match-play (Bangsbo, 1994a). This is due to the activation of deaminase reaction of adenylate kinase and adenosine monophosphate and supported by elevated levels of the inosine monophosphate degradation product, hypoxanthine, in the blood during match-play. Furthermore, higher levels of uric acid have been recorded post-match which has been related to the oxidisation of hypoxanthine (Bangsbo, 1994a). However, similar to blood lactate analysis, the activity in the previous 5mins to sample is considered important and is therefore another inefficient method of quantifying total energy expenditure of soccer match-play.

Table 14: Blood lactate measurement during and after soccer match-play.

Source	Details	Time	Blood Lactate (mmol/L)
Smaros, (1980)	Match-play	1st half/2nd half	4.9±1.6/4.1±1.3
Ekblom (1986)	Elite Swedish National	1st half/2nd half	~3/~14
	Division 1	1st half/2nd half	9/7
	Division 2	1st half/2nd half	8/6
	Division 3	1st half/2nd half	5/6
	Division 4	1st half/2nd half	4/3.8
Carli et al., (1986)	Match-play	1st half/2nd half	1.5 – 4.0
Rohde et al., (1988)	Match-play	1st half/2nd half	5.1±1.6/3.9±1.6
Gerisch et al., (1988)	German, top amateurs	1st half/2nd half	5.6±2.0/4.7±2.2
	German Elite	1st half/2nd half	5.65/6.06
Maclaren et al., (1988)	4-a-side	Post match	4.5
	Recreational	Post match	5.87
	Competition	Post match	5.5
Tumilty et al., (1991)	National Junior level	Post match	2.4
Bangsbo et al., (1991)	Danish Professional	1st half/2nd half	4.9/3.7

2.6.5 Metabolism

It has been suggested that the mean relative energy expenditure in soccer is approximately 70% VO_{2max} corresponding to an energy production of ~5700KJ (1360Kcal) for a 75kg player with a VO_{2max} of 60 $ml \cdot kg^{-1} min^{-1}$ (Bangsbo, 1994a). However, this negates the excess of energy requirements of locomotion over 11km or the expense from associated soccer specific activities (Reilly, 1997). This would indicate that the calculation of energy expenditure through rates of metabolism provides only a simplistic estimation of total energy cost.

2.6.5.1 Levels of Glycogen

The dominant substrates to provide fuel for the body are carbohydrate and fat. Carbohydrate is stored in muscle (300-500g) and liver (50-100g) as glycogen. In addition, a further amount (5g) is circulating in the blood as glucose. Muscle glycogen appears to decrease rapidly during match-play with mean thigh muscle concentrations ranging from 96mmol•kg^{-1} pre-match, 32mmol•kg^{-1} at half-time and 9mmol•kg^{-1} post-match (Saltin, 1973). In addition, post match reductions of 63% (Jacobs et al., 1982), 50% (Leatt and Jacobs, 1989) and complete depletion (Karlsson et al., 1972) have also been recorded. Saltin (1973) stresses the importance of high levels of pre-match glycogen and reports of use of glucose polymer supplements reduced the typical decrement seen in 2nd half distance covered and fatigue experience in tournaments (Foster et al., 1986; Kirkendall, 1993). It is also reported that the consumption of glucose in food and drinks has a sparing effect on stores of muscle glycogen (Leatt and Jacobs, 1989; Shephard, 1990; Bangsbo et al., 1992; Nevill et al., 1993; Nicholas et al., 1995; Zeederberg et al., 1996; Ostojic and Mazic, 2002; Achten and Jeukendrup, 2003a) and positive effects on performance after consumption of a maltodextrin solution in soccer players have been reported (Miles et al., 1992; Ostojic and Jorga, 2003). However, there appears to be no relationship between glucose consumption and the execution of soccer skills (tackling, heading, dribbling and shooting) late in a match (Zeederberg et al., 1996) questioning the efficacy of using this as a method of quantifying energy expenditure within match-play.

2.6.5.2 Oxidation of Fat

Bangsbo (1994a) observed increases in the concentration of fatty free acids in the blood during soccer match-play, with higher levels reported in the second half. Large uptakes of glycerol by various tissues were reported with the most predominant uptake by the liver (Bangsbo, 1994a). This suggests that higher levels of energy expenditure occur in intermittent type exercise than continuous exercise at relative intensity due to the splanchnic blood-flow in periods of rest during match-play (Ahlborg and Felig, 1982; Ahlborg et al., 1986). Consequently, levels of glycerol may represent a gluconeogenic precursor during soccer. However, intramuscular lipolysis complicates the evaluation of fat metabolism (Essén et al., 1977; Kang et al., 2004). Ketone bodies may also play a role in providing a source of energy from fat oxidisation although evidence suggests this is of only minor significance in exercise and is not a useful evaluative method. (Katz et al., 1986; Hargreaves et al., 1998). Although depletion of glycerol may be a useful general measurement of expenditure, it plays no role in anaerobic exercise and therefore underestimates total energy expenditure.

2.6.5.3 Levels of Hydration

Dehydration contributes to symptoms of fatigue and can have a negative influence on match-play towards the end of the match (Reilly, 1997). Typically, an approximate reduction of 2L is observed (Maughan and Leiper, 1994; Davies et al., 1995; Burke and Hawley, 1997; Meir and Murphy, 1998) which can be exacerbated when playing in hot and/or humid conditions (Reilly, 2003a). Fluid loss of 3.1% body mass has been reported during a match at 33°C and 40% humidity with similar reductions reported at 26.3°C and 78% humidity (Mustafa and Mahmood, 1979). Furthermore, players who have higher rates of sweat production often experience higher levels of fatigue at the end of a match resulting in lower levels of performance (Reilly, 1997). To this end, Maughan and Leiper (1994) have proposed a strategy for rehydration through a process of monitoring body mass pre and post-exercise and consumption of carbohydrate-electrolyte drinks whereas it has also been suggested to adopt a strategy of hyperhydration, particularly in hot and humid climates (Rico-Sanz et al., 1996). Overall, measurement of fluid loss is a useful method for estimating physical exertion and provides information surrounding homeostasis, although far removed from providing an accurate assessment of energy expenditure.

2.6.7 Levels of ATP and Creatine Phosphate

Although the majority of energy for soccer performance is provided by the aerobic pathways (Smaros, 1980; Bangsbo, 1994a; Reilly, 1997), critical high intensity movements such as sprinting or jumping (Yamanaka et al., 1988; Balsom and Ekblom, 1992; Balsom et al., 1999; Nicholas et al., 1999; Aziz et al., 2000; Mujika et al., 2000; Rienzi et al., 2000; Wragg et al., 2000; Mohr et al., 2003; Rahnama et al., 2003) are performed through utilisation of ATP and creatine phosphate (CP) (Karlsson et al., 1972). Therefore, overall degradation of CP and stored ATP can also provide information as to the high intensity energy requirements of soccer. However, as long duration periods of low intensity exercise also occur within match-play, CP is rapidly resynthesised, therefore affecting the concentration during match-play and thus limiting the use of the method (McMahon and Jenkins, 2002).

2.6.8 Physiology of Soccer-Specific Movement and Positional Differences

The unorthodox movements that are performed in soccer such as backward and sideways movements also provide a higher exertional cost than forward movement (Reilly and Bowen, 1984; Williford et al., 1998). The frequent alteration of acceleration, deceleration, angular runs, and changes of direction, jumps, contests for possession, tackling and evasion provides further complexity to the assessment of physical performance. Reilly and Bowen (1984) reported disproportional increases in energy expenditure at a variety of speeds between forward, backward and sideways movement. Williford et al., (1998) quantified the cardiorespiratory relationship identifying that sideways movements produce the highest energy cost and backward and sideways movements were more demanding than forward movements. This was the case for measurements of VO_2, ratings of perceived exertion (RPE) (Borg, 1998), heart rate and respiratory exchange ratio. Table 15 provides a summary of the findings of these studies.

Table 15: Exertional costs of three different linear modes of motion (Reilly and Bowen, 1984; Williford et al., 1998).

Source	**Measurement**	**Speed (km h^{-1})**	**Strikers**	**Backwards**	**Sideways**
Reilly and Bowen, (1984)	kJ min^{-1}	5	37.0 ± 2.6	44.8 ± 6.1	46.6 ± 3.2
	RPE (20 Point Scale)	5	6.7 ± 0.1	8.6 ± 2.0	8.7 ± 2.0
	kJ min^{-1}	7	42.3 ± 1.7	53.4 ± 3.5	56.3 ± 6.1
	RPE (20 Point Scale)	7	8.0 ± 1.4	11.2 ± 2.9	11.3 ± 3.2
	kJ min^{-1}	9	50.6 ± 4.9	71.4 ± 7.0	71.0 ± 7.5
	RPE (20 Point Scale)	9	10.2 ± 2.1	14.0 ± 2.0	13.8 ± 2.5
Williford et al., (1998)	Ml•kg^{-1}min^{-1}	8.5	12.42 ± 2.29	15.95 ± 2.45	22.10 ± 4.76
	L•min^{-1}	8.5	0.83 ± 0.16	1.06 ± 0.15	1.46 ± 0.30
	RER	8.5	0.77 ± 0.06	0.90 ± 0.06	0.90 ± 0.09
	Heart Rate (Beats•min^{-1})	8.5	113 ± 10	132 ± 16	140 ± 15
	RPE (20 Point Scale)	8.5	8.5 ± 1.7	9.2 ± 2.2	10.6 ± 2.1
	Ml•kg^{-1}min^{-1}	13.4	27.15 ± 2.50	31.33 ± 5.77	32.58 ± 5.74
	L•min^{-1}	13.4	1.83 ± 0.35	2.11 ± 0.36	2.16 ± 0.38
	RER	13.4	0.81 ± 0.06	0.97 ± 0.06	1.01 ± 0.08
	Heart Rate (Beats•min^{-1})	13.4	146 ± 7	168 ± 11	169 ± 10
	RPE (20 Point Scale)	13.4	10.6 ± 2.4	11.7 ± 2.5	13.2 ± 2.3

In terms of positional differences, several studies have reported that defenders (specifically full-backs) travel furthest in unorthodox modes of motion during match-play followed by strikers and finally midfielders (Reilly and Thomas, 1976; Withers et al., 1982; Rienzi et al., 2000). Perhaps more appropriately, Bangsbo et al., (1991) reported the %time spent in unorthodox modes of motion accounted for 1.6% of performance of all players. The contributions by players of different playing positions were strikers (2.1%) followed by midfielders (1.4%) and defenders (1.3%). This suggests that players should have a dynamic movement repertoire which should be incorporated into skill development and conditioning regimens. This is aided by a conditioning method for speed (acceleration), agility (a complex chains of movement skills) and quickness (overcoming inertia) known as SAQ® which has proven effective in the conditioning of soccer players (Pearson, 2001b; Polman et al., 2004)

2.6.9 Physiological Performance Demands of Soccer and Positional Differences

An important consideration when assessing the physical demands of soccer are the specific match activities that are performed. The fundamental skill of dribbling has been shown to provide an additional exertional cost with the skill of one touch every three strides increasing linearly with faster running speeds with a constant rise of $5.2kJ.min^{-1}$ (Reilly and Ball, 1984). Essentially, when dribbling a ball under close control stride length patterns reduce, stride frequency increases and agility movements are incorporated to evade opponents. Alternatively, when dribbling in full stride, the player will often have to regulate the stride pattern to maintain control of the ball within the boundaries of the playing surface. Kawakami et al., (1992) provide further evidence through direct measurement of VO_2 reporting a value of $4.0lmin^{-1}$ for dribbling and values of $2.0\text{-}4.0lmin^{-1}$ for common training drills (1 Vs 1; 3 Vs 1). Further activities such as slide tackling, powerful heading, and long passing also provide an extra physiological stress to the player which appears to be difficult to quantify (Bangsbo, 1994a)

Different playing positions have specific roles to perform within match-play which regularly involve different specific activities. For example, strikers and central defenders are significantly more engaged in situations where they have to jump or are required to head the ball whereas defenders tend to make more tackles (Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo, 1994a; Di Salvo and Pigozzi, 1998; Wells and Reilly, 2002). Table 16 provides a summary of findings for the performance for different playing positions.

2.6.11 Summary of Physiological Demands of Soccer

Several physiological assessments have been made to investigate the demands of soccer match-play (e.g. Smaros, 1980; Van Gool et al., 1988; Balsom and Ekblom, 1992; Balsom, 1994; Bangsbo, 1994e, d; Drust et al., 1998; Mohr et al., 2003). However, most measurements appear to be limited in their value, mainly due to the lack of uniformity of the demands of the three bioenergetic systems. Consequently, it may be suggested that many physiological measurements of match-play lack validity and reliability. In this respect, heart rate and VO_2 values provide an overestimation of energy expenditure of variable magnitude due to high outputs recorded when a player recovers from sustained high intensity activity (e.g. Tumilty, 1993b; Balsom et al., 1994a; Balsom et al., 1994b; Lothian and Farrally, 1995; Drust et al., 2000b).

Table 16: Performance contributions by players of different positions (N = number of players).

Source	Measure	N	Pos/Level	Touches	Shots	Headers	Jumps	Turns	Tackles
Reilly & Thomas (1976)	Mean (Range)	40	All	5.3 (0-14)	1.4 (0-6)	-	15.5 (0-38)	-	-
Withers et al., (1982)	Mean±se	20	All	51.4±11.4	-	9.9±5.7	9.49±6.5	49.9±13.0	13.1±5.3
		5	Defenders	53.4±4.7	-	13.4±6.8	11.8±8.3	52.8±17.3	14.4±2.1
		5	Full backs	50.6±13.2	-	8.0±1.7	7.3±3.3	60.0±6.5	13.2±3.0
		5	Midfielders	48.2±19.0	-	5.2±3.1	5.0±4.4	44.3±9.1	13.0±8.5
		5	Strikers	53.2±5.7	-	13.0±6.0	13.3±7.3	42.3±11.7	11.8±6.5
Bangsbo et al., (1991)	Mean±se	14	All 1st Half	-	-	5.1±1.3	-	-	5.8±1.0
			All 2nd Half	-	-	3.8±1.0	-	-	5.1±0.8
		4	Defenders	-	-	6.3±2.0	-	-	13.0±2.3
		7	Midfielders	-	-	8.4±1.8	-	-	10.5±2.3
		3	Strikers	-	-	11.2±3.6	-	-	9.9±1.8

Also, inconsistent findings have been reported for body temperatures and substrate values found within the body (e.g. Ekblom et al., 1971; Bangsbo, 1994a; Mohr et al., 2004). Additionally, this information is limited to providing overall energy costs through regression analysis and should account for individual variability and environmental constraints which is problematic when assessing inter and intra-subject differences. To this end, levels of waste products from exercise such as blood lactate, ammonia, hypoxanthine and uric acid are affected by activity levels approximately 5mins prior to sample (e.g. Carli et al., 1986; Gerisch et al., 1988; MacLaren et al., 1988; Rohde and Espersen, 1988; Bangsbo et al., 1991; Tumilty, 1993b). Furthermore, a value for overall energy expenditure is in itself a limitation as it negates any specific detail of the performance. Therefore, the requirement to obtain a detailed analysis of the physical demands of soccer is unprecedented. To this end, higher physiological costs have been observed in unorthodox movements such as backward running and lateral movement (Reilly and Bowen, 1984; Williford et al., 1998) as well as increased exertions in the execution of specific skills such as dribbling (Reilly and Ball, 1984). Different playing positions also have specific roles to perform within match-play requiring different energetic costs. For example, strikers and central defenders are significantly more engaged in situations where they have to jump or are required to head the ball whereas defenders tend to make more tackles (Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo, 1994a; Di Salvo and Pigozzi, 1998; Wells and Reilly, 2002). Match-play detail of these major parameters is scarce as well as the identification of any specific positional energetic differences. In order to allow for progression in physiological match-play research, it appears fundamental to perform a thorough investigation into the specificities of the physical demands.

2.7 Physical Conditioning in Soccer

Fundamentally, soccer players require a high aerobic capacity (Smaros, 1980; Dawson et al., 1993; Reilly, 1994b, 1997; Wadley and Le Rossignol, 1998; Aziz et al., 2000; Helgerud et al., 2001; Hoff et al., 2002; Achten and Jeukendrup, 2003b), muscular strength and endurance (Cabri et al., 1988; Taiana et al., 1988; Cabri et al., 1991; Cabri and Clarys, 1993; Wisløff et al., 1998; Odetoyinbo, 2004; Wisløff et al., 2004), speed, speed endurance and agility (Ali and Farrally, 1991a; Balsom and Ekblom, 1992; Mujika et al., 2000; Yap et al., 2000; Buttifant et al., 2002; Ostojic, 2004; Polman et al., 2004) and flexibility (Leatt et al., 1987; Ackland and Bloomfield, 1996; Bloomfield and Wilson, 1998; Hawkins and Fuller, 1998). A holistic approach must therefore be adopted to physical fitness development. Moreover, when considering the volume of fixtures at elite levels, the demands of the coaching staff for physical based technical and tactical practices and the potential for overtraining and burnout (Hawley and Schoene, 2003), the conditioning regime must be carefully constructed to be highly effective. The interaction of multiple dynamic physical activities often produces a hybrid of physiological and biomechanical stresses. Furthermore, higher levels of soccer require increased levels of physical fitness through the increased physical and physiological demands from repeated high intensity activity (Balsom and Ekblom, 1992; Di Salvo and Pigozzi, 1998; Mujika et al., 2000; O'Donoghue et al., 2001; Strudwick et al., 2002).

Few significant scientific studies have been conducted to investigate effective methods of soccer-specific physical conditioning (Di Salvo and Pigozzi, 1998; Wisløff et al., 1998; Helgerud et al., 2001; Hoff et al., 2002; Polman et al., 2004; Thatcher and Batterham, 2004). To this end, only one study has used data collected from time-motion analysis to create a soccer-specific exercise protocol (SSEP) (Thatcher and Batterham, 2004). This was based on the distances covered (km) by players in match-play and use of a non-motorised treadmill. Validity was ascertained through measurement of physiological variables (heart rates, capillary blood and expired air samples and RPE). The findings of this study suggest that the SSEP forwarded induced a similar physiological load to soccer match-play. However, as many limitations exist surrounding physiological measurements of intermittent exercise and use of values of distance covered (km), the SSEP is far removed from the specific physical demands of soccer match-play. This would imply that other methods of conditioning may be more suitable to enhance specific aspects of soccer fitness. In this respect, two main methods of conditioning (programmed and random) have been identified (see: Bangsbo, 1994b, c) and recognised as credible methods of conditioning for soccer (Hoff et al., 2002). In both circumstances, each method follows the basic principles of conditioning (specificity, overload, overcompensation, progression, reverse effects, recovery and individual responses to training) (Briggs, 2001; Hoffman, 2002; Kilvan, 2003). Programmed conditioning (PC) is a method in which all participants are exposed to the same stress through specific extrapolated aspects of match-play (e.g. soccer dribble intervals). Also, PC is suitable for all aspects of soccer conditioning and measurable through distance, frequency, speed and time. Random conditioning (RC) methods are more laissez-faire in their approach and involve all participants being exposed to overloading stresses of varying extents within each session (e.g. small-sided games) though RC is perhaps unsuitable for some of the aspects of soccer conditioning including strength and flexibility. RC is comprised of manipulations of match-play and is therefore a highly specific form of soccer exercise, though measurement and standardisation is more complex. The subtle difference between the two methods is that PC requires a fitness specialist to directly deliver, control and take responsibility for administering overload throughout each session to each participant, whereas in RC the participant is individually responsible for overload. However, in RC the fitness specialist indirectly creates the overload through manipulation of pitch size, number of participants, frequency and duration of games and the addition of special rules to promote a higher work rate (Bangsbo, 1994b, c). Furthermore, PC methods provide ongoing obvious and instant feedback during each session, whereas RC methods may be more difficult to quantify instantaneously. An example of use of these methods is that of the periodised conditioning programme that prepared the Korean National Team for the FIFA World Cup in 2002 (Verheijen, 2004). All endurance conditioning was completed in the form of random conditioning and supplemental sprint conditioning was performed in a programmed and controlled manner. Emphasis was placed upon extensive endurance conditioning through multiple (3-9) 10min periods of 11v11 and intensive endurance conditioning through multiple (5-9) 8min periods of 7v7 with 2min recoveries between all periods of match-play. Extensive interval conditioning was conducted through 2 series of 6-10 3min periods of 3v3 and a range of recoveries between periods (1-3min) and 4min rest period between series. Repeated sprint ability was conditioned through 2-4 series of 6-10 15m maximal efforts against an opponent and incorporated a shooting drill on goal. Recovery between efforts was consistent at 10s and 4min rest periods were held between series. Finally, maximum sprinting ability was enhanced through 2-4 series of 8-10 5m sprints with an opponent and also incorporated a shooting practice. A longer recovery period of 30s was determined between efforts and again, 4min rest periods were adhered to between series. Korea finished fourth in the tournament, twice playing through extra-time and was widely complimented in the media for their high-tempo style of play and high levels of physical fitness demonstrated by all members of the squad.

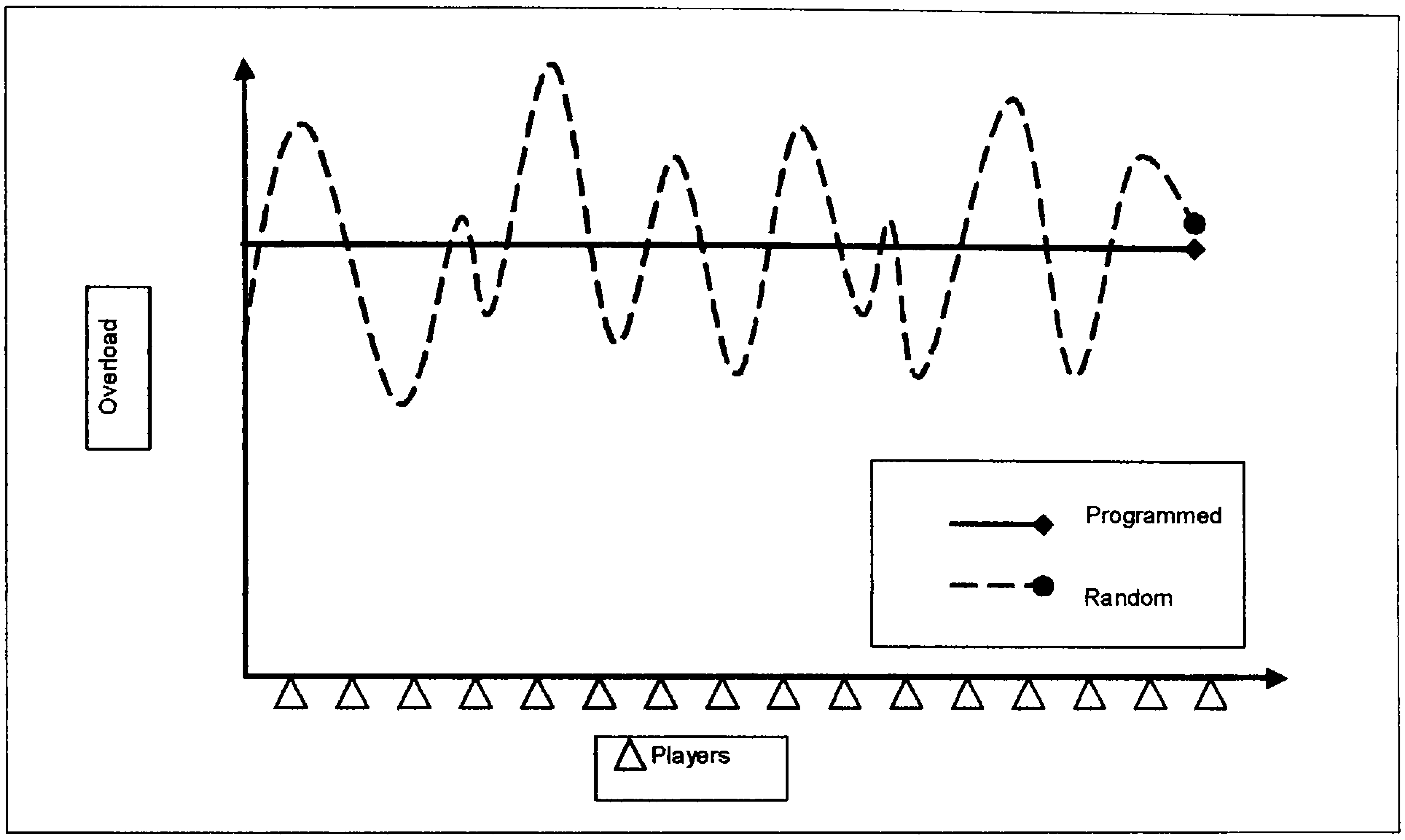
2.7.1 Programmed Conditioning Methods

Programmed physical conditioning methods have proved successful in preparing soccer players for match-play (Bangsbo, 1994c; Yap et al., 2000; Helgerud et al., 2001; Hoff et al., 2002; Hoff and Helgerud, 2004). Interval training (4 x 4min @90-95% max HR twice a week for eight weeks) has been shown to improve soccer performance by increasing the distance covered in match-play, enhancing work intensity, increasing the number of sprints and direct match-play activity (Helgerud et al., 2001). Also improvements were observed in the jump performance of soccer players after a 10 week loaded vertical jump programme of PC (Gauffin et al., 1989). More recently, SAQ® (Speed, Agility, Quickness) (see: Pearson, 2001b, a; Pearson et al., 2002) has been validated as an effective conditioning method for elite female soccer players (Polman et al., 2004). Developed in the USA and made popular in American Football in the 1980s, the method involves a system of progressive exercises with instruction aimed at developing fundamental abilities to enhance the capabilities of dynamic sport athletes to be more skilful at faster speeds and with greater precision (Pearson, 2001b). Through SAQ® conditioning, it is thought that athletes may become more able to react to stimuli, start more quickly and efficiently, move effectively in multi-directions, and prepared to change direction or stop quickly to make a play in a fast, smooth, efficient, and repeatable manner (Brown et al., 2000; Pearson, 2001b). It is claimed that these improvements come through developing athletes' acceleration and speed over short distances, deceleration and changes in direction, footwork patterns, movement responses, arm action, as well as linear, lateral, diagonal, and vertical movements (Brown et al., 2000; Pearson, 2001b). However, statements regarding the efficacy of SAQ® conditioning are purely subjective and essentially lack empirical evidence to support the claims made by the licensed SAQ® commercial organisations. In addition, there is also a fundamental lack of understanding regarding the underlying mechanisms to the theory of the SAQ® conditioning regime.

2.7.2 Random Conditioning Methods

Random physical conditioning methods have also proven to be effective in preparing soccer players from match-play (Bangsbo, 1994b, c; Allen et al., 1997; Luxbacher, 2003; Jeffreys, 2004; McCarry, 2004; Owen et al., 2004; Chamari et al., 2005). RC can provide a high degree of match-play specificity although in a trade-off with full control of the coach over the conditioning and prescribed overload. However, as the conditioning is essentially skill-based, a degree of skill development may even be possible to achieve under conditions of physical fatigue (Chamari et al., 2005). In this respect, Allen et al., (1998) identified that 5-a-side soccer on a pitch 1/3 the size of a standard 11-a-side surface provides a suitable physical and physiological overload for 11-a-side match-play with significant increases in high intensity and direct soccer activity. In addition, MacLaren et al., (1988) discovered similarly elevated levels of high intensity activity as well as time spent in possession in 4-a-side soccer games. However, as the level of overload is ultimately voluntary, although encouraged, the coach is presented with a unique challenge to ensure all players receive an appropriate overload on the specific neurophysiological systems to instigate supercompensation (Saltin et al., 1977; Holloszy and Coyle, 1984; McFarlane, 1985; Briggs, 2001). Figure 5 proposes the levels of overload expected of players participating in programmed and random conditioning session. This model illustrates that each PC and RC session is different through levels of overload achieved by each participant. It is therefore very important to monitor levels of exertion with each conditioning session. Heart rate monitoring has been widely accepted as providing a valid measurement of intensity of match-play (Ali and Farrally, 1991b; Dip et al., 1993; Helgerud et al., 2001; Hoff et al., 2002; Achten and Jeukendrup, 2003b; Carling and Le Gall, 2004; Scott, 2004) although some limitations exist regarding the physiological measurement of intermittent exercise and this raises an issue regarding reliability. In this respect, Hoff et al., (2002) found no significant differences between programmed and random conditioning methods in terms of mean values of oxygen uptake, RER, ventilation and breathing frequency, though heart rate values were significantly higher in programmed conditioning. However, Hoff's PC protocol was based on continuous exercise in contrast to the intermittent exercise in random conditioning which has otherwise been shown to be of higher energy cost at the same level of oxygen consumption due to the splanchnic blood-flow in periods of recovery (Ahlborg and Felig, 1982; Ahlborg et al., 1986). Alternatively, time-motion analysis provides a higher degree of ecological validity and ratings of perceived exertion (RPE) (Borg, 1998) combined with exercise duration may be a superior method of monitoring high intensity intermittent exercise load (Foster, 1998).

Figure 5: Proposed levels of overload expected of players performing a programmed and random conditioning session.



2.7.3 Motor Skill Learning

Higher levels of soccer require increased levels of physical fitness resulting from the elevated demands of high intensity activity (White et al., 1988; Mangine et al., 1990; Tumilty, 1993a; Dunbar and Power, 1995; Mercer et al., 1995; Hillis, 1998; Rienzi et al., 2000; Casajus, 2001; O'Donoghue et al., 2001; Strudwick et al., 2002; Arnason et al., 2004). The dynamic nature of soccer-specific movements suggests this increase is accompanied by elevated demands to perform complex chains of movement skills (interpreted as agility) in conjuncture with speed (both acceleration and deceleration) and quickness (overcoming inertia). These fundamental skills require a co-ordinated process of perception, cognition and action. Evidence identifies that skill acquisition and skilled performance share underlying mechanisms across the perceptual, cognitive, and motor domains (Rosenbaum, 1987; Carlson and Yaure, 1990). This framework is supplemented with an attentional system that selects some sources of information for processing over others and a memory that stores vast amounts of knowledge (Ackerman, 1988). This process often involves deliberate and conscious reasoning although many cognitive actions are automatic and unconscious. Learning would suggest developing better strategies for dealing with complexity, with one method to automate more of the skill thereby reducing the attentional demands (Singer, 2002).

Learning is a process involving the acquisition of increased skill capability and has been formally defined as *"the process of acquiring knowledge, attitudes, or skills from study, instruction, or experience"* (Miller and Findlay, 1996). Athletes constantly seek to advance their capability for skilled behaviour through a series of internal processes associated with practice or experience which aim to result in relatively permanent changes. Generally, skills can be learnt from direct participation (whole) or through a process of skill breakdown (part) though skills that require a high degree of interlimb coordination are best served by whole-task practice (Wenderoth et al., 2003; Tennant and Tennant, 2004). However, it is accepted that basic introductory athletic skills should be mastered sequentially to arrive at precise task performance (Keele et al., 1998). Automaticity of basic skills in sport is essential for successful performance (Singer, 2002). As athletes learn a motor skill, the aim of subsequent executions of that skill is to require less attentional effort (Kahneman, 1973). Automatisation of the basic elements of sensory and motor control provides athletes with processing and movement efficiency which allows more concentration on specific performance information (Mechling, 1990). Skill acquisition can be better appreciated through models of motor learning (Fitts, 1964; Anderson, 1982). The three-stage model identifies cognitive and behavioural changes in skill development and imply that development occurs in a cognitive, intermediate or associative and autonomous stage. A different perspective, based on the writings of Bernstein (neo-Bernsteinian perspective), suggest that learning is a process in terms of mastering the redundant degrees of freedom. Learning a motor skill is to solve a problem of how best to harness the degrees of freedom available to the human motor system. This perspective also identifies 3 stages: novice, advance and expert (Bernstein, 1967; Vereijken, 1991).

There are several recognised principles for learning and skill acquisition which share similarities in the principles of physical conditioning (Briggs, 2001; Hoffman, 2002). For example, the principle of specificity stipulates that adaptations are limited to the specific stresses placed on the cognitive and neural networks (learning and skill acquisition) or the bioenergetic and mechanical systems (physical conditioning) (Henry, 1968; Barnett et al., 1973; Saltin et al., 1977; Sale and MacDougall, 1981; Holloszy and Coyle, 1984; Wolpaw and Carp, 1990; Morrissey et al., 1995). The basis for the specificity of learning principle is an applied two-stage model considers how conditions associated with skills influence the goals to be accomplished by a learner at each stage of the learning process (Gentile, 1972). This identifies the lack of transfer in the learning of a task in a stable environment and performance in an unstable environment. This concept identifies that the similarity of the environmental conditions and processing in practice, compared to those in transfer, has a strong influence on transfer performance (Barnett et al., 1973; Schmidt and Lee, 1999). This theory of specificity implies that skills are best learnt in the conditions they are to be performed. As athletes learn skills that are sport specific, changing the conditions in practice under which a skill is performed will require a substantial shift in the underlying abilities (Schmidt and Lee, 1999). Also, this theory indicates the sensory information used early in learning will be valuable as learning continues due to skill acquisition involving the development of modality-dependent representations of a movement (Proteau et al., 1998). In addition, neurological adaptations occur as a result of specific practice and the learning process. Structural and functional alternations have been observed within the nervous system altering the control strategies of co-ordinated movement (Brooks, 1986; Fournier and Perrot-Deseilligny, 1989; Glickstein and Yeo, 1989; Wolpaw and Carp, 1990). This suggests that certain reflexive pathways are positively altered as a function of learning.

Movement pattern specificity producing motor skills has been expressed as the fundamental constituent of any movement related to speed and power (Sale, 1992; Schmidtbleicher, 1992; Ackland and Bloomfield, 1996). Furthermore, many sporting skills require a very precise moment and direction of force application which may favour specialised equipment to enhance conditioning and facilitate learning. However, the neural pattern for the precise force application is acquired only by repetition of the desired skill (Poliquin, 1990). Thus, precise movement patterns of specific motor skills are needed to entrain appropriate motor programs effectively for efficient co-ordination of muscular contraction (Barnett et al., 1973).

2.7.4 Summary of Physical Conditioning and Motor Skill Learning

Soccer match-play requires a plethora of physical fitness abilities including a high aerobic and repeated sprint capacity (e.g. Aziz et al., 2000; Helgerud et al., 2001; Hoff et al., 2002; Achten and Jeukendrup, 2003b). In addition, muscular strength and endurance, speed, agility, quickness and flexibility are also considerable vital attributes (Wisløff et al., 1998; Polman et al., 2004; Thatcher and Batterham, 2004; Wisløff et al., 2004). It is also important for players to have a soccer-specific movement repertoire to complement the various match-play skills. To this end, considering time constraints in talent development, overtraining and burnout and maintaining skill and fitness levels, it may be optimal to combine skill development with physical conditioning as both domains share underlying principles. This provides an advantage of learning and practicing skills under specific match-play conditions (e.g. fatigue) to enhance transfer into competition and gain physical development (Barnett et al., 1973). However, it is critical that match-play demands must be thoroughly investigated to facilitate learning. In terms of practice, programmed and random learning and conditioning methods have been shown to be credible (Carlson and Yaure, 1990; Bangsbo, 1994b, c; Hoff et al., 2002). Programmed methods follow a strict plan usually based on time or distance and the coach is directly responsible for the physical overload to instigate supercompensation. Random methods usually involve a variation of 90min 11-a-side match-play with the players responsible for their personal physical overload, though the coach may facilitate this through rules of match-play. In both circumstances, levels of exertion should be monitored and assessed (Foster, 1998). Heart rate monitoring is widely accepted as a useful method though the intermittent nature of the conditioning provides an overestimation of exertion to an unknown magnitude (Reilly, 1997). Alternatively, time-motion analysis can provide an assessment to physical output and ratings of perceived exertion and exercise duration may be a more credible method of monitoring intermittent exercise.

CHAPTER THREE:

STUDY ONE:

ANALYSIS OF AGE, STATURE, BODY MASS, BMI AND QUALITY OF ELITE SOCCER PLAYERS FROM FOUR EUROPEAN LEAGUES

3.1 Introduction

Several sports require specific physical characteristics that indicate suitability for, or potential to compete in that sport at the highest level. Various anthropometric characteristics of athletes have been shown to be reasonable predictors for participation at the highest level in sports such as swimming (Ackland et al., 1993), basketball, rugby league and American football (Norton and Olds, 2000). Surprisingly, there is no research available exploring these characteristics within all four leading European soccer leagues. It might well be that the recent changes in demands in soccer (Williams et al., 1999) have been accompanied by physical characteristic changes in soccer players that have been of greater magnitude than that of the normal population. This is an important issue because even small changes in these physical characteristics of players could result in a large reduction in the pool of people to draw from in the general population who have the suitable physical characteristics to be successful in soccer as has already been observed in rugby (Olds, 2001). Furthermore, the comparison of players in different leagues and in different positions might provide some valuable information regarding the different demands placed on soccer players in different leagues (Reilly et al., 2000a; Rienzi et al., 2000; Strudwick et al., 2002).

It is well documented that different positions in soccer constitute various different demands. Such findings suggest heterogeneity in physical characteristics that might be important for success in particular positions in soccer (Ekblom, 1986; Mangine et al., 1990; Tumilty, 1993a; Bangsbo, 1994e, 1998b; Reilly et al., 2000a; Dowson et al., 2002; Ostojic, 2002; Strudwick et al., 2002). The first aim of the present study was to investigate whether there are physical differences (age, stature, body mass, body mass index) between players in different positions in the four different leagues. This will provide information into the diversity in playing style as well as the variation in what is being valued in soccer players in the various countries. This also provides information towards the adaptations of different training regimes in respect to body mass and body mass index as well as normative data for purposes of talent identification and position specific selection (Fisher and Dean, 1998; Helsen et al., 2000; Reilly et al., 2000a; Williams and Reilly, 2000; Franks et al., 2002). The second aim of the present study was to assess the quality of the players of each of the four Leagues by surveying their international status, nationality and FIFA world ranking and participation in the FIFA World Cup 2002. This will offer information regarding the actual quality of international players within these leagues which, in turn, provides information about which league would be of the highest quality, differences in playing style, talent identification and player selection. A cross-sectional analysis approach was selected as retrospective reliable data was unavailable for longitudinal analysis. As the four leading European leagues were selected for analysis, the results provide valuable information concerning the current status and possible future development of European soccer.

3.2 Materials and Methods

Data were collected concerning 2085 professional soccer players from all 76 club squads playing in the English FA Premier League, the German Bundesliga, the Italian Serie A and the Spanish Premiera Division (La Liga) during the 2001-2002 season (Wilson, 2003). Data regarding every player's age (years), playing position (goalkeeper, defender, midfielder, and striker), stature (m), body mass (kg), BMI ($kg.m^{-2}$), nationality and corresponding FIFA world ranking (www.fifa.com, 2002), number of international appearances and international goals scored were collected. Players were considered to be an international if they had obtained at least one full international cap. Therefore, retired internationals still playing club football were considered to be an international player. Table 17 provides the number of players by position for each of the four countries. Finally, it was established whether the players participated in the 2002 FIFA World Cup Finals in order to gain an assessment of the current internationals involved in each league (www.fifaworldcup.com, 2002).

Table 17: Number of subjects by playing position for each of the four countries included in the study.

Position	**FA Premier League**	**La Liga**	**Serie A**	**Bundesliga**	**Total**
Goalkeeper	68	56	60	50	234
Defender	185	167	163	150	665
Midfielder	202	201	180	164	747
Striker	123	104	96	116	439
Total	578	528	499	480	2085

It was recognised that there may be inaccuracies with the data, in particular regarding measurement of stature and body mass. There was no standardised procedure used to measure these variables so method and time of measurement are unknown. Therefore, a random sub-sample of 218 players was tested for the reliability of stature and body mass against two other secondary sources (Macias, 2002; Rollin and Rollin, 2002). There were positive correlations between the data set used in the current investigation and the alternative sources for stature (r = 0.92 and r = 0.94) and body mass (r = 0.87 and r = 0.94). The values reveal acceptable reliability according to the recommended correlations of 0.9 or above (Hopkins and Manly, 1989). Paired t-tests revealed significant differences between the data set used and each of the two alternatives for both stature and body mass. The variance in the values reported within the data set used in the current investigation and the two alternative sources was assessed using standard error of measurement (SEM). There were SEM values of 0.018m and 0.015m between the data set and the two alternative sources for stature. The data set used also had SEM values of 2.78kg and 1.74kg when compared to the two alternative sources. However, the 95% confidence limits for the SEM for stature were 0.017m to 0.021m compared to the first alternative source and 0.014m to 0.017m when compared to the second. The 95% confidence limits for the SEM for body mass were 2.54kg to 3.07kg compared to the first alternative source and 1.60kg to 1.92kg when compared to the second source. This shows that the differences between the data used in the current investigation and the two alternative sources are fairly consistent and would, therefore, have little impact on differences between positional groups or leagues. It is recognised that the measurement error in stature and body mass cause consequential inaccuracy in BMI.

A series of two-way analysis of variances tests was applied to the anthropometric variables using league and player position as between subjects' effects. Where league or position were found to have a significant influence, Bonferroni adjusted post-hoc tests were employed to compare pairs of leagues or pairs of positions. The distribution of the number of international appearances and international goals were positively skewed ($z_{Skew} = \pm16.9$ and ±48.9 respectively). This was due to most international players having a below mean number of caps and many international players (particularly goalkeepers and defenders) never having scored an international goal. Furthermore the FIFA world ranking of a player's country was also positively skewed ($z_{Skew} = \pm23.7$) and there were a restricted number of values (79 different countries) for the 874 international players. Therefore, the four leagues were compared in terms of international appearances, international goals and FIFA world ranking of the player's country using Kruskal-Wallis H tests. Nominal categories such as origin of player, international status and whether or not a player had competed in the 2002 World Cup were compared between the four leagues using frequency profiles and Chi squared test of independence. Where a Chi squared test revealed a significant different frequency profile between the leagues, the observed frequencies were compared with the frequencies expected in the frequency profile for the whole sample used and applied equally to each individual league.

3.3 Results

Table 18 illustrates the age, stature, body mass and BMI of players of different playing positions within each league. Position had a significant effect on age ($F(3,2069) = 9.0$, $P<0.001$) with Bonferroni adjusted post-hoc tests revealing that goalkeepers were significantly older than midfielders and strikers ($P<0.05$) while defenders were significantly older than strikers ($P<0.05$). There were significant differences in the stature ($F(3,2069) = 21.1$, $P<0.001$), body mass ($F(3,2069) = 31.3$, $P<0.001$) and BMI ($F(3,2069) = 15.7$, $P<0.001$) of players between the four leagues (see Table 18). Bonferroni adjusted post-hoc tests revealed that players in the Bundesliga were significantly taller and heavier than players in the other three leagues ($P<0.05$). Players in the FA Premier League were significantly taller than players in La Liga ($P<0.05$) but not Serie A and significantly heavier than players from Serie A ($P<0.05$) but not La Liga. The BMI of players in the Bundesliga and La Liga were significantly greater than that of players in the FA Premier League and Serie A ($P<0.05$). Position also had a significant effect on the stature ($F(3,2069) = 161.3$, $P<0.001$), body mass ($F(3,2069) = 171.7$, $P<0.001$) and BMI ($F(3,2069) = 15.4$, $P<0.001$) of players with Bonferroni adjusted post-hoc tests revealing significant differences between each pair of positions ($P<0.05$). The BMI of goalkeepers was significantly greater than that of all other positions ($P<0.05$) and that the BMI of midfielders was significantly lower than that of all other positions ($P<0.05$). There was a significant interaction effect of league and position on the stature ($F(9,2069) = 3.1$, $P<0.01$), body mass ($F(9,2069) = 4.1$, $P<0.001$) and BMI ($F(9,2069) = 2.5$, $P<0.01$) of players. Defenders were heavier than strikers in all leagues except in Serie A where strikers were heavier than defenders. Strikers were taller than midfielders in all leagues except La Liga where midfielders and strikers had the same mean stature and BMI. The BMI of midfielders in the Bundesliga was the same as that of defenders.

Table 18: Mean±sd of age (years), stature (m), body mass (kg) and BMI (kg.m^{-2}) of the players in the four leagues by playing position.

Position	FA Premier League	La Liga	Serie A	Bundesliga	Total
Age (years)					
Goalkeeper	28.2±5.5	27.3±4.0	27.2±6.0	26.9±5.5	27.4±5.3
Defender	26.7±4.6	27.0±4.0	26.9±4.2	26.5±4.2	26.8±4.3
Midfielder	25.6±4.6	26.4±4.2	26.2±3.8	26.7±4.5	26.2±4.3
Striker	25.6±4.8	25.6±3.4	25.3±4.4	26.6±4.2	25.8±4.2
Total	26.3±4.8	26.5±4.0	26.4±4.4	26.6±4.4	26.4±4.4
Stature (m)					
Goalkeeper	1.88±0.04	1.85±0.04	1.86±0.04	1.89±0.04	1.87±0.04
Defender	1.82±0.06	1.80±0.05	1.81±0.05	1.84±0.05	1.82±0.05
Midfielder	1.79±0.05	1.79±0.05	1.78±0.05	1.79±0.06	1.79±0.05
Striker	1.81±0.06	1.79±0.06	1.81±0.06	1.82±0.06	1.81±0.06
Total	1.81±0.06	1.80±0.06	1.81±0.05	1.83±0.06	1.81±0.06
Body mass (kg)					
Goalkeeper	86.3±6.9	81.1±4.3	79.1±5.5	85.5±6.0	82.2±6.2
Defender	76.3±6.6	75.5±5.2	74.9±4.8	78.4±5.2	76.2±5.7
Midfielder	72.0±6.0	73.6±4.6	71.7±4.4	74.3±5.4	72.9±5.3
Striker	74.6±6.5	73.8±6.4	75.2±5.3	77.2±6.1	75.2±6.2
Total	75.3±7.3	75.0±5.6	74.3±5.4	77.5±6.4	75.5±6.3
BMI (kg.m^{-2})					
Goalkeeper	23.5±1.7	23.6±1.0	22.8±1.2	23.9±1.2	23.4±1.4
Defender	23.0±1.3	23.2±1.1	22.9±1.0	23.1±1.1	23.0±1.1
Midfielder	22.6±1.4	23.0±1.2	22.7±1.1	23.1±1.0	22.8±1.2
Striker	22.9±1.5	23.0±1.2	22.9±1.0	23.3±1.1	23.0±1.2
Total	22.9±1.5	23.1±1.1	22.8±1.1	23.2±1.1	23.0±1.2

Table 19 expresses the number of foreign players as a fraction of the total number players as well as a percentage. For the FA Premier League, domestic players include players from England, Scotland, Wales, Northern Ireland and Republic of Ireland. There was no significant difference in the percentage of foreign goalkeepers ($\chi^2_3 = 6.6$, $P>0.05$) or strikers ($\chi^2_3 = 5.1$, $P>0.05$) between the four leagues. However, there was a significantly different percentage of foreign defenders (χ^2_3 = 30.2, P<0.00) and midfielders (χ^2_3 = 10.4, P<0.05) between the four leagues with a greater percentage of foreign defenders and midfielders in the Bundesliga than in the other leagues. Overall, there were significantly different percentages of foreign players between the four leagues (χ^2_3 = 37.2, P<0.001) with a greater percentage of foreign players in the Bundesliga than the other three leagues.

Table 19 also illustrates the number of international players as a fraction of all players and as a percentage of all players. There was no significant difference between the four leagues for the proportion of strikers who were international players (χ^2_3 = 2.3, P>0.05). However, the overall percentage of players who were international players did significantly differ between the leagues (χ^2_3 = 25.8, P<0.001) as did the percentage of goalkeepers (χ^2_3 = 10.9, P<0.05), defenders (χ^2_3 = 9.4, P<0.05) and midfielders (χ^2_3 = 12.7, P<0.01) who were international players. Table 19 indicates that the percentage of players who were internationals was highest in the FA Premier League, higher than expected in the Bundesliga and lower than expected in La Liga and Serie A.

Table 19: Percentage of foreign players and international players in each of the four leagues by position.

Position	FA Premier League	La Liga	Serie A	Bundesliga	Total
% of Foreign Players					
Goalkeeper	26/68	14/56	12/60	11/50	63/234
	(38.2%)	(25.0%)	(20.0%)	(22.0%)	(26.9%)
Defender	63/185	44/167	50/163	81/150	238/665
	(34.1%)	(26.3%)	(30.7%)	(54.0%)	(35.8%)
Midfielder	74/202	74/201	63/180	82/164	293/747
	(36.6%)	(36.8%)	(35.0%)	(50.0%)	(39.2%)
Striker	57/123	45/104	41/96	65/116	208/439
	(46.3%)	(43.3%)	(42.7%)	(56.0%)	(47.4%)
Total	220/578	177/528	166/499	239/480	802/2085
	(38.1%)	(33.5%)	(33.3%)	(49.8%)	(38.5%)
% of International Players					
Goalkeeper	29/68	15/56	13/60	9/50	66/234
	(42.6%)	(26.8%)	(21.7%)	(18.0%)	(28.2%)
Defender	88/185	54/167	60/163	63/150	265/665
	(47.6%)	(32.3%)	(36.8%)	(42.0%)	(39.8%)
Midfielder	107/202	74/201	73/180	79/164	333/747
	(53.0%)	(36.8%)	(40.6%)	(48.2%)	(44.6%)
Striker	63/123	49/104	40/96	58/116	210/439
	(51.2%)	(47.1%)	(41.7%)	(50.0%)	(47.8%)
Total	287/578	192/528	186/499	209/480	874/2085
	(49.7%)	(36.4%)	(37.3%)	(43.5%)	(41.9%)

Table 20 shows the origin of the 802 foreign players within the four leagues. There were significantly different profiles of foreign players between the four leagues (χ^2_{21} = 280.0, P<0.001) with more Northern European players than expected playing in the FA Premier League and more Eastern Europeans and Africans than expected playing in the Bundesliga. Table 20 also illustrates that there were considerably more South American players than expected in La Liga and Serie A.

Table 20: The geographical origin of foreign players in each of the four soccer leagues.

Origin	FA Premier League	La Liga	Serie A	Bundesliga	Total
Western Europe	66	22	29	41	158
Southern Europe	29	33	32	44	138
Northern Europe	51	7	7	18	83
Eastern Europe	14	11	14	62	101
North and Central America	14	4	0	4	22
South America	16	95	72	29	212
Africa	17	4	9	32	62
Asia and Oceania	13	1	3	9	26
Total	220	177	166	239	802

Western Europe - British Isles, Germany, Belgium, the Netherlands, Luxembourg, France, Switzerland, Austria and Liechtenstein.

Southern Europe - Italy, Spain, Portugal, Greece, Turkey, Yugoslavia, Croatia, Slovenia, Bosnia, Macedonia, Albania, Kosova.

Northern Europe - Sweden, Norway, Denmark, Finland, Iceland, Latvia, Lithuania, Estonia.

Eastern Europe - Bulgaria, Romania, Czech Republic, Slovakia, Russia, Ukraine, Moldova, Belarus, Poland, Hungary.

Table 21 represents the number of international appearances and goals scored by the 874 international players in the four leagues. One goalkeeper scored a goal while playing for his country necessitating the use of two decimal places. Kruskal-Wallis H tests revealed no significant difference between the number of international appearances made by international defenders ($\chi^2_3 = 1.4$, $P>0.05$), midfielders ($\chi^2_3 = 6.3$, $P>0.05$), or strikers ($\chi^2_3 = 5.2$, $P>0.05$) between the four leagues. There was no significant difference between the four leagues for the number of international goals scored by international players in general ($\chi^2_3 = 1.4$, $P>0.05$) or by international players of any playing position ($\chi^2_3 < 4.1$, $P>0.05$). However, there were significant differences between the four leagues for the number of international appearances made by international goalkeepers ($\chi^2_3 = 9.0$, $P<0.05$) as well as international players in general ($\chi^2_3 = 13.4$, $P<0.01$) with international players from the FA

Premier League and the Serie A having earned more caps than their counterparts in La Liga and the Bundesliga. Furthermore, international strikers in Serie A scored observably more international goals than international strikers in the other three leagues. Table 21 also illustrates the FIFA world ranking of the countries that the 874 international players represent. Kruskal-Wallis H tests revealed significant differences in the FIFA world rankings of the countries represented by international players in general within the four leagues ($\chi^2_3 = 214.3$, $P<0.001$) as well as the FIFA world rankings of countries represented by international players of each position ($\chi^2_3 > 21.8$, $P<0.001$). The international players whose countries were ranked highest were from La Liga followed by the Serie A. This was true of each position except defenders where the Serie A's international defenders came from countries with higher FIFA world rankings.

Finally, Table 22 represents the number of players from each league that competed in the 2002 FIFA World Cup. There was no significant difference between the percentage of internationals from any individual position who competed in the 2002 FIFA World Cup between the four leagues ($\chi^2_3 < 6.8$, $P>0.05$). However, there were significantly different percentages of international players in general who competed in the 2002 FIFA World Cup between the four leagues ($\chi^2_3 = 12.6$, $P<0.01$) with more international players than expected from Serie A participating and fewer internationals than expected from the FA Premier League participating.

Table 21: Mean±sd of the number of international appearances made by international players, goals scored by international players and FIFA world ranking of countries of the international players by position for each of the four countries.

Position	FA Premier League	La Liga	Serie A	Bundesliga	Total
International appearances					
Goalkeeper	26.2±29.8	9.3±8.9	32.2±28.0	15.8±18.2	22.1±25.6
Defender	25.8±24.6	25.4±28.2	27.4±29.3	21.2±22.1	25.0±25.9
Midfielder	25.3±21.6	20.3±21.1	21.0±22.3	21.0±24.3	22.2±22.3
Striker	25.0±22.6	18.6±18.7	23.8±21.3	16.7±15.9	21.0±20.0
Total	25.5±23.5	20.4±22.4	24.4±25.0	19.7±21.3	22.8±23.2
International goals scored					
Goalkeeper	0.03±0.2	0.0±0.0	0.0±0.0	0.0±0.0	0.02±0.1
Defender	1.1±2.4	1.4±4.0	1.5±2.7	1.0±1.5	1.3±2.7
Midfielder	2.9±4.0	2.3±4.4	2.1±3.5	2.4±4.9	2.5±4.2
Striker	7.1±7.9	6.2±8.6	9.4±13.0	5.4±9.0	6.9±9.6
Total	3.0±5.2	2.9±5.9	3.3±7.3	2.7±5.9	3.0±6.0
FIFA world ranking					
Goalkeeper	36.7±30.9	8.1±7.8	16.0±20.0	35.8±27.3	26.0±27.3
Defender	29.8±24.7	12.2±13.6	9.0±12.2	32.0±31.2	22.0±24.5
Midfielder	29.7±27.9	9.7±10.0	12.4±16.3	31.2±27.5	21.8±24.5
Striker	30.3±28.4	14.4±19.0	20.4±34.9	27.7±21.7	24.0±26.8
Total	30.6±27.3	11.5±13.8	13.3±21.3	30.7±27.1	22.7±25.3

Table 22: Number of international players who competed in the 2002 FIFA World Cup by playing position for each of the four countries.

Position	FA Premier League	La Liga	Serie A	Bundesliga	Total
Goalkeeper	8/29 (27.6%)	5/15 (33.3%)	5/13 (38.5%)	4/9 (44.4%)	22/66 (33.3%)
Defender	13/88 (14.7%)	11/54 (20.4%)	16/60 (26.7%)	17/63(26.6%)	57/265 (21.4%)
Midfielder	21/107 (19.6%)	20/74 (27.0%)	26/73 (35.6%)	18/79 (22.8%)	85/333 (25.5%)
Striker	13/123 (20.6%)	11/49 (22.4%)	15/40 (37.5%)	9/58 (15.5%)	48/210 (22.9%)
Total	55/287 (19.2%)	47/192 (24.5%)	62/186 (33.3%)	48/209 (22.9%)	212/874 (24.2%)

3.4 Discussion and Conclusions

The first aim of the present study was to establish whether differences existed in age, stature, body mass and BMI between players in different positions in the different leagues. As measurement timings and methods are unknown the data are therefore vulnerable to measurement error. However, many significant differences have been found between leagues and positional groups in the presence of measurement error. Secondly, the study investigated which of the four soccer leagues (English FA Premier League, Spanish Premiera Division, Italian Serie A and German Bundesliga) contained the highest quality players. The Spanish Premiera Division was found to be the league containing the highest quality players according to the FIFA world rankings of the international players. Differences were also found between the age, stature, body mass and BMI of players in either different positions and/or different leagues. Generally, players in the German Bundesliga, for example, had the greatest stature, body mass and BMI of all four leagues. Some noticeable differences were also observed for individual positions in the different leagues suggesting either differences in playing style and physical demands of the league or, alternatively, that there are desirable characteristics of players with teams in all four leagues seeking such players. In this respect, age had a significant influence on position, but not league, with goalkeepers being older than midfielders and strikers and defenders being older than strikers. This would suggest that distinct differences exist concerning the physical demands of match-play for each position, with lengthened career durations for defensive roles. Alternatively, it may be the selection strategy of teams within the four selected leagues who desire to have experience in their defensive positions.

The decision as to which of the four selected leagues contained the highest quality players is dependent on which selection of variables is used and their validity towards making such a decision. Data regarding foreign players, the number of international players, appearances and goals, are variables that can not directly indicate quality, for example, many highly ranked FIFA nations play a different number of international games than some lower ranked FIFA nations offering more opportunities to gain appearances and to score goals. Furthermore, the number of 2002 FIFA World Cup participants in each league also lacks validity as highly ranked nations such as the Netherlands, Columbia and the Czech Republic did not compete in the 2002 FIFA World Cup Finals. This leaves the FIFA World ranking of international players' countries as the best of the variables used in the current investigation on which to suggest which league contained the highest quality players. In this respect, when the FIFA World Rankings were collected (www.FIFA.com, March, 2002), Spain's La Liga contained the highest quality players. It is worth noting that although international players from Spain's La Liga and the Italian Serie A perform for countries ranked higher by FIFA, the English FA Premier League contained the highest number of international players. This may reflect the different demands of clubs competing in the different leagues. Players with different international requirements may also choose to play in leagues with fewer games. In England, the maximum number of competitive games a FA Premier League club would have to perform in the 2001/02 season was 69. This was five more games than in Spain (64), eight more than in Germany (61) and eleven more than in Italy (58) (Wilson, 2003). An additional issue that could have a bearing on player characteristics are the styles of play adopted by a country and their respective domestic league club (e.g. Lewis and Hughes, 1988; Ali and Farrally, 1990; Reilly et al., 1991; Yamanaka et al., 1993; Kuper, 1994; Bangsbo and Pietersen, 2000; Ensum et al., 2002; Taylor et al., 2002; Taylor and Williams, 2002; Yamanaka et al., 2002; Reilly, 2003b; Bloomfield et al., 2004c). The English game, in this respect, is said to be characterised by a more forthright, fast and physical approach (Hawkins and Fuller, 1999; Croucher, 2002; O'Donoghue, 2003) whereas football in the Italian Serie A by a more cautious, methodical, defensive and technical approach (Castagna and D'Ottavio, 1999; Roi et al., 2005). In addition, the English style of play is said to level out the work rate, that is, all outfield players are expected to put in the same amount of effort (Reilly, 2003b). As a consequence of this, the number of games to be played, and the chosen style of play, there is more potential for injury and chronic fatigue in the English season and clubs need to have larger squads to cope with these demands. In order to meet this demand, the majority of clubs desire many international players in order to rotate the first team throughout the season and still maintain quality. At the same time, first team international players from highly ranked FIFA nations often require regular first team club football to secure their international position.

The Bundesliga was found to have the largest number of foreign players, with more than half of the defenders, midfielders and strikers originating from outside Germany. A relatively large number of these players originated from Eastern Europe and West Africa. Alternatively, in Spain and Italy more of the foreign players came from South America and the majority of foreign players in the FA Premier League originated from Northern and Western Europe. These distributions of foreign players suggests that cultural, climatic, lifestyle and language differences are important factors for players to move to certain leagues and that clubs are scouting players from countries from which they assume they can integrate well to their domestic game (Maguire and Stead, 1996; Maguire and Pearton, 2000).

The differences between the leagues in stature, body mass and BMI also suggest that the styles of soccer may vary, with teams from different leagues preferring different types of players in certain playing positions. Based on the observations in the current study it could be suggested that play in the Bundesliga is based on power and athleticism. Hence, players from this league were generally taller, heavier and had a higher BMI indicating that Bundesliga players might either have more body fat or be more muscular than players from the other leagues. With regard to the latter, traditional German training and conditioning methods employed suggest players to be more muscular (e.g. Rapp and Schoder, 1977; Nowacki et al., 1987; Thyron, 1996; Schmolinsky, 2000). This is also a reflection on the type of foreign player suitable for the Bundesliga. A second notable difference between the four leagues was the finding that Spanish midfielders and strikers did not differ in stature and BMI and that strikers in the Serie A were heavier than defenders. Again, these findings may reflect upon the style of play and physical demands of the different leagues. Match analysis reveals that Spanish teams attack more frequently than teams from the other three leagues. La Liga's players score more goals per game and are 'deadlier' in terms of accuracy and chances converted. Conversely, English and Italian teams are better defensively (www.optasoccer.com, 2002).

It is evident that soccer is a game that is evolving in terms of the demands placed on players in different positions (O'Donoghue et al., 2001; Bangsbo and Michalsik, 2002; Reilly, 2003c; Mohr et al., 2004; Bloomfield et al., Under review). Olds (2001), in this respect, found that rates of increase in body mass and BMI in rugby union players was significantly above that of the normal population whereas increases in stature were similar to the secular population. The present study only partly supported these findings. For example, the FA Premier League players were found to be approximately 1 (one) cm taller than their counterparts just over a decade ago (White et al., 1988). It is generally accepted that there is an increase of approximately 1 (one) cm in stature per decade in the general population in developed countries (Meredith, 1976; Pheasant, 1996). Body mass of the FA Premier League players in the present study, on the other hand, was found to be more than 1.4kg lower that that of the players in 1988 (75.3kg vs. 76.7kg respectively). The 1 (one) cm increase in stature seen in the secular population is accompanied by a 1 (one) kg increase in body mass (Pheasant, 1996). These findings would suggest that the FA Premier League players have perhaps become leaner or more angular and even more athletic in comparison to players approximately a decade ago. Given the greater distances covered while sprinting, this would seem the case (Mohr et al., 2003) . Similar results were obtained for the Serie A players. However, whereas a reduction in body mass was observed for FA Premier League players, Serie A's players are taller on average whilst maintaining a similar body mass in comparison to players in 1988. In particular, Italian professionals have been reported with a mean stature and body mass of 1.77m and 74.4kg respectively for Serie A players (Faina et al., 1988) whereas the current study found an average stature of 1.81m and body mass of 74.3kg. Unfortunately, no retrospective data were available for the La Liga or the Bundesliga players.

On average, players in all four leagues have been found to be taller and leaner than the secular population of their respective country (Peebles and Norris, 1998). In particular, players in La Liga were on average 7cm taller than the general Spanish population (Theis et al., 1999) whereas Serie A players were 5cm, and Premier League and Bundesliga players were 3cm taller than their respective populations (Peebles and Norris, 1998). This would disagree with Norton and Olds (1996) observation that soccer players were similar to the secular population. This might have consequences for talent identification and team selection. With regard to the former, it is well established that selection of talented young soccer players is biased towards those who are physically more developed (Simmons and

Paull, 2001). The relative age effect or season-of-birth bias has been found in most soccer leagues, including the four leagues under consideration and suggests that those born during the early phase of selection year are more likely to be professional players (Barnsley et al., 1992; Brewer et al., 1992; Verhulst, 1992; Dudink, 1994; Brewer et al., 1995; Hansen et al., 1999; Musch and Hay, 1999; Helsen et al., 2000; Simmons and Paull, 2001; Glamser and Vincent, 2004). This appears to be particularly true for players representing their country in youth soccer (Under 17 and Under 20) (Barnsley et al., 1992). The consequences of this talent identification strategy might have resulted in soccer players being on average taller than the general population and suggests that the pool of players selectors can draw upon is decreasing. However, lack of stature, for example, is not in itself a barrier to success, though being tall may make an individual more suitable for specific positions such as goalkeeper, centre back, or 'target' striker (Reilly et al., 2000a). This might be particularly the case for goalkeepers. Being tall appears to be a prerequisite to become a professional goalkeeper. This is reflected by discussions in the popular press on the stature of some goalkeepers. For example, it has been suggested that certain international goalkeepers were not tall enough to play at the highest level (Wilson, 2001). Furthermore, it has been reported that some teenage trainee goalkeepers in England, in desperation to increase stature have gone to extraordinary measures to stretch their frame an inch or two (Taylor, 2001). These issues would imply that physique is seen as more important than skill, with soccer clubs being unlikely to take chances with late developers.

An additional issue associated with talent identification and team selection is the heterogeneity found in stature, body mass and BMI for the players in the different positions (Ekblom, 1986; Mangine et al., 1990; Tumilty, 1993a; Bangsbo, 1994e, 1998b; Reilly et al., 2000a; Dowson et al., 2002; Ostojic, 2002; Strudwick et al., 2002). These results may support findings by Davis et al., (1992) who found that goalkeepers were heavier and had a higher percentage of body fat. Furthermore, differences have been found in activities conducted by outfield players (e.g. Van Gool et al., 1988; Bangsbo et al., 1991; Drust et al., 1998; O'Donoghue, 1998; Mohr et al., 2003) and VO_{2max} (Al-Hazzaa et al., 2001; Helgerud et al., 2001; Bangsbo and Michalsik, 2002; Hoff et al., 2002). Midfielders, in this respect, have been found to cover significantly more distance during matches (e.g. Reilly and Thomas, 1976; Ekblom, 1986; Bangsbo et al., 1991; Drust et al., 1998; Rienzi et al., 2000; Strudwick and Reilly, 2001; Mohr et al., 2003). Defenders take part in physical battles with strikers, having to jump frequently and tackle significantly more than any other outfield player (Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo, 1994a; Di Salvo and Pigozzi, 1998; Wells and Reilly, 2002). Furthermore, defenders perform fewer runs and all out sprints in comparison to the other outfield players (O'Donoghue, 1998).

It is well established that different positions in soccer have distinct requirements. The finding that goalkeepers were significantly older than midfielders and strikers and that defenders were significantly older than strikers would indicate that attacking positions are associated with reduced career duration at the highest level. The lower work rates discovered in defenders compared to other outfield players (O'Donoghue, 1998) might be a partial explanation for the higher average age in defenders. The fact that, in general, the majority of play is in front of defenders might also reduce their chances of getting injured by being able to anticipate tackles (Mechling, 1990; Grehaigne et al., 2001). In contrast, it has also been reported that injury risk is mainly related to tackling and being tackled or by making or receiving a 'charge' from another player (Rahnama et al., 2003). Goalkeepers, on the other hand, have a special role in soccer. For this position it is often suggested to be an advantage to be older or have extended experience. The only 40-year-old player in the current study was a goalkeeper.

In conclusion, according to the criteria used in the present investigation, the Spanish Premiera Division (La Liga) was found to be the European league containing the highest quality players. Furthermore, the differences in age, stature, body mass and BMI between players in different positions in the different leagues would indicate different physical demands. This not only has consequences for talent identification and selection but would also indicate that physical conditioning programs need not only be tailored to specific positions in soccer, but also to the demands of the specific leagues (Bloomfield et al., 2004a; Bloomfield et al., 2005b).

CHAPTER FOUR:

STUDY TWO:

A NEW TIME-MOTION ANALYSIS METHOD: DESCRIPTION AND RELIABILITY OF THE 'BLOOMFIELD MOVEMENT CLASSIFICATION'

4.1 Introduction

In order to produce skilled behaviour it is important to identify the discrete requirements of sporting activities. This is facilitated through use of computerised video-analysis software to perform time-motion analysis (Hughes, 2003). This is recognised as a useful, non-invasive, method that provides valuable information into the physical exertion of a player with the results regarded as being of much value to coaches and managers (Ali and Farrally, 1991a). The two main outputs of the analysis include interpretations of distances covered and detail regarding various modes of motion. However, on review of the current studies performed there appear to be large discrepancies between values for total distances covered in match-play by soccer players and details regarding modes of motion mainly due to methodological differences (e.g. Reilly and Thomas, 1976; Ekblom, 1986; Bangsbo et al., 1991; Drust et al., 1998; Rienzi et al., 2000; Strudwick and Reilly, 2001; Mohr et al., 2003) (See Table 7, p. 54). In terms of distances covered, data is limited as it omits important information concerning the discrete requirements of soccer activities and essentially provides an underestimation of total energy expenditure. It is therefore more valuable to investigate the movements made which accumulate to cover the total distance. However, fewer than 8 modes of motion have often been chosen and it is clear that this does not provide a high enough degree of specificity to detail the physical demands of soccer (Barnett et al., 1973; Sale and MacDougall, 1981; Rosenbaum, 1987; Morrissey et al., 1995; Hill et al., 1998).

The present study involves the formation of a new time-motion analysis methodology that accounts for motions, directions, intensities and events (turns, on the ball activity) named the 'Bloomfield Movement Classification' (BMC). The BMC was designed after multiple observations of individual players in a range of invasion sports (soccer, field hockey, rugby union, rugby league, basketball and netball) with particular attention paid to movement. Motions, directions, intensities, types of turn and playing ('on the ball') activities were noted, recorded and discussed with those participants observed. The Observer Version 5.0 (Noldus Information Technology, The Netherlands) was chosen as the software platform to perform the collection, management and presentation of the BMC as observational data could be collected, reviewed and edited with synchronised display of the corresponding video images (Noldus et al., 1999). Furthermore, the system allows for an independent configuration to be composed consisting of states (continuous and time-phased) and events (instantaneous and not time-phased) to define how observed behavioural data is to be notated. The Observer 5.0 configuration is comprised of behaviours (state or event) and allows for two further modifiers to be added and used to describe the behaviour. Once the initiation of a behaviour was observed, a representative key pressed on a QWERTY (AT Enhanced) keyboard followed by the keys for the appropriate modifiers signify the entry and recording in an Event Log (see Figure 6).

Figure 6: The Observer 5.0 Event Log

The BMC can be applicable to multiple-sprint invasion sports due to the inclusion of codes for motion and events (e.g. turns) and the versatility of an 'On the Ball Activity' category which can be specifically adapted for the observed sport. For the purposes of this study the BMC's 'On the Ball Activity' has been designed specifically for soccer. The BMC includes 14 timed modes of motion and 3 'other' non-timed movement events, 14 directions, 4 intensities, 5 turning categories and 7 'On the Ball' activity classifications (Table 23). However, due to the expansive nature of the configuration some impossible scenarios could potentially be coded in the observation (e.g. sprint, backward, low intensity). These impossible scenarios were noted and made aware to the observer (Table

24). Furthermore, all classifications were then thoroughly defined for purposes of interpretation and inter-reliability (Table 25).

Table 23: The 'Bloomfield Movement Classification' Behaviours and Modifiers.

BEHAVIORS **(Modifiers in parenthesis)**	**MODIFIERS**
1. TIMED	**(A) Direction**
Motion	Forwards, Forwards Diagonally Right/Left, Sideways Right/Left, Backwards, Backwards Diagonally Right/Left, Arc Forwards Left to Right/Right to Left, Arc Backwards Left to Right/Right to Left, Arc Sideways Right/Left
Sprint (A+B), Run (A+B), Shuffle (A+B), Skip (A+B), Jog (A+B), Walk (A), Stand Still, Slow Down (A+B), Jump (C), Land, Dive (D), Slide (D), Fall, Get Up (B)	**(B) Intensity**
Initial Channel	Low, Medium, High, Very High
Start of Observation	**(C) Jump**
	Vertical, Forwards, Backwards, Sideways (E)
2. INSTANTANEOUS (NON-TIMED)	**(D) Dive**
	Feet first, Head first
Other Movement	**(E) Turn**
Stop (B), Swerve (E), Impact(F+B)	Right/Left
	(F) Type
Turns	Push, Pull, Pushed, Pulled, Other
0^0-90^0 (E)	**(G) Control**
90^0-180^0 (E)	Right/Left foot, Head, Chest, Thigh, Other
180^0-270^0 (E)	**(H) Pass/Shoot**
270^0-360^0 (E)	Long Air, Short Air, Long Ground, Short Ground, Other
>360^0 (E)	**(I) How**
On the Ball Activity	Right/Left Foot, Header, Backheel, Overhead, Other
Receive (G), Pass (H+I), Shoot (H+I), Dribble (J+K), Tackle, Trick, Other	**(J) Dribble**
	Start, End
	(K) Touches
	Start,1-3, 4-6, 7-10, >10

Table 24: The impossible scenarios of the 'Bloomfield Movement Classification'.

Behaviour	Modifier 1	Modifier 2
SPRINT	Sideways Left/Right, Backwards, Backward Diagonally Left/Right, Arc Backwards, Arc Sideways	Low Medium
RUN	Sideways Left/Right, Arc Sideways	Low Very High
SKIP		High Very High
JOG	Sideways Left/Right, Arc Sideways	High Very High
WALK	Sideways Left/Right, Arc Sideways	
SLOW DOWN	Sideways Left/Right, Backwards, Backward Diagonally Left/Right, Arc Backwards, Arc Sideways	

Table 25: The interpretation and definitions of the behaviours and modifiers of the 'Bloomfield Movement Classification'.

Behaviour	Definition
SPRINT	- Maximal effort, rapid motion.
RUN	- Manifest purpose and effort, usually when gaining distance.
SHUFFLE	- Moving with a very short stride length, e.g. readjusting. footwork, stumbling, or when braking heavily from a sprint.
SKIP	- Moving with small bound-like movements.
JOG	- Moving at a slow monotonous pace (slower than running, quicker than walking).
WALK	- Moving slowing by stepping.
SLOW DOWN	- Succeeded only after a sprint when maximal effort diminished.
STAND STILL	- More or less stationary or staying in one spot.
FALL	- Descending to the ground.
GET UP	- Ascending from the ground.
JUMP	- Spring free from the ground by the muscular action of feet and legs
LAND	- Entered after JUMP when contact with ground is made.
DIVE	- To purposefully, controllably and rapidly propel the body through the air either feet or head first.
SLIDE	- Moving along the ground, always succeeds a dive.
STOP	- To brake suddenly.
SWERVE	- To rapidly change direction in one movement without turning the body.
IMPACT	- Any contact made with another player.
0^0-90^0	- Turn ≤ ¼ circle.
90^0-180^0	- Turn > ¼ circle but ≤ ½ circle.
180^0-270^0	- Turn > ½ circle but ≤ ¾ circle.
270^0-360^0	- Turn > ¾ circle but ≤ full circle.
>360^0	- Turn > full circle in one motion.
PASS	- Any attempt to give the ball to a team-mate. Entered as contact made with the ball along with how.
RECEIVE	- Any time a ball was controlled prior to a pass/shot/dribble. Entered as contact made with the ball along with how.
SHOOT	- Any attempt on goal. Entered as contact made with the ball along with how.
DRIBBLE	- Any time a ball was received and then moved under control. Entered at the end of the dribble along with number of touches.
TACKLE	- Any attempt to tackle an opponent.
TRICK	- Any ball-skills performed when dribbling.
OTHER	- Any other incident that is outside the configuration.

Modifier	Definition
DIRECTION	
FORWARDS (FW)	- Head, shoulders, hips all face forward
FW DIAGONALLY RIGHT	- Player's body turned 45^0 left, head turned left, player looks over left shoulder, left leg crosses in front of right leg, moving in a forward direction.
FW DIAGONALLY LEFT	- Player's body turned 45^0 right, head turned right, player looks over right shoulder, right leg crosses in front of left leg, moving in a forward direction.
SIDEWAYS RIGHT/LEFT	- Head, shoulders, hips all face forward and legs & feet do not cross.
BACKWARDS (BK)	- Head, shoulders, hips all face forward
BK DIAGONALLY RIGHT	- Player's body turned 45^0 right, head turned 45^0 left, left leg crosses behind right leg, moving in a backward direction.
BK DIAGONALLY LEFT	- Player's body turned 45^0 left, head turned 45^0 right, right leg crosses behind left leg, moving in a backward direction.
ARC FW/BK/SIDEWAYS	- Player (often leaning to one side) moving in a semi-circular direction
INTENSITY	
LOW	- Little effort
MEDIUM	- Some effort
HIGH	- Great effort
VERY HIGH	- Maximal effort
JUMP	
VERTICAL	- Jump and land in the same spot.
FORWARD	- Jump and land in a spot further forward.
BACKWARD	- Jump and land in a spot further backward.
TURN	
RIGHT	- Right shoulder moves backwards
LEFT	- Left shoulder moves backwards
TYPE	
PUSH/PULL	- Subject instigates the contact
PUSHED/PULLED	- Subject receives the contact
OTHER	- Any other contact e.g. a collision, a kick/punch

4.2 Materials and Methods

The BMC was applied to individual soccer players using footage from FA Premier League matches collected from Sky Sports Interactive Service (British Sky Broadcasting Group, UK) using the ‘PlayerCam’ facility. This source provided a clear picture, with a separate camera focused solely upon a single player at any time (see Figure 7).

Figure 7: Sky Sports Interactive 'PlayerCam' Facility (Extreme right of screen)

Throughout a match (~90mins), 6 players are seen on ‘PlayerCam’ for approximately 15mins each, chosen at the discretion of Sky Sports. Footage was recorded on VHS and converted to MPEG format using Dazzle Moviestar Version 4.22 (Fremont, USA). Each MPEG file was edited in M1-Edit Pro Version 4.00.0012 (Mediaware Solutions Pty Ltd, USA) so that each player viewed had a separate file with the opening frame taken from the start of the player being tracked and the final frame taken when focus changed to a new player or at half or full-time. To begin coding an MPEG file in The Observer 5.0, the Observational Window must first become customised so that the video image, event log, video control, and configuration key codes are visible (see Figure 6, p. 121). Due to the detail of the BMC, the process of data entry was extremely time consuming considering the frequency of changes in discrete movements. Short sections (3-15secs) of the observation were initially viewed at 1x normal speed and replayed to perform data entry using a frame by frame rate of 0.04 seconds for discrete activities and at 1x normal speed for continuous, unchanging motion. The Observer 5.0 also supports a 'Quick Review' function in the video control that performs a video replay and was set at 5s playback. The work-station was based in a well-heated research laboratory mounted on a non-reflective surface beside a window with blinds reducing primary and secondary glare. The 15inch screen was set at seated eye level and observers viewed no closer than 40inches (Jaschinski-Kruza, 1988). A maximum of two hours was set for periods of observation to reduce symptoms of eyestrain (Atencio, 1996). In addition, observers were encouraged to take regular 'eye-breaks' by looking away from the screen for a few minutes. This also enabled optimal cognitive functioning and enhanced quality of data entry.

4.3 Reliability of the BMC

Two independent observers applied the Bloomfield Movement Classification implemented in The Observer Version 5.0 (Noldus Information Technology, The Netherlands) to a single subject's purposeful movement (5mins 45s within 15mins of Sky's

PlayerCam coverage of the player). This took between 4 and 6 hours for each observer to enter. The two recorded sequences of timed movements and instantaneous events were saved into Microsoft Excel spreadsheets that could be loaded into a reliability evaluation algorithm (O'Donoghue, 2005) that had been developed in MatLab 7.0.1 to determine the kappa statistic. This algorithm determined the proportion of observation time where the two observers agreed on the movement type, direction and intensity. The times where both observers agreed that an inter-clip divided was being displayed were excluded from the calculation of kappa. The proportion of instantaneous events agreed by both observers within the same 1s of observation time was determined. These proportions were adjusted to address the proportion where they would be expected to agree by chance and thus the kappa statistic was evaluated for movement type, direction, intensity, turning and game related activity. Altman's (1991) classification of kappa was used to interpret the reliability of the BMC when used to analyse soccer. Values of over 0.8 are interpreted as a very good strength of agreement, values between 0.6 and 0.8 are interpreted as a good strength of agreement, values between 0.4 and 0.6 are interpreted as a moderate strength of agreement, values between 0.2 and 0.4 are interpreted as a fair strength of agreement and values between 0.0 and 0.2 are interpreted as a poor strength of agreement. It is possible to obtain kappa values of less than 0.0 (O'Donoghue et al, 2005) and these are interpreted as a very poor strength of agreement.

4.3.1 BMC Reliability Results

Some of the values for movement type, direction, intensity, turning and game related activity were not performed by the player according to either observer. Such values have, therefore, been excluded from tables 26 to 30. There was a good strength of agreement between the two observers for movement type (κ = 0.7277). Table 26 shows stand still movement and slowing down were the two areas responsible for most disagreement between the observers. Observer 1 classified 23.4s of the observation time as being spent performing standing still activity compared with 8.2s by observer 2. Slowing down was recorded for similar volumes of time by the 2 observers but they only agreed with each other that the player was slowing down during 6.2s of the observation time. The disagreements arose from the two observers deeming slowing down to have started at different times and to have ceased at different times.

Table 27 shows that both observers agreed that the majority of movement was performed in a forward direction. However, there were times where each observer recorded forward movement and the other observer recorded some other direction of movement, particularly movement to the right and arced movement forward left or forward right. There was 1.8s of the observation time where one observer had recorded forward movement while the other had recorded backward movement. However, despite these occasional disagreements, a good strength of agreement was achieved for the direction of movement between the 2 observers (κ = 0.6968).

Table 26: Time (s) recorded for different movement types by the 2 independent observers.

Observer 1	Observer 2										
	Stand Still	Walk	Sprint	Jog	Run	Skip	Shuffle	Jump	Slow Down	Inter-Clip	Total
Stand Still	7.4	8.0	0.2	0.8	0.6	5.9	0.0	0.0	0.4	0.0	23.4
Walk	0.3	22.2	0.0	1.4	0.1	2.4	0.0	0.0	0.0	0.1	26.4
Sprint	0.3	0.0	27.9	0.1	0.2	0.6	0.4	0.1	0.3	0.0	30.0
Jog	0.0	1.6	0.7	84.1	2.9	6.4	0.7	0.0	1.4	0.4	98.2
Run	0.0	0.0	1.6	4.6	16.2	0.8	0.6	0.0	0.1	0.0	24.0
Skip	0.0	0.8	0.2	5.2	3.8	85.4	2.4	0.5	0.0	0.0	98.5
Shuffle	0.0	0.2	1.0	1.4	3.8	3.0	19.0	0.0	1.5	0.0	30.1
Jump	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	1.2
Slow Down	0.0	0.0	3.0	0.0	2.5	0.8	0.0	0.0	6.2	0.0	12.6
Inter-Clip	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Total	8.2	33.0	34.6	97.8	30.3	105.3	23.1	1.8	10.1	0.6	344.8

Table 27: Time (s) recorded for different directions by the 2 independent observers.

Observer 1	Observer 2																
	FLD	Fwd	FRD	FLA	FRA	Left	N/A	Rght	LRA	RLA	BLD	Bwd	BRD	Vert	BLA	BRA	Total
FLD	**2.9**	0.6	1.9	1.2	0.0	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3
Forward	1.6	**154.3**	1.7	5.1	4.0	1.8	1.2	3.6	0.5	0.0	0.0	1.4	0.2	0.0	0.0	0.0	175.4
FRD	0.0	0.9	**13.4**	1.8	0.2	0.4	0.0	0.3	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	18.3
FLA	0.0	0.0	0.0	**7.1**	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.0	7.8
FRA	2.3	1.2	0.8	0.0	**14.3**	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.7
Left	0.1	1.3	0.0	0.1	0.0	**15.3**	0.0	1.4	1.4	0.0	0.0	0.1	0.0	0.0	0.0	0.0	19.7
N/A	0.0	4.4	0.3	0.0	0.2	3.7	**11.9**	1.2	0.0	0.0	0.1	1.4	0.6	0.0	0.0	0.0	23.8
Right	0.2	10.6	1.6	0.6	0.0	0.6	0.0	**32.9**	0.3	0.8	0.0	1.2	0.4	0.5	0.0	0.0	49.7
LRA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	**5.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4
RLA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0
Backward	0.0	0.4	0.2	0.0	0.0	1.5	0.0	1.4	0.0	0.0	0.6	**11.9**	0.5	0.0	0.0	0.0	16.5
BRD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0
Vertical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.2**	0.0	0.0	1.2
BLA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0
BRA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
Total	7.0	173.6	19.9	15.9	18.8	23.8	13.1	42.0	7.7	0.8	0.6	17.8	1.8	1.8	0.0	0.0	**344.8**

Key: FLD (Forward Left Diagonal); FRC (Forward Right Diagonal); FLA (Forward Left to Right Arc); FRA (Forward Right to Left Arc); N/A (No direction); LRA (Sideways Left to right Arc); RLA (Sideways Right to Left Arc); BLD (Backward Left Diagonal); BRD (Backward Right Diagonal); BLA (Backward Left to Right Arc); BRA (Backward Right to Left Arc); Fwd (Forward); Bwd (Backward)

Table 28 shows that there was a total of 5s of observation time where low intensity movement was confused with high or very high intensity movement. Similar volumes of high and very high intensity movement were recorded by the 2 observers. Observer 1 tended to record more low intensity movement and less moderate intensity movement than Observer 2. Overall, a good strength of agreement was achieved between the 2 observers for the intensity of movement performed by the player ($\kappa = 0.7062$).

Table 28. Time (s) recorded for different intensities of movement by the 2 independent observers.

Observer 1	Observer 2				
	Low	Medium	High	Very High	Total
Low	147.2	30.0	2.6	0.4	180.2
Medium	7.8	85.4	9.2	1.6	103.9
High	1.7	6.8	27.8	1.8	38.1
Very High	0.3	0.6	1.8	19.9	22.6
Total	156.9	122.7	41.4	23.8	344.8

There were 39 occasions where one observer recorded a turn or swerve but the other observer did not record any turning or swerving within the same 1s of observation time. Table 29 uses "Nothing" to represent this. There were 2 occasions where turning to the left recorded by observer 1 was recorded as turning to the right by observer 2. Most of the turning recorded by the 2 observers was of less than 90°. A moderate strength of agreement was achieved between the 2 observers for turning ($\kappa = 0.5639$).

Table 29. Frequency of turns and swerves recorded by 2 independent observers.

Observer 1	Observer 2												
	L <90	L 90-180	L 180-270	L 270-360	R < 90	R 90-180	R 180-270	R 270-360	Swerve Left	Swerve Right	Stop	Nothing	Total
L<90	42											12	54
L90-180		5											5
L180-270	1				1	1						3	
L270-360	1											1	
R<90					41							7	48
R90-180						3						1	4
R180-270												0	
R270-360												0	
Swerve L									1				1
Swerve R													0
Stop											3		3
Nothing	4	2			11						2		19
Total	46	9	0	0	52	4	1	0	1	0	5	20	138

Table 30 shows that there was a pass and a tackle recorded by observer 1 that were not deemed to be games related events by Observer 2 as well as an incident of pulling recorded by Observer 2 that Observer 1 did not record. The only other disagreement for game related activity was where Observer 1 recorded a pass being played by the player while Observer 2 recorded the player receiving the ball. This was an occasion where there was a one-touch pass receiving and passing of the ball that should have been recorded as passing rather than receiving. The kappa value of 0.7891 for game related activity is interpreted as a good strength of agreement between the 2 observers.

Table 30. Frequency of game related events recorded by 2 independent observers.

Observer 1	Observer 2						
	Push	Pull	Pass	Receive	Tackle	Nothing	Total
Push	2						2
Pull							0
Pass			11	1		1	13
Receive				7			7
Tackle					3	1	4
Nothing		1					1
Total	2	1	11	8	3	2	27

4.4 Discussion and Conclusions

Performance analysis is an area of sports science where reliability of measurement is critically important. Time-motion analysis systems are no exception to this. Unless automatic player tracking systems are used (Liebermann et al., 2002), there will be a human operator who is a part of the measurement instrument rather than separate from it. This can result in movement data being entered inaccurately due to the subjective nature of human movement recognition, variable observer reaction to events being performed by the subject and indeed different interpretations of performance indicators relating to work-rate and movement by different observers. For example, McLaughlin and O'Donoghue (2001) found that one observer had a tendency to record 10% more time spent performing high intensity activity than the other observer used in an inter-operator reliability study involving 28 subjects.

Four of the five kappa values obtained in the current investigation are interpreted as a good strength of inter-operator agreement with the remaining value being moderate. This should be viewed as sufficiently reliable for time-motion analysis research, particularly when one considers that kappa is a harsh reliability statistic in three ways. Firstly, anything other than exact agreement on a value will be treated as a total disagreement. For example, a disagreement between running and sprinting will be treated the same way as a disagreement between sprinting and standing still movement. Where the player is running 22.5° to the right of directly forward, one observer may classify the direction as forward and the other observer may classify the direction as forward right diagonal. This will be treated as a total disagreement with no partial marks for the two directions representing adjacent 45° sectors. The second way in which kappa is a harsh reliability statistic is related to instantaneous events. Altman (1991) has described how kappa can be used to measure the strength of agreement when two medical professionals diagnose the status of a disease in a set of patients. In this medical example, the two observers have already agreed that each case is to be diagnosed and classified. When kappa is used to analyse the reliability of recording events in a sports performance, the two observers may disagree on the total number of events. The "nothing" rows and columns of Tables 29 and 30 only count disagreements where one observer has recorded an event and classified it but the other observer does not agree that an event of any type has occurred. Those many 1s intervals where both observers agree that no discrete event has occurred are rightly excluded from these tables and the calculation of kappa. However, it must be recognised that this will lead to lower kappa values than in applications such as the medical example used by Altman (1991). The third way in which kappa is harsh when used with the BMC is where two different aspects of movement (direction and turning) become confused. One observer may view a movement as being a single movement performed in an arced direction while the other observer may consider the movement to be composed of two straight direction movements with a turn in between them. This will cause disagreements for the classification of direction of movement as well as instantaneous turning that will be treated as total disagreements during the calculation of kappa values for direction and turning. This was found to reduce kappa values to a level interpreted as moderate when analysing movement of netball players using the BMC (Williams and O'Donoghue, in Press).

In conclusion, the current investigation has evaluated the reliability of the Bloomfield Movement Classification when used to analyse the on-field movement of soccer players. A good strength of inter-operator agreement was achieved for the type of movement, direction of movement, intensity of movement and game related activities. A moderate strength of agreement was achieved for the analysis of turning. There is more scope for the reduction of kappa values when the kappa statistic is used to classify discrete events performed in sport than when it is used in other applications where the total number of events is agreed by both observers prior to classification. This makes the moderate strength of agreement achieved for turning to be acceptable for time-motion analysis research. The BMC is labour intensive and prone to inaccuracies due to the subjective nature of movement type, direction as well as the point of transition from one movement type to another movement type and the point of transition from movement in one direction to movement in another direction. Therefore, when the Bloomfield Movement Classification is used to analyse movement patterns in any sport, it is essential to establish the level of reliability of the method when being used by the observers involved in the research.

CHAPTER FIVE:

STUDY THREE:

PHYSICAL DEMANDS OF OUTFIELD POSITIONS IN FA PREMIER LEAGUE SOCCER

5.1 Introduction

Through better knowledge and comprehension of performance, more informed decisions regarding physical preparation, selection, or tactical adaptations can be made. Chapter 3 identified that significant differences exist between elite players of different positions in terms of age, stature, body mass and body mass index. This would suggest that the physical demands of match-play are also different for each position. Wide ranges of distances covered have been reported (e.g. Reilly and Thomas, 1976; Ekblom, 1986; Bangsbo et al., 1991; Drust et al., 1998; Rienzi et al., 2000; Strudwick and Reilly, 2001; Mohr et al., 2003) with the greatest overall distances covered by midfield players who act as links between defence and attack (Reilly and Thomas, 1976; Bangsbo et al., 1991; Rienzi et al., 2000; Strudwick and Reilly, 2001; Mohr et al., 2003). However, this is a general figure that provides little information as to the specificity of performance (Barnett et al., 1973; Hakkinen et al., 1989; Hill et al., 1998) and also underestimates energy expenditure (Reilly, 1997). It is therefore important to achieve a more detailed analysis of performance. This can be achieved through observation of various modes of motion that provide information regarding different intensities of play such as walking, jogging, cruising, sprinting, backwards and sideways movements (e.g. Reilly and Thomas, 1976; Bangsbo et al., 1991; O'Donoghue, 1998; O'Donoghue et al., 2001; Mohr et al., 2003). In terms of energy expenditure, an estimated 10-20% of match-play constitutes of high intensity activity (HIA) (Yamanaka et al., 1988; Balsom and Ekblom, 1992; Balsom et al., 1999; Nicholas et al., 1999; Aziz et al., 2000; Mujika et al., 2000; Rienzi et al., 2000; Wragg et al., 2000; Mohr et al., 2003; Rahnama et al., 2003) and the remaining 80-90% of performance is spent in low to moderate intensity activity (Reilly and Thomas, 1976; Bangsbo et al., 1991; O'Donoghue, 1998; O'Donoghue et al., 2001; Mohr et al., 2003).

However, the frequent alterations of activities, numerous accelerations and decelerations, changes of direction, unorthodox movement patterns and the execution of various technical skills also contribute significantly to energy expenditure (Bangsbo, 1994a; Reilly, 1997; Bangsbo, 1998c). In this respect, it is estimated that between 1000 and 1500 discrete movement changes occur within each match at a rate of every 5-6s, having a pause of 3s every 2min (Strudwick et al., 2002; Reilly, 2003c). More recently, Drust et al., (1998) discovered a mean number of 19 sprints within match-play which occurred every 4-5min and Strudwick et al (2002) observed a change in activity every 3.5s, a bout of HIA every 60s, and a maximal effort every 4mins. In international level field hockey, a sport with close relations to the physiological demands of soccer (Aziz et al., 2000), repeated sprint activity (minimum 3 sprints with a mean recovery less than 21s between sprints) was observed on 17 occasions with a mean of 4(±1) sprints per bout with 95% of recovery in active motion (Spencer et al., 2004).

It has also been reported that midfield players in soccer have higher absolute VO_{2max} values than defenders and strikers with a mean value of 62.6±4.0 (Bangsbo, 1994e) and around 75% of VO_{2max} discovered during match-play (Reilly and Thomas, 1976; Ekblom, 1986; White et al., 1988; Tumilty, 1993a; Bangsbo, 1994e, a, 1997; Aziz et al., 2000; Castagna and D'Ottavio, 2001; Castagna et al., 2002a). Also, Reilly and Thomas (1976) reported that defenders and strikers covered more distance in walking and sprinting and less in jogging and cruising than the midfield players. However, strikers have been found to perform the most number of maximal sprints and for longer durations, followed by midfielders and defenders (O'Donoghue, 1998). Rienzi et al., (2000) identified that defenders perform more backward movement than strikers with high intensity backwards and sideways movement requiring an elevated energy expenditure of 20-40% in comparison to forward running (Reilly and Bowen, 1984; Williford et al., 1998). Furthermore, different soccer related activities such as slide tackling, powerful heading, and long passing provide an extra physiological stress to the player (Reilly, 1997) with different playing positions having to regularly perform different specific activities. In this case, strikers and centre backs are significantly more engaged in situations where they have to jump or are required to head the ball whereas defenders tend to make more tackles (Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo, 1994a; Di Salvo and Pigozzi, 1998; Wells and Reilly, 2002).

Despite this research, the majority of soccer-related studies investigating the physical and physiological demands have reported macroscopically with frequency, duration, mean±sd or totals providing a summary of the overall physical requirements of soccer. To progress this knowledge it is important to implement the 'Bloomfield Movement Classification' (BMC) (Bloomfield et al., 2004b) together with a ratio scale based on time-motion analysis to provide a higher level of detail (e.g. O'Donoghue, 2003). This would provide a higher level of information regarding the intermittent nature of match-play together with detail of the movements involved. Through acquiring this more specific knowledge it becomes possible to facilitate superior methods of physical preparation of players (Barnett et al., 1973; Sale and MacDougall, 1981; Leatt et al., 1987; Hakkinen et al., 1989). The aims of this present study were to provide detail regarding Purposeful Movement (PM) and Recovery (R), performed by players in three different positions (defender, midfielder and striker).

5.2 Materials and Methods

5.2.1 Purposeful Movement and Recovery

Data were collected regarding 373 players representing various FA Premier League clubs during the 2003-2004 season from 62 publicly televised matches (Sky Sports, British Sky Broadcasting Group, UK). Ethical approval was granted by committees from the University of Hull and Leeds Metropolitan University. Individual players were observed and recorded (DVD-R) using the Interactive 'PlayerCam' Service (a separate camera focused solely upon a single player at any time) which provided clear, unobstructed and close images (See Figure 7, p. 125). Six players were followed by 'PlayerCam' for approximately 15min intervals during a match (0-15min, 15-30min, 30-45min, 45-60min, 60-75min, 75-90min) with the choice of players viewed selected by Sky Sports. All players chosen for analysis were outfield players (all positions except goalkeeper) and were on the field from the start of the match. The Observer Version 5.0 (Noldus Information Technology, The Netherlands) (Noldus et al., 1999) was selected as platform for computerised video-analysis (See Figure 6, p. 121) where players were coded by a two-movement classification of Purposeful Movement (PM) and Recovery (R). PM was defined as any perceived purposeful and deliberate movement made by the player to influence match-play or change location on the field, regardless of intensity, and R consisting of the remaining activity. PM could therefore also incorporate some low intensity activity as a lead in and out of higher intensity activity, within the overall movement as an unorthadox motion (e.g. skipping sideways) or a connecting motion (e.g. run forward high (3s) - jog forward low (4s) - run forward high (6s)).

5.2.2 Reliability of Purposeful Movement and Recovery

Two independent observers applied the two movement classification (PM & R) in The Observer Version 5.0 (Noldus Information Technology, The Netherlands) to six subject's 15mins of Sky Sports PlayerCam coverage. The recorded sequences of timed movements were saved into a Microsoft Excel spreadsheet that could be transformed into a reliability evaluation algorithm (O'Donoghue, 2005) that had been developed in MatLab 7.0.1 to determine the kappa statistic. This algorithm determined the proportion of observation time where the two observers agreed on the two classifications. Altman's (1991) classification of kappa was used to interpret the reliability of the two movement classification where values of over 0.8 are interpreted as a very good strength of agreement, values between 0.6 and 0.8 are interpreted as a good strength of agreement, values between 0.4 and 0.6 are interpreted as a moderate strength of agreement, values between 0.2 and 0.4 are interpreted as a fair strength of agreement and values between 0.0 and 0.2 are interpreted as a poor strength of agreement. A frame rate of 0.04s was selected for playback and video was paused and scrolled for an accurate perceived start and finish of PM. There was a good strength of agreement between the two observers ($\kappa = 0.758$) and within both observers ($\kappa = 0.797$). The level of agreement achieved for this two-movement classification is acceptable for time-motion analysis research.

Table 31: Reliability of two-movement classification.

Classification Scheme	Agreement type	□ mean±SD	Strength of agreement				
			Poor	Fair	Moderate	Good	V Good
2 movements	Inter-observer	0.758±0.233	0	0	1	4	1
	Intra-observer	0.797±0.061	0	0	0	3	3

5.2.3 Repeated Purposeful Movement and Recovery

Purposeful movements and recoveries were categorised according to their durations. There were short bursts of 0-6.0s, medium length bursts of 6.01-15.99s and long bursts of 16s or over. One reason for this selection was due to the analysis of the energy systems. It has been reported that the first 5-6s of a 30s Wingate test of anaerobic capacity predominantly utilises the ATP-PC system, with some contribution from glycolytic sources after 6s and aerobic sources increasingly after 10s (Smith and Hill, 1991). Considering that the purposeful movement periods being analysed in the current investigation contain activity of multiple intensities, it was decided to deem purposeful movement periods of over 16s rather than those of over 10s. However, even with bursts of 6s being performed, recovery duration has an impact of the sources of energy used (Wootton and Williams, 1983; Balsom et al., 1992a). Some recent support for this stems from an investigation into the effect of three different recovery durations on the performance of ten 6s sprints performed on a non-motorised treadmill (Hughes et al., In Press). They found that when the sprints were performed every 25s (effectively a recovery of 19s), there was a significantly lower mean maximal sprint speed, a significantly higher mean heart rate and a significantly higher mean oxygen consumption than when the sprints commenced every 40s or every 55s (effectively recoveries of 36s and 49s). The recoveries in the current investigation were classed as short if they were from 0-15.99s, medium if they were 16-40.99s in duration and long if they lasted 41s or longer. There were very few recoveries of over 40s and therefore repeated purposeful movement bouts were defined as sets of 2 or more purposeful movements separated by recoveries of 0-15.99s. This recovery duration was less than the 19s short duration used by Hughes et al., (In Press) as they investigated 6s sprints whereas the purposeful movement bouts in the current investigation also incorporate some low intensity activity.

5.2.4 Detail of Purposeful Movement

In addition, 15% of the players (n = 55; 18 defenders, 18 midfielders, 19 strikers) were randomly selected with efforts made to include 3 players from each of the six 15min match periods to analyse the PM further. Players selected had a mean±sd of 36.35±25.21 full international appearances for their respective nations at the time of observation. The 1563 PMs were then analysed using the Bloomfield Movement Classification (BMC) for time-motion analysis. This method provides detail on locomotive and non-locomotive movements as well as direction, intensity, turning/swerving and 'on the ball' activity. A frame rate of 0.04s was selected using Observer 5.0 which was sufficient to determine changes in movement classifications and provided an accurate, detailed and reliable analysis. The three positional groups were compared using a series of Kruskal Wallis H tests. Where a significant positional effect was found, Mann-Whitney U tests were used to compare each pair of positions.

5.3 Results

5.3.1 Periods of Purposeful Movement and Recoveries

Table 32 shows the frequency of purposeful movements of different durations and the durations of the subsequent recovery periods. All purposeful movements of over 6s were grouped together to satisfy the assumptions of the chi square test of independence. However, no significant relationship was found between the duration of purposeful movement and the duration of the following recovery period ($\chi^2_2 = 1.9$, $P = 0.379$).

Table 32: Frequency of PMs of different durations and the durations of subsequent recovery periods observed in all 15min match periods.

PMs	**Recoveries**			
	0-15.99s	**16-40.99s**	**>41s**	**All Recoveries**
0-6s	13.0±9.4	4.1±2.6	1.5±1.4	18.7±10.8
7-15s	10.2±4.6	4.5±2.2	1.8±1.4	16.5±4.5
>16s	2.2±2.1	1.0±1.3	0.4±0.7	3.6±3.1
All PMs	25.4±12.7	9.7±3.1	3.7±2.0	38.7±11.9

Table 33 illustrates that position had a significant influence on the mean duration of PMs. Follow-up Mann Whitney U tests revealed that the proportion of observation time spent performing purposeful movement was significantly lower for strikers than for defenders and midfielders and that defenders performed significantly fewer purposeful movements than midfielders and strikers ($P<0.05$). There were significant differences between each pair of positional groups for the duration of the mean purposeful movement performed ($P<0.05$) with defenders performing the longest purposeful movements and had significantly longer recovery periods between purposeful movements than midfielders ($P<0.05$). Table 33 also contains the number of bursts and recoveries of different durations performed by players of different playing positions. The number of PMs of 16s or longer performed by strikers was significantly fewer than that of defenders ($P<0.05$) and midfielders ($P<0.05$). Follow-up Mann Whitney U tests revealed that there were significant differences between each pair of positions for the number of bursts of 0s-6.0s ($P<0.05$). Strikers performed significantly fewer bursts of 16s and longer than defenders and midfielders ($P<0.05$). Defenders performed significantly fewer recoveries of 0s to 16s than strikers and midfielders ($P<0.05$). Strikers performed significantly more recoveries of 16s to 40.99s than defenders and midfielders ($P<0.05$).

Table 33: Summary comparison of positional groups, PMs and Rs of different durations and analysis of repeated purposeful movement bouts observed in all 15min match periods.

Variable	**Position**				H_2, P
	Striker (n=209)	**Midfielder (n=138)**	**Defender (n=26)**	**All (n=373)**	
%Time spent performing PM	29.9±8.4	35.9±8.8	38.3±9.2	32.7±9.2	46.4, $P < 0.001$
Frequency of PMs	39.6±11.9	39.0±11.7	29.7±8.4	38.7±11.9	18.1, $P < 0.001$
Mean PM duration (s)	7.3±2.2	9.1±2.8	12.0±3.8	8.3±2.8	76.3, $P < 0.001$
Mean recovery between PMs (s)	18.6±7.8	17.1±6.8	20.2±5.8	18.2±7.4	8.3, $P = 0.015$
PM of 0-6.0s	20.9±10.7	17.3±9.8	8.0±8.3	18.7±10.8	37.3, $P < 0.001$
PM of 6.01-15.99s	16.3±4.6	16.9±4.5	15.1±4.4	16.5±4.5	4.3, $P = 0.116$
PM of >16s	2.5±2.4	4.8±3.0	6.5±4	3.6±3.1	76.9, $P < 0.001$
Recovery of 0-15.99s	25.6±13.1	26.5±12.4	17.3±7.8	25.4±12.7	12.7, $P = 0.002$
Recovery of 16-40.99s	10.2±3.3	9.1±2.7	8.7±3.1	9.7±3.1	13.2, $P = 0.001$
Recovery of >41s	3.8±2.1	3.5±1.9	3.7±2.0	3.7±2.0	2.5, $P = 0.289$
Number of RPMBs	8.1±2.3	7.8±1.9	6.9±1.9	7.9±2.1	7.9, $P = 0.019$
Mean PMs per RPMB	4.1±1.5	4.3±1.5	3.5±0.9	4.1±1.5	9.6, $P = 0.008$
Mean PM duration within RPMB (s)	7.2±2.2	8.9±2.8	11.8±3.6	8.2±2.9	73.2, $P < 0.001$
Mean recovery duration within RPMBs(s)	6.2±1.2	5.7±1.1	6.1±1.2	6.0±1.2	9.6, $P = 0.008$
Mean recovery duration between RPMBs(s)	36.6±8.9	37.1±10.8	37.7±8.4	36.9±9.6	0.6, $P = 0.740$
Number of PMs outside RPMBs	6.5±3.4	5.1±2.7	5.9±1.8	5.9±3.2	13.7, $P = 0.001$
Mean PM duration outside RPMB (s)	7.9±3.9	10.2±5.1	12.2±6.8	9.1±4.8	35.3, $P < 0.001$

5.3.3 Repeated PM bouts

A repeated purposeful movement bout (RPMB) is defined as any period of 2 or more PMs separated by recoveries of 15s or less. Table 33 also includes the comparison of the three different positional groups in terms of performance indicators relating to RPMBs. There was a positional effect on each of these variables with the exception of the mean recovery period duration outside repeated purposeful movement bouts. Follow-up Mann Whitney U tests revealed that defenders performed significantly fewer RPMBs than midfielders and strikers ($P<0.05$). The mean number of PMs per RPMB was significantly lower for defenders than for midfielders ($P<0.05$). There were significant differences between each pair of positions for the duration of PMs within RPMBs ($P<0.05$) with defenders performing the longest PMs within RPMBs. Midfielders experienced a significantly shorter duration of recovery within RPMB than strikers ($P<0.05$), although strikers performed significantly more PMs outside RPMBs than midfielders ($P<0.05$) but performed significantly shorter PMs outside RPMBs than midfielders and defenders ($P<0.05$). This is useful when formulating specific physical conditioning practices and a general session is provided in Table 34.

Table 34: Suggested non-positional specific match-play training drill (Total duration: 15min 34s).

Series	Activity	Duration (s)	Cumulative Duration (s)
1	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	50
2	Recovery of 30s	30	80
3	Single PM of 9s	9	89
4	Recovery of 45s	45	134
5	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	184
6	Recovery of 30s	30	214
7	Single PM of 9s	9	223
8	Recovery of 45s	45	268
9	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	318
10	Recovery of 30s	30	348
11	Single PM of 9s	9	357
12	Recovery of 45s	45	402
13	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	452
14	Recovery of 30s	30	482
15	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	532
16	Recovery of 45s	45	577
17	Single PM of 9s	9	586
18	Recovery of 30s	30	616
19	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	666
20	Recovery of 45s	45	711
21	Single PM of 9s	9	720
22	Recovery of 30s	30	750
23	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	800
24	Recovery of 45s	45	845
25	Single PM of 9s	9	854
26	Recovery of 30s	30	884
27	RPMB of 4 x 8s PM and 6s recovery (4 PMs and 3 recoveries)	50	934

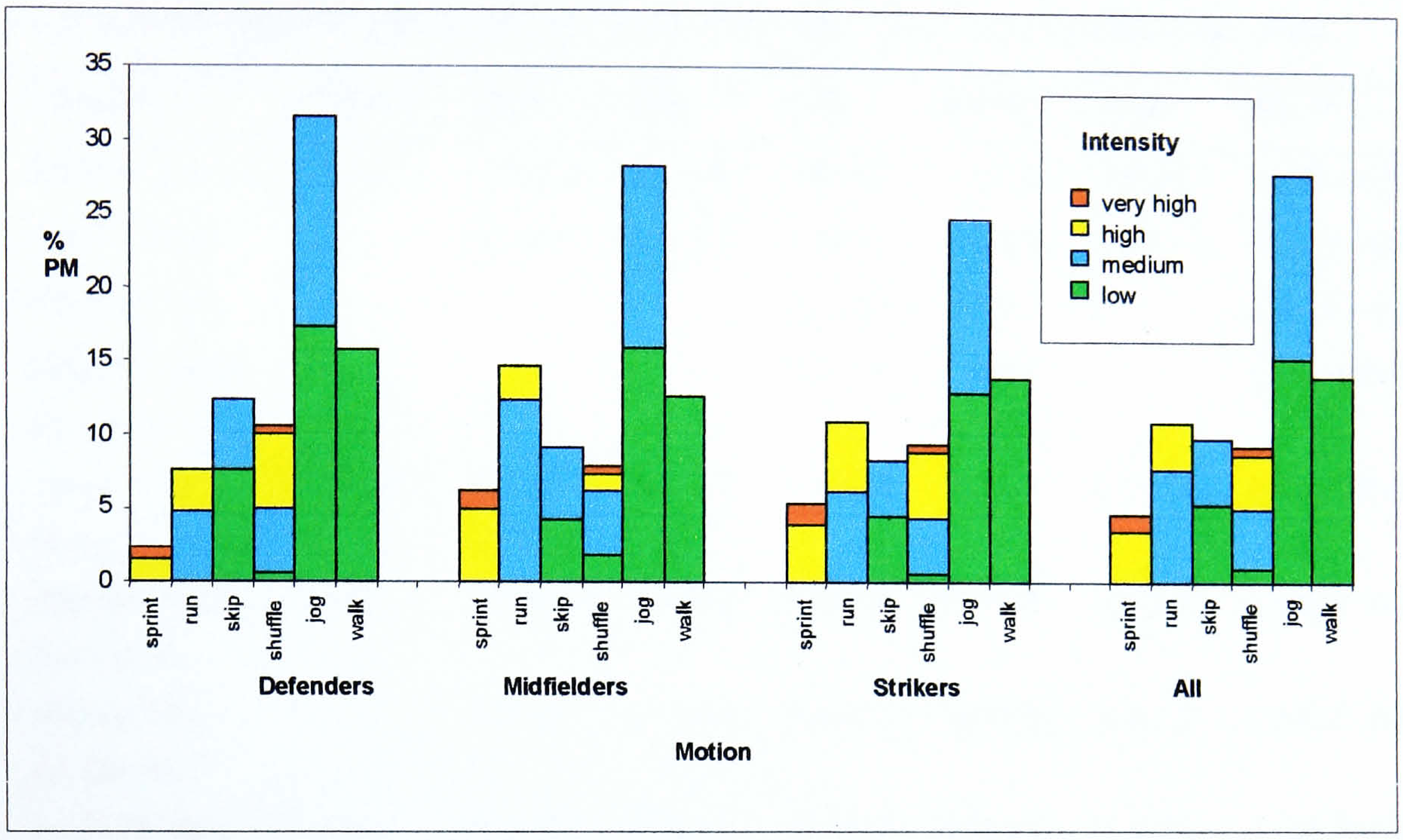
5.3.4 Activity Performed within Purposeful Movements

Table 35 shows the detail of the time-motion analysis of PMs for 55 block random selected subjects according to the BMC (See Chapter 4). Position had a significant influence on the percentage of PM time spent standing still, running, sprinting, skipping, shuffling and performing 'other' timed movement (slow down, fall, get up, jump, land, dive and slide). There were no significant differences between the positions for the percentage of PM time spent walking or jogging. Figure 8 shows the % of different levels of intensity of each of the motions. Positional group had no significant influence on the proportion of purposeful movement time spent performing activity at low, medium or very high durations ($H_2 \leq 2.6$, $P>0.05$). However, there was a significant influence of position on the proportion of PM time spent performing high intensity activity (H_2 = 9.9, P = 0.007) with the 27.3±12.4% of PM time spent performing high intensity activity by forwards being significantly greater than the 14.2±9.8% performed by midfielders ($P<0.01$).

Table 35: Time-motion analysis of PM performed by players of different positions (% time spent in each motion).

Activity	**Striker (n=19)**	**Midfielder (n=18)**	**Defender (n=18)**	**All (n=55)**	***H_2*, *P***
Standing	5.3 ± 3.5	2.1 ± 1.6	6.3 ± 2.5	4.6 ± 3.2	22.4, *P*<0.001
Walking	14.1 ± 3.8	12.8 ± 4.2	15.8 ± 4.5	14.2 ± 4.3	3.6, P = 0.163
Jogging	24.7 ± 8.7	28.3 ± 12	31.5 ± 6.8	28.1 ± 9.6	4.6, P = 0.101
Running	11.1 ± 4.5	14.6 ± 9.2	7.6 ± 3.6	11.1 ± 6.8	9.6, P = 0.008
Sprinting	5.5 ± 3.3	6.4 ± 3.1	2.5 ± 1.3	4.8 ± 3.2	17.4, *P*<0.001
Skipping	8.3 ± 2.8	9.1 ± 3.8	12.3 ± 6.2	9.9 ± 4.7	8.3, P = 0.016
Shuffling	9.5 ± 1.6	7.9 ± 2.1	10.5 ± 3.2	9.3 ± 2.6	8.0, P = 0.018
Other	21.5 ± 7.7	18.8 ± 5.6	13.6 ± 8	18.1 ± 7.8	7.8, P = 0.020

Figure 8: Time-motion and intensity analysis of PM performed by players of different positions.



Tables 36 and 37 show the directions travelled within the analysed motion. Kruskal Wallis H tests revealed that position had a significant influence on the frequency in each PM of moving in the directions of forward straight backwards straight arc forward left to right, arc forward right to left, turning left, sideways right and forward diagonal left. Kruskal Wallis H tests also revealed significant differences between the playing positions for the percentage of each PM spent moving backwards straight, sideways left, sideways right, backward diagonal right and arc forward right to left. Position had no significant influence on the percentage of each PM in any of the other directions.

Table 36: Percentage direction travelled of different motions within PM for all players (n=55). (Note: there was also 22.6 ± 7.4% of PM performing movement without any direction not included in this table).

Direction	Sprint	Run	Jog	Skip	Shuffle	Walk	H_2, *P*
Forward straight	3.6±2.3	7.2±5.3	20.5±8.4	1.2±0.9	5.1±2.0	9.7±3.0	6.5, P = 0.039
Back straight	-	0.1±0.2	1.3±2.0	1.5±1.0	1.0±0.7	3.1±1.9	19.1, P<0.001
Sideways left	-	-	-	3.5±2.0	1.0±0.7	-	13.3, P = 0.001
Sideways right	-	-	-	3.0±2.0	0.9±0.7	-	8.9, P = 0.011
Forward diagonal left	0.3±0.4	1.0±0.9	2.1±1.3	0.1±0.2	0.5±0.4	0.5±0.5	19.7, P<0.001
Forward diagonal right	0.3±0.5	1.2±1.2	1.9±1.2	0.2±0.4	0.6±0.5	0.6±0.7	≤ 5.8, P>0.050
Backward diagonal left	-	0.0±0.1	0.1±0.3	0.1±0.2	0.1±0.2	0.1±0.2	≤ 5.8, P>0.050
Backward diagonal right	-	0.0±0.2	0.1±0.1	0.1±0.2	0.1±0.2	0.0±0.2	≤ 5.8, P>0.050
Arc backward left-right	-	-	0.1±0.6	-	-	-	≤ 5.8, P>0.050
Arc backward right-left	-	-	-	-	-	-	≤ 5.8, P>0.050
Arc forward right-left	0.4±0.5	0.8±0.9	1.0±0.9	0.0±0.1	0.1±0.2	0.0±0.1	17.2, P<0.001
Arc forward left-right	0.3±0.4	0.7±0.6	1.0±1.0	0.0±0.1	0.0±0.1	0.1±0.2	22.3, P<0.001
Arc sideways left	-	-	-	0.0±0.1	0.0±0.1	-	≤ 5.8, P>0.050
Arc sideways right	-	-	-	0.1±0.2	0.1±0.3	-	≤ 5.8, P>0.050

Note: Due to the rounding of data to one decimal place, slight inconsistencies are observed in total % time spent and % direction travelled. Data has been verfied.

Table 37: Frequency and (%) mean±sd of directional movements travelled within PM performed by players of different positions.

Direction	**Striker** (n=19)	**Midfielder** (n=18)	**Defender** (n=18)	**All** (n=55)	H_2, P
Forward straight	4.7 ± 1.2 (36.7±9.6)	5.2 ± 0.9 (38.2±10.9)	4.4 ± 0.8 (39.0±8.5)	4.8 ± 1.0 (37.9±9.6)	≤ 5.8, P>0.050
Backward straight	0.7 ± 0.3 (5.6±2.7)	0.7 ± 0.3 (5.2±2.8)	1.3 ± 0.4 (10.1±3.5)	0.9 ± 0.4 (7.0±3.7)	22.2, P<0.001
Left (turn/swerve)	2.2 ± 0.5 (0.1±0.2)	1.7 ± 0.5 (0.0±0.0)	2.5 ± 0.4 (0.0±0.1)	2.1 ± 0.6 (0.0±0.1)	≤ 5.8, P>0.050
Right (turn/swerve)	2.2 ± 0.7 (0.1±0.1)	1.8 ± 0.5 (0.0±0.0)	2.3 ± 0.5 (0.0±0.1)	2.1 ± 0.6 (0.0±0.1)	≤ 5.8, P>0.050
Sideways left	0.5 ± 0.2 (0.8±0.5)	0.5 ± 0.2 (0.6±0.5)	0.9 ± 0.3 (1.5±0.8)	0.6 ± 0.3 (1.0±0.7)	16.0, P<0.001
Sideways right	0.5 ± 0.2 (3.5±1.6)	0.5 ± 0.2 (3.2±1.7)	0.7 ± 0.3 (5.0±3.0)	0.6 ± 0.2 (3.9±2.3)	6.3, P = 0.044
Forward diagonal left	0.5 ± 0.2 (4.5±1.7)	0.6 ± 0.2 (4.9±2.0)	0.5 ± 0.3 (4.5±2.2)	0.5 ± 0.2 (4.6±1.9)	≤ 5.8, P>0.050
Forward diagonal right	0.6 ± 0.2 (5.4±2.2)	0.6 ± 0.3 (4.4±2.7)	0.6 ± 0.3 (5.1±2.9)	0.6 ± 0.3 (5.0±2.6)	≤ 5.8, P>0.050
Backward diagonal left	0.0 ± 0.0 (0.3±0.4)	0.0 ± 0.1 (0.3±0.4)	0.1 ± 0.1 (0.6±0.6)	0.0 ± 0.1 (0.4±0.5)	≤ 5.8, P>0.050
Backward diagonal right	0.0 ± 0.0 (0.2±0.3)	0.0 ± 0.0 (0.1±0.2)	0.1 ± 0.1 (0.5±0.6)	0.0 ± 0.1 (0.3±0.4)	7.7, P = 0.022
Arc backward left-right	0.0 ± 0.0 (0.0±0.0)	0.0 ± 0.0 (0.0±0.0)	0.0 ± 0.0 (0.3±1.0)	0.0 ± 0.0 (0.1±0.6)	≤ 5.8, P>0.050
Arc backward right-left	0.0 ± 0.0 (0.0±0.1)	0.0 ± 0.0 (0.0±0.0)	0.0 ± 0.0 (0.1±0.2)	0.0 ± 0.0 (0.0±0.1)	≤ 5.8, P>0.050
Arc forward right-left	0.2 ± 0.1 (2.5±1.7)	0.2 ± 0.1 (2.8±1.0)	0.1 ± 0.1 (1.6±1.4)	0.2 ± 0.1 (2.3±1.5)	7.1, P = 0.029
Arc forward left-right	0.2 ± 0.1 (2.5±1.6)	0.2 ± 0.1 (2.8±1.5)	0.1 ± 0.1 (1.8±1.5)	0.2 ± 0.1 (2.4±1.5)	≤ 5.8, P>0.050
Arc sideways left	0.0 ± 0.0 (0.0±0.1)	0.0 ± 0.0 (0.0±0.0)	0.0 ± 0.0 (0.1±0.2)	0.0 ± 0.0 (0.1±0.2)	≤ 5.8, P>0.050
Arc sideways right	0.0 ± 0.0 (0.2±0.4)	0.0 ± 0.0 (0.0±0.1)	0.0 ± 0.0 (0.2±0.3)	0.0 ± 0.0 (0.1±0.3)	≤ 5.8, P>0.050

Table 38 contains the frequency of turns and swerves within each PM and a suggested match-play total. Position had a significant influence on the number of 0° to 90° left, 0° to 90° right and 270° to 360° left turns made in a match. Position also had a significant influence on the number of swerve left movements made per match. The frequency per match of the remaining turns or swerves were not significantly different between the positions.

Table 38: Frequency of turning and swerving within PM observed in a 15min interval (and suggested within match) performed by players of different positions.

Direction	**Striker (n=19)**	**Midfielder (n=18)**	**Defender (n=18)**	**All (n=55)**	H_2 , P
0-90° right	1.9 ± 0.6	1.4 ± 0.4	2.0 ± 0.5	1.8 ± 0.6	
	(323.7 ± 105.1)	(248.3 ± 97.3)	(344.3 ± 91.0)	(305.8 ± 104.7)	14.3, P = 0.001
0-90 ° left	1.8 ± 0.5	1.4 ± 0.4	2.1 ± 0.4	1.8 ± 0.5	
	(302.2 ± 81.2)	(243.0 ± 93.5)	(364.3 ± 88.4)	(303.2 ± 99.3)	9.2, P = 0.010
90-180 ° right	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	
	(43.3 ± 15.6)	(49.3 ± 25)	(43.0 ± 16.8)	(45.2 ± 19.4)	$\leq$4.6, P>0.050
90-180 ° left	0.3 ± 0.1	0.3 ± 0.2	0.3 ± 0.1	0.3 ± 0.1	
	(51.5 ± 13.9)	(47.0 ± 24.5)	(49.3 ± 21.4)	(49.3 ± 20.1)	$\leq$4.6, P>0.050
180-270 ° right	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
	(2.5 ± 4.2)	(4.7 ± 3.9)	(2.3 ± 3.0)	(3.2 ± 3.8)	$\leq$4.6, P>0.050
180-270 ° left	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
	(2.2 ± 3.6)	(3.0 ± 4.7)	(2.0 ± 2.9)	(2.4 ± 3.8)	$\leq$4.6, P>0.050
270-360 ° right	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
	(1.3 ± 2.5)	(0.7 ± 1.9)	(0.0 ± 0.0)	(0.7 ± 1.9)	$\leq$4.6, P>0.050
270-360 ° left	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
	(0.6 ± 1.9)	(2.3 ± 3.6)	(0.0 ± 0.0)	(1.0 ± 2.5)	8.4, P = 0.015
Swerve right	0.1 ± 0.1	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	
	(8.5 ± 8.3)	(5.7 ± 7.3)	(7.7 ± 6.4)	(7.3 ± 7.4)	$\leq$4.6, P>0.050
Swerve left	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	
	(12.0 ± 9.6)	(4.0 ± 6.5)	(9.3 ± 10.3)	(8.5 ± 9.4)	8.4, P = 0.015

Table 39 shows a frequency profile of 'other' movements performed within total match-play. Position had a significant influence on the number of times per match that players jumped backwards, dived feet first and stopped with low intensity. Position also had a significant influence on the number of times per match that several of the impact actions were performed or occurred. These included pushing at low and medium intensities, pulling at low, medium and high intensities, being pushed at low and high intensities and being pulled at medium and high intensities. There was no significant difference between the playing positions for the frequency of any of the other movements shown in Table 40. Finally, Table 40 contains a profile of soccer (on-the-ball) activity. A Kruskal Wallis H test revealed that there was no significant difference between the total number of on-the-ball movements performed in a match by players of different positions. The frequency of only four individual on-the-ball activities were significantly different between the positions; 'pass-long-air' with the right foot, 'pass-long-air' with the head, 'pass-short-ground' with the right foot and receiving the ball on the chest. There were no significant differences between the playing positions for the frequency of any of the other 'On the Ball Activities' performed in a match although it was noticible that midfielders received the ball with their right foot more than strikers and defenders and that midfielders and strikers dribbled more than dcfcndcrs.

Table 39: Frequency of 'Other Activity' movement within total match-play performed by players of different positions.

'Other' Activity	Striker (n=19)	Midfielder (n=18)	Defender (n=18)	All (n=55)	H_2, P
Fall	6.9 ± 6.7	5.3 ± 6.1	6.3 ± 5.6	6.2 ± 6.1	≤ 5.5, P>0.050
Get up, low	4.1 ± 5.7	3.0 ± 5.1	2.7 ± 4.7	3.3 ± 5.1	≤ 5.5, P>0.050
Get up, medium	2.2 ± 4.6	2.3 ± 3.6	2.3 ± 3.6	2.3 ± 3.9	≤ 5.5, P>0.050
Get up, high	2.2 ± 3.0	0.7 ± 1.9	3.7 ± 5.9	2.2 ± 4.1	≤ 5.5, P>0.050
Get up, very high	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 1.4	0.1 ± 0.8	≤ 5.5, P>0.050
Jump, forwards	7.6 ± 10.2	3.7 ± 5.5	6.0 ± 5.8	5.8 ± 7.6	≤ 5.5, P>0.050
Jump, vertical	8.2 ± 8.1	8.7 ± 9.9	11.3 ± 13.8	9.4 ± 10.7	≤ 5.5, P>0.050
Jump, backwards	0.6 ± 2.8	0.3 ± 1.4	2.0 ± 2.9	1.0 ± 2.5	7.0, P = 0.031
Jump, sideways, right	1.9 ± 3.5	0.0 ± 0.0	1.3 ± 4.4	1.1 ± 3.3	≤ 5.5, P>0.050
Jump, sideways, left	2.2 ± 4.6	0.3 ± 1.4	2.7 ± 4.2	1.7 ± 3.8	≤ 5.5, P>0.050
Diving, head first	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 1.4	0.1 ± 0.8	≤ 5.5, P>0.050
Diving, feet first	1.6 ± 3.4	1.0 ± 3.1	4.0 ± 4.6	2.2 ± 3.9	8.4, P = 0.015
Sliding, head first	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 1.4	0.1 ± 0.8	≤ 5.5, P>0.050
Sliding, feet first	2.2 ± 3.6	3.0 ± 5.1	2.7 ± 3.7	2.6 ± 4.1	≤ 5.5, P>0.050
Land	20.5 ± 19.7	13.0 ± 9.3	23.3 ± 18.2	19.0 ± 16.7	≤ 5.5, P>0.050
Stop, low	2.8 ± 4.2	7.7 ± 5.7	4.0 ± 5.4	4.8 ± 5.5	8.5, P = 0.014
Stop, medium	20.5 ± 17.4	15.3 ± 14.0	21.7 ± 18.2	19.2 ± 16.5	≤ 5.5, P>0.050
Stop, high	13.6 ± 13.7	7.7 ± 6.4	11.0 ± 14.7	10.8 ± 12.2	≤ 5.5, P>0.050
Stop, very high	0.9 ± 2.2	0.3 ± 1.4	0.0 ± 0.0	0.4 ± 1.6	≤ 5.5, P>0.050
Impact, push, low	1.6 ± 2.7	0.7 ± 1.9	4.0 ± 5.0	2.1 ± 3.7	6.1, P = 0.048
Impact, push, medium	4.4 ± 6.9	2.7 ± 4.2	10.3 ± 11.6	5.8 ± 8.6	6.4, P = 0.041
Impact, push, high	12.6 ± 13.8	7.7 ± 7.1	8.0 ± 8.2	9.5 ± 10.3	≤ 5.5, P>0.050
Impact, push, very high	0.3 ± 1.4	0.0 ± 0.0	0.7 ± 1.9	0.3 ± 1.4	≤ 5.5, P>0.050
Impact, pull, low	0.3 ± 1.4	0.0 ± 0.0	2.3 ± 3	0.9 ± 2.1	12.7, P = 0.002
Impact, pull, medium	0.9 ± 3.0	0.3 ± 1.4	4.0 ± 4.6	1.7 ± 3.6	12.2, P = 0.002
Impact, pull, high	2.5 ± 5.4	0.3 ± 1.4	3.3 ± 4.7	2.1 ± 4.4	6.8, P = 0.033
Impact, pushed, low	3.5 ± 7.0	0.0 ± 0.0	2.0 ± 5.0	1.9 ± 5.1	7.8, P = 0.020
Impact, pushed, medium	1.6 ± 2.7	3.0 ± 5.5	3.3 ± 5.1	2.6 ± 4.6	≤ 5.5, P>0.050
Impact, pushed, high	23.7 ± 20.4	8.3 ± 7.5	13.3 ± 10.6	15.3 ± 15.3	8.9, P = 0.012
Impact, pushed, very high	1.9 ± 5.7	0.7 ± 1.9	0.3 ± 1.4	1.0 ± 3.6	≤ 5.5, P>0.050
Impact, pulled, low	0.6 ± 2.8	0.0 ± 0.0	1.0 ± 4.2	0.5 ± 2.9	≤ 5.5, P>0.050
Impact, pulled, medium	2.8 ± 4.6	0.0 ± 0.0	2.7 ± 5.1	1.9 ± 4.1	7.5, P = 0.023
Impact, pulled, high	3.5 ± 5.0	0.7 ± 1.9	0.7 ± 1.9	1.6 ± 3.6	7.3, P = 0.025
Impact, pulled, very high	0.3 ± 1.4	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.8	≤ 5.5, P>0.050
Impact, other, medium	0.9 ± 2.2	1.3 ± 3.3	1.0 ± 2.3	1.1 ± 2.6	≤ 5.5, P>0.050
Impact, other, high	4.7 ± 4.3	3.3 ± 4.2	5.3 ± 8.7	4.5 ± 6.0	≤ 5.5, P>0.050
Impact, other, very high	0.6 ± 1.9	0.0 ± 0.0	0.7 ± 1.9	0.4 ± 1.6	≤ 5.5, P>0.050

Table 40: Frequency of 'On the Ball Activity' within total match-play performed by players of different positions.

On-the-Ball Activity	Striker (n=19)	Midfield (n=18)	Defender (n=18)	All (n=55)	H_2 , P
Pass, long air (right foot)	1.3 ± 2.5	7.0 ± 6.9	9.7 ± 6.9	5.9 ± 6.7	15.6, $P<0.001$
Pass, long air (left foot)	0.3 ± 1.4	1.0 ± 2.3	1.7 ± 3.4	1.0 ± 2.5	≤ 5.6, $P>0.050$
Pass, long air (header)	0.3 ± 1.4	0.0 ± 0.0	7.3 ± 8.9	2.5 ± 6.1	21.4, P = 0.234
Pass, short air (right foot)	4.4 ± 6.6	4.7 ± 5.7	1.3 ± 3.3	3.5 ± 5.5	≤ 5.6, $P>0.050$
Pass, short air (left foot)	0.9 ± 2.2	1.3 ± 3.3	0.3 ± 1.4	0.9 ± 2.4	≤ 5.6, $P>0.050$
Pass, short air (header)	8.8 ± 9.2	5.0 ± 6.6	7.0 ± 6.9	7.0 ± 7.7	≤ 5.6, $P>0.050$
Pass, long ground (right foot)	0.9 ± 3.0	2.0 ± 5.8	4.0 ± 6.2	2.3 ± 5.2	≤ 5.6, $P>0.050$
Pass, long ground (left foot)	0.3 ± 1.4	0.3 ± 1.4	1.7 ± 3.4	0.8 ± 2.3	≤ 5.6, $P>0.050$
Pass, short ground (right foot)	13.9 ± 9.6	27.3 ± 28.8	9.0 ± 7.8	16.7 ± 19.3	6.1, P = 0.046
Pass, short ground (left foot)	4.7 ± 7.4	3.3 ± 4.2	4.0 ± 8.7	4.0 ± 6.9	≤ 5.6, $P>0.050$
Shoot, long air (right foot)	0.0 ± 0.0	0.3 ± 1.4	0.0 ± 0.0	0.1 ± 0.8	≤ 5.6, $P>0.050$
Shoot, long air (left foot)	0.3 ± 1.4	0.3 ± 1.4	0.0 ± 0.0	0.2 ± 1.1	≤ 5.6, $P>0.050$
Shoot, short air (right foot)	0.6 ± 1.9	0.3 ± 1.4	0.0 ± 0.0	0.3 ± 1.4	≤ 5.6, $P>0.050$
Shoot, short air (header)	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 1.4	0.1 ± 0.8	≤ 5.6, $P>0.050$
Shoot, long ground (left foot)	0.3 ± 1.4	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.8	≤ 5.6, $P>0.050$
Shoot, short ground (right foot)	0.6 ± 2.8	0.3 ± 1.4	0.0 ± 0.0	0.3 ± 1.8	≤ 5.6, $P>0.050$
Shoot, short ground (left foot)	0.3 ± 1.4	0.3 ± 1.4	0.0 ± 0.0	0.2 ± 1.1	≤ 5.6, $P>0.050$
Receive (right foot)	14.8 ± 11.2	22.7 ± 20.4	11.7 ± 12.1	16.4 ± 15.5	≤ 5.6, $P>0.050$
Receive (left foot)	6.3 ± 7.6	11.0 ± 10.3	5.0 ± 8.0	7.4 ± 8.9	≤ 5.6, $P>0.050$
Receive (head)	0.0 ± 0.0	0.3 ± 1.4	0.0 ± 0.0	0.1 ± 0.8	≤ 5.6, $P>0.050$
Receive (chest)	3.5 ± 4.2	1.3 ± 2.6	0.7 ± 1.9	1.9 ± 3.2	6.9, P = 0.032
Receive (thigh)	0.9 ± 2.2	0.3 ± 1.4	0.0 ± 0.0	0.4 ± 1.6	≤ 5.6, $P>0.050$
Dribble	18.0 ± 13.4	22.7 ± 24.3	12.0 ± 12.5	17.6 ± 17.7	≤ 5.6, $P>0.050$
Tackle	3.8 ± 5.0	5.0 ± 5.5	4.0 ± 5.8	4.3 ± 5.4	≤ 5.6, $P>0.050$
Trick (step over)	0.9 ± 3.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 1.8	≤ 5.6, $P>0.050$
Trick (Cryuff turn)	0.6 ± 1.9	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 1.1	≤ 5.6, $P>0.050$
Trick (other)	0.3 ± 1.4	1.0 ± 3.1	0.0 ± 0.0	0.4 ± 2.0	≤ 5.6, $P>0.050$
Total	102.3 ± 51.1	139.7 ± 111.1	90.3 ± 47.6	110.6 ± 76.9	2.9, P = 0.234

5.4 Discussion and Conclusions

The first aim of the present study was to identify and detail the physical demands of FA Premier League soccer through reporting the intermittent activity of Purposeful Movement (PM) and Recovery (R) performed by players of three different positions (defender, midfielder and striker). It is important to establish that, unlike traditional analyses, identifying different levels of physical effort through categories based on varying intensities. In this respect,, a sprint may be performed both submaximally (high intensity) and maximally (very high intensity). PM is defined as any perceived purposeful and deliberate movement made by the player to influence match-play or change location on the field regardless of intensity and R consisting of the remaining activity. Secondly, the study investigated whether differences existed in PM and R and repeated purposeful movement bouts (RPMBs) defined as any period of 2 or more PMs separated by recoveries of 15s or less between the different positions. Finally, the investigation also involved a time-motion analysis of 15% of the subjects applying the BMC (Bloomfield et al., 2004b).

Defenders were found to perform the most (%) and longest PMs, however the strikers performed the highest frequency of PM, although of significantly lower mean duration. It therefore appears that the physiological and bioenergetic requirements of these positions arc vcry diffcrcnt. In support of this, although thcsc playcrs rcgularly covcr a similar distance, variation of heart rate values have been recorded (Reilly and Thomas, 1976; Ekblom, 1986; Van Gool et al., 1988; Dip et al., 1993; Bangsbo, 1994d; Drust and Rcilly, 1995; Drust ct al., 1998; D'Ottavio and Castagna, 2001b; Krustrup and Bangsbo, 2001; Krustrup et al., 2002; Foster et al., 2003; Thatcher and Batterham, 2004). To this end, it is surprising that there is a scarcity of information regarding the importance of individualised training and conditioning programmes according to positional roles (e.g. Di Salvo and Pigozzi, 1998).

In terms of PM and R, soccer may be described as a form of chaos as a poor relationship exists between the duration of PM and subsequent R for any player. Although heart rate analysis may be useful for monitoring the general training load, due to the acyclical and intermittent nature of soccer, this type of data is unable to provide detail regarding anaerobic bouts of short duration, recoveries of short duration or to distinguish between movement directions, modes of motion, or high intensity non-locomotive activities that make up the game of soccer. This suggests heart rate monitoring is more suitable for evaluating continuous and cyclical forms of exercise (Jeukendrup and Van Dieman, 1998). In addition, wide discrepancies have been reported in the distances covered by players with range values of 9-14km (Reilly and Thomas, 1976; Ekblom, 1986; Van Gool et al., 1988; Dip et al., 1993; Bangsbo, 1994e, d; Drust and Reilly, 1995; Drust et al., 1998; D'Ottavio and Castagna, 2001b; Krustrup and Bangsbo, 2001; Krustrup et al., 2002; Foster et al., 2003; Mohr et al., 2003; Thatcher and Batterham, 2004) which is partially due to different methodologies utilised but also reflects on the evolution of the physical demands of elite level soccer and supports the necessity for re-evaluation of the modern game (Drust et al., 1998; Miyagi et al., 1999; Rienzi et al., 2000; Strudwick et al., 2002).

Further evidence of positional differences is witnessed in the analysis of the duration of the bouts of PM and R. Strikers perform a higher frequency of short PMs (0-6.0s) than the other positions suggesting a greater emphasis should be placed upon anaerobic capacity in physical preparation than in the conditioning regime for defenders and midfielders (Tumilty, 1993a; Mercer et al., 1995; Aziz et al., 2000; Al-Hazzaa et al., 2001; Helgerud et al., 2001; Hoff et al., 2002). In contrast, defenders and midfielders performed significantly more PM greater than 16s which suggested greater importance in development of VO_{2max}. However, defenders performed significantly fewer recoveries of 0-15.99s than the other positions indicating less importance of a repeated PM capacity. In this respect, midfielders perhaps require the greatest repeated PM capacity as they perform the highest number of recoveries between 0-15.99s and less recoveries than the strikers between 16-40.99s. This would correspond with the greater overall distances recorded and higher VO_{2max} values witnessed than in defenders and strikers through their role as links between defence and attack (Reilly and Thomas, 1976; Smodlaka, 1978; Smaros, 1980; Ekblom, 1986; White et al., 1988; Tumilty, 1993a; Bangsbo, 1994e, a, 1997; Aziz et al., 2000; Castagna and D'Ottavio, 2001; Castagna et al., 2002a; Edwards and Clark, 2002). In addition, midfielders and strikers perform significantly more repeated PM bouts than defenders. To this end, midfielders have significantly longer PMs within the RPMB and significantly shorter recoveries than the other positions with a mean PM outside of the RPMB longer than the overall mean. This implies that midfielders continue to be engaged in the most physical activity during match-play which remains consistent with previous findings (Reilly and Thomas, 1976; Bangsbo et al., 1991; Bangsbo, 1994a; Drust et al., 1998; O'Donoghue, 1998; Rienzi et al., 2000; Strudwick and Reilly, 2001; Mohr et al., 2003). Strikers were found to perform more, although significantly shorter, bouts of PM than the other players. This may possibly be explained through a more isolated role in the team formation with fewer players in close support than in the midfield and defence. In terms of physical conditioning, it therefore appears that, irrespective of position, a 15min period of soccer competition involves about 8 RPMBs each containing about 4 PMs lasting 8.2s on average with subsequent recoveries of 6.0s. In addition to these 8 RPMBs, there are about 6 additional PMs of 9.1s that are separated from the RPMBs. The recoveries between

RPMBs as well as isolated PMs are between 30s and 45s (mean ~37s) (See Table 34, p. 138).

Overall midfielders spent the least time standing still and the most time running and sprinting with defenders performing most skipping and shuffling movements and strikers engaged in high levels of sprinting and shuffling. In this respect, the inclusion of SAQ® (Speed, Agility, Quickness) conditioning in the players conditioning regime could be of great benefit (Polman et al., 2004). In particular defenders and strikers could benefit from this type of conditioning. Midfielders on the other hand would benefit from interval running over longer distances (Bangsbo, 1997; Helgerud et al., 2001; Hoff et al., 2002) at a lower intensity. Midfielders were also found to perform the most 'forward-straight' movement with defenders engaged in the highest amount of backwards and sideways movements. The majority of diagonal and arc movements were performed in forward directions with forward and midfield players involved in more than defenders which suggests these are important in order to manipulate and create space or to evade a marker and be in a position to receive a pass from a team-mate. Significant differences were also found for 'forward-diagonal-left' movements which would suggest that teams prefer to attack on the right side of the pitch and that more players may also have lateral dominance in the right leg. This appears to be typical in professional soccer as more right footed players than left footed have been observed in the study of mixed footedness (Grouios et al., 2002). This is also supported by more than twice as many 'receives' being made by the right foot than the left foot for all positions. In addition, turning 45° left from a forward diagonal left movement allows for the right leg to perform the drive step in acceleratory forward straight movement. In this respect, very high frequencies of turns were made within match-play with the majority between 0-90°. Approximately 700 were made by defenders, 500 by midfielders and 600 by strikers, however midfielders and strikers perform more turns of 270-360° perhaps relating to efforts in close encounters to evade a marker or parts of match-play were they are required to face their own goal and the ball is transferred overhead such as at goal-kicks. The amount of 90-180° turns is relatively evenly distributed with all positions performing approximately between 90-100 in match-play. Consequently, it may be possible to question the validity of soccer specific endurance fitness tests such as the Loughborough Intermittent Shuttle Test (Nicholas et al., 2000), the Yo-Yo Test (Krustrup et al., 2003) and other Multi-Stage Fitness Tests (Léger et al., 1988; Balsom, 1990). Although these 'gold standard' tests have been assessed through physiological measures and related closely with the physiological load imposed through match-play, they appear to lack validity with respect to the physical demands as well as under-providing protocols for different positions. Alternatively, the Interval Field Test (Bangsbo and Lindquist, 1992) may be considered a more valued test as it aims to marry the physical and physiological demands though should be modified to relate to modern match-play for each position.

As identified by Bangsbo (1994a), extra physiological costs are created through on-the-ball and 'other' movement activities. In terms of the latter, strikers and defenders fall to the ground most in match-play with defenders required to get-up quickly more suggesting this is another area important for physical preparation. These positions also perform the most jumping which supports previous findings (Reilly and Thomas, 1976; Withers et al., 1982; Bangsbo, 1994a; Di Salvo and Pigozzi, 1998; Wells and Reilly, 2002) with defenders performing significantly more backward jumping as well as diving-feet-first which may be related to attempts to intercept passes or block shots and crosses rather than making tackles. It also appears to be important for midfielders to have the ability to jump vertically, most probably to contest for possession from goal kicks. Strikers may also need to be the physically strongest players as they engage in more high intensity activity than the other players. This may also relate to shortened career durations in comparison with more defensive players (Bloomfield et al., 2005b). In addition, due to their high frequency of PM and RPMB they also have higher levels of stopping at high intensity which suggests they perform more cutting movements which is observed through high levels of swerving as well as slowing more rapidly over shorter distances. These activities will produce shearing forces on the lower limbs and appropriate strength training and pre-habilitation practices must be adopted and emphasised (Nyland et al., 1997; Hawkins and Fuller, 1999; Besier et al., 2001; Ackland et al., 2003; Cochrane et al., 2003; Arnason et al., 2004). Furthermore, strikers also perform the most impact at high intensity and should be physically strong in pushing and pulling activities in the upper body as well as have abilities to withstand being pushed and pulled at high intensity. This emphasises the importance of developing core stability, proprioception and kinesthetic awareness (Ackland et al., 2003). It follows that defenders should also have sufficient body strength in order to compete with the strikers. In addition, FA Premier League defenders and strikers have been found to be heavier and with higher BMI, although only slightly taller, than midfielders (See Chapter 3). In addition, power is also required for soccer-specific abilities such as 'out-jumping' opponents and in particular in defence where there are significantly more long passes made with the foot or head (Wisløff et al., 1998; Odetoyinbo, 2004; Wisløff et al., 2004).

The highest frequency of passes was made by midfielders with a significant majority played short and on the ground. Players mostly used their feet to receive a pass although strikers used their chest and thigh more than other players. Unsurprisingly, strikers had more shots and performed more tricks than other players whereas midfielders dribbled more and made more tackles than defenders. These factors should all be considered when evaluating the energetic costs of match-play as events such as dribbling which create an additional energy cost (Reilly and Ball, 1984), as well as the extra costs from locomotive and non-locomotive movement, direction, intensity and turning (Reilly and Bowen, 1984; Williford et al., 1998).

In conclusion, according to the criteria used in the present investigation, match-play differences clearly exist between striker, midfield and defending players. In this respect, it appears that differences exist between the bioenergetic demands for each position with strikers requiring a high anaerobic capacity for repeated bouts of short, high intensity movement and defenders and midfielders requiring a higher VO_{2max} for longer repeated bouts of movement. This would indicate that physical conditioning, assessment, recovery and nutritional programs need to be tailored to specific positions in soccer.

CHAPTER SIX:

STUDY FOUR:

EFFECTIVE CONDITIONING FOR SOCCER MATCH-PLAY

6.1 Introduction

Soccer match-play requires a highly complex hybrid of physical fitness abilities including a high aerobic and repeated sprint capacity (e.g. Aziz et al., 2000; Helgerud et al., 2001; Hoff et al., 2002; Achten and Jeukendrup, 2003b), muscular strength and endurance, speed, agility, quickness and flexibility (Wisløff et al., 1998; Polman et al., 2004; Thatcher and Batterham, 2004; Wisløff et al., 2004). The physical activity of soccer (match-play) is described as stochastic, acyclical and intermittent with uniqueness through its variability and unpredictability (Nicholas et al., 2000; Wragg et al., 2000) making the physical conditioning of players a complex process. This match-play activity has also been characterised by periods of purposeful movement (PM) and recovery (R) which are typically active, though non-continuous (see Chapter 5). In general, players are engaged in PM for a third of the total ~90min match time (i.e. ~30mins in total) and receive a 15min passive recovery period at the midpoint of the match. PM is comprised of a short period of activity (mean±sd) 8.3±2.8s and a subsequent period of R (mean±sd) 18.2±7.4s and involves a wide range of locomotion, intensity, direction, unorthodox movement (e.g. diving and sliding) as well as soccer-specific activity with distinct differences existing between playing positions (e.g. Van Gool et al., 1988; Bangsbo et al., 1991; Drust et al., 1998; Mohr et al., 2003; Thatcher and Batterham, 2004; Bloomfield et al., Under review). In this respect, the short periods of PM activity (and wide range of movements associated) relate to speed, agility and quickness aspects of soccer performance (Bloomfield et al., 2004b). To succeed in elite soccer, it is necessary for players to have high levels of fitness and consequently optimally conditioned to repeatedly perform high levels of PM throughout an entire match. Few significant scientific studies have been conducted to investigate effective methods of soccer-specific physical conditioning (Di Salvo and

Pigozzi, 1998; Wisløff et al., 1998; Helgerud et al., 2001; Hoff et al., 2002; Polman et al., 2004; Thatcher and Batterham, 2004). In this respect, two main methods of conditioning (programmed and random) have been identified (see: Bangsbo, 1994b, c) and recognised as credible methods of physical conditioning for soccer (Hoff et al., 2002). In both circumstances, each method follows the basic principles of physical conditioning (specificity, overload, supercompensation, progression, reverse effects, recovery and individual responses to conditioning) (Briggs, 2001; Hoffman, 2002; Kilvan, 2003). Programmed conditioning (PC) is a method in which all participants are exposed to the same stress through the repetition of specific aspects of match-play (e.g. interval running). Also, PC is suitable for all aspects of physical conditioning for soccer and measurable through distance, frequency, speed and time. Random conditioning (RC) methods are more laissez-faire in their approach and involve all participants being exposed to overloading stresses of varying extents within each session (e.g. small-sided games). However, RC is perhaps unsuitable for some aspects of soccer conditioning including strength and flexibility. RC is comprised of manipulations of match-play and is therefore a highly specific form of soccer exercise, though measurement and standardisation is more complex. The subtle difference between the two methods is that PC requires a fitness specialist to directly deliver, control and take responsibility for administering specificity and overload throughout each session to each participant, whereas in RC the participant is individually responsible for overload. However, in RC the fitness specialist indirectly creates the specificity and overload through manipulation of pitch size, number of participants, frequency and duration of games as well as the incorporation of special rules (Bangsbo, 1994b, c). Furthermore, PC methods provide instant feedback during each session, whereas RC methods appear more difficult to quantify instantaneously. An example of the conjoined use of these methods is that of the periodised conditioning programme that prepared the Korean National Team for the FIFA World Cup in 2002 (Verheijen, 2004). All endurance conditioning was completed in the form of RC and supplemental sprint conditioning was performed in a programmed and controlled manner (PC). Korea finished fourth in the tournament, twice playing through extra-time and the players were widely complimented in the media for their high-tempo style of play and high levels of physical fitness demonstrated by all members of the squad. Recently, SAQ® (Speed, Agility, Quickness) (see: Pearson, 2001b, a; Pearson et al., 2002) has been validated as an effective PC conditioning method for elite female soccer players (Polman et al., 2004). Developed in the USA and made popular in American Football in the 1980s, the method involves a system of progressive exercises with instruction aimed at developing fundamental abilities to enhance the capabilities of dynamic sport athletes to be more skilful at faster speeds and with greater precision (Pearson, 2001b). Through SAQ® conditioning, it is thought that athletes may become more able to react to stimuli, start more quickly and efficiently, move effectively in multi-directions, and prepared to change direction or stop quickly to make a play in a fast, smooth, efficient, and repeatable manner (Brown et al., 2000; Pearson, 2001b). It is claimed that these improvements come through developing athletes' acceleration and speed over short distances, deceleration and changes in direction, footwork patterns, movement responses, arm action, as well as linear, lateral, diagonal, and vertical movements (Brown et al., 2000; Pearson, 2001b). However, the statements regarding the efficacy of SAQ® conditioning have yet been validated and essentially lack empirical evidence to support the claims made by the licensed SAQ® commercial organisations. In addition, there is also a fundamental lack of understanding regarding the underlying mechanisms to the theory of the SAQ® conditioning regime. The main objective of this study was to investigate the efficacy of programmed and random conditioning methods through neurophysiological and physical performance adaptations of speed, agility and quickness. PC would be performed through the SAQ® conditioning regime and RC would be conducted through small-sided soccer games. A second aim was to investigate the efficacy of the use of specialised SAQ® conditioning equipment.

6.2 Materials and Methods

6.2.1 Experimental Design

This study examined the effectiveness of programmed and random conditioning. The study, therefore, consisted of three learning/conditioning programmes: programmed conditioning (PC), random conditioning (RC) and no physical conditioning (NC) (control condition). Before the start of the training programme participants completed a battery of physical fitness tests. These tests were selected on the basis that they measure essential components to be successful in soccer. Participants than took part, two times a week for six weeks, in their respective conditioning programmes. Subsequently, participants were tested again on the selected physical fitness tests. To investigate whether the use of specialised equipments would be beneficial to performance the PC group was split in a group who received programmed conditioning using specialised SAQ® equipment whereas another group completed similar exercises without such equipment. RC consisted of manipulations of supervised 5-a-side soccer and finally NC consisted of either no intervention or playing soccer video games using a Sony Playstation2™. The rationale for this intervention was to include movement skill conditioning but without physical conditioning to explore neurophysiological variables as the playing of video games involves considerable mental effort for successful performance (Kwan, 2004). In addition, increased speed and agility on the part of the player may also improve video game performance. It was predicted that such improvements in speed, agility and quickness would be based on changes in the central nervous system. Such central changes may therefore benefit an overall movement repertoire. Similar effects have been identified in imagery studies. For example, imagery of strength conditioning in the right arm/leg results in increased strength not solely in the imagined limb but also in the contra-lateral limb. This would suggest that changes in the central nervous system are partially responsible for the improvements in performance rather than peripheral changes (Finsen et al., 2001).

6.2.2 Participants

Participant recruitment took place on the campuses of the University of Hull and Leeds Metropolitan University and involved distribution of posters and leaflets to students as well as video presentations of the SAQ® conditioning programme. The study initially consisted of 60 participants which was determined as more than sufficient for statistical analysis based on a power calculation regarding the repeated measures with multiple measurements design of the study. Inclusion criteria for participation in the study included that the participants had to be novice untrained soccer players who were, prior to commencement, considered to be untrained (no formally organised recreational exercise above moderate-level intensity for at least 4 weeks prior to commencement of the study). Twenty participants were stratified randomised (male/female) to each main group and sub group, however, due to participant safety, two same sex groups were selected for RC. Of these, 46 completed the entire intervention (males=25, females=21) aged 20.5±3.1 years (mean±sd) The study was approved by the Leeds Metropolitan University ethics committee based on the research proposal and risk assessment (Appendix D) and before the start of the study each subject completed a lifestyle and medical questionnaire (Appendices E and F). Once approved as a suitable candidate, each participant signed an informed consent statement (Appendix G).

6.2.3 Procedures

All conditioning for PC and RC took place inside a sports hall (30m x 18m) and participants in the no intervention condition either watched video's or played soccer video games using a Sony Playstation2™ in a separate room. The first PC group was assigned SAQ® conditioning with the use of specialised equipment (fast foot ladders, 6" and 12" hurdles, viper resistance belts and flexicords, stride canes, reaction balls, sprint resistors and breakaway belts) (Pearson, 2001b, a; Pearson et al., 2002) (Appendix H). The second PC group performed the same SAQ® conditioning programme but without any specialised SAQ® equipment though utilised traditional coaching equipment (e.g. cones and marker spots). All PC was delivered by an accredited SAQ® practitioner.

Each participant received (mean±sd) 12.2±2.1 hours of directed physical or non-physical conditioning. All participants had at least 24hr recovery between conditioning sessions and each session was 45mins in duration after a 15min generalised warm-up. Sessions were structured to increase intensity gradually each week (Table 41) and session ratings of perceived exertion (RPE) (Borg, 1998) (Appendix I) were collected randomly and used to correct for load for each conditioning group. For PC, the first two weeks were aimed to introduce, learn and develop basic SAQ® drills and emphasise correct movement mechanics. The following two weeks were aimed at introducing more complex patterns and resistance drills to emphasise minimal ground contacts and develop stride frequency. The objective of the final two weeks was to accumulate potential by combining the developed SAQ® drills and incorporate reaction drills.

Table 41: Six-week programmed and random conditioning interventions.

PHASE	SAQ® WITH EQUIPMENT (PC)	SAQ® WITHOUT EQUIPMENT (PC)	SMALL-SIDED GAMES (RC)
Week 1&2 **Aimed Intensity** **60-70%** **Borg Scale** **10-12**	• **6 x 6" Hurdles** • Walk throughs • Run throughs • Lateral run throughs • Bunny hops • Lateral bunny hops • **Fast Foot Ladder** • 1 foot per square run • Miss a square run • Hopskotch • Bunny hops • Lateral 2 feet per square run	• **7m length** • Walk, high knees • Run, high knees • Lateral, high knees • Bunny hops • Lateral bunny hops • **5m length** • Fast feet run • 'Burning coal' run • Bunny hops • Lateral fast feet run	• **2 x 20min matches** • 5min rest interval • Rotate goalkeeper every 4min • Ball to be kept on the ground • No player to enter goalkeeper area (5m radius from centre of goal)
Week 3&4 **Aimed Intensity** **70-80%** **Borg Scale** **13-15**	• **6" & 12" Hurdles & Fast Foot Ladder** • **T, X, Y, H patterns** • 2 foot per square run • Single leg runs • Lateral runs • Carioca • Icky shuffles • Ali shuffles • Step-ups (3, 4) • Bunny hops • Simple reaction drills • **Viper Belt** • 10m runs	• **7m & 5m lengths** • **T, X, Y, H patterns** • Fast feet runs • Single leg runs • Lateral runs • Carioca • Icky shuffles • Ali shuffles • Step-ups (3, 4) • Bunny hops • Simple reaction drills • **Partner resistance** • 10m let gos	• **3 x 15min matches** • 3min rest interval • Rotate goalkeeper every 3min • Ball to be kept on the ground • Score with one touch finish within 5m radius from centre of goal.
Week 5&6 **Aimed Intensity** **>80%** **Borg Scale** **>15**	• **6" & 12" Hurdles, Fast Foot Ladders, swerve cones, stride canes** • 20m courses (races) • W drill (Hurdles) • N drill (Ladder) • Zig Zags • **Viper Belt** • 10m sprints • 5m hollow sprints • Overspeed • **Reaction Ball** • Manic 21s • **Breakaway Belts** • Mirror drills • Get up and go's	• **20m courses (races)** • W drill • N drill • Zig Zags • **Partner resistance** • 10m let go's • Let go hollow sprints • Overspeed • **Partner drills** • Mirror drills • Get up and go's (tag)	• **4 x 12min matches** • 2min rest interval • No goalkeepers • Ball to be kept on the ground • Score with one touch finish within 5m radius from centre of goal. • No player can score 2 consecutive goals • 2 touch possession • 3 sec possession • Complete 10 passes before a goal attempt

6.2.3 Performance Assessment

Prior to all interventions, the participants were required to complete a battery of physical fitness tests. These tests were repeated after the 6 week intervention programme. Due to the physiological and psychological demands of testing, the tests were scheduled so that participants received full recovery between each trial and had a 48hr recovery period surrounding the day of testing. Testing was completed in one day and in the sequence presented in this section which avoided the limiting factors of residual fatigue or loss of motivation. Each participant performed all field-based tests with 30 participants (minimum 5 from each of the six groups) also completing additional testing in laboratory settings. Prior to the first testing session, participants received a comprehensive familiarisation session on one day which also provided data toward assessment of reliability. Before any tests were administered, a warm-up session was conducted with emphasis on increasing core temperature and mobilisation. Similarly, the tests were also succeeded by a short session of low intensity exercise and whole body static stretching to aid recovery (Bloomfield and Wilson, 1998; Reilly, 1998). The tests selected for the current study were based on their use in previous studies on physical fitness and specifically, conditioning in soccer. Speed, agility and acceleration have been shown to be relatively independent qualitics (Buttifant ct al., 2002) and also, functional strcngth, balancc and flcxibility (Bloomfield and Wilson, 1998; Wisløff et al., 1998; Ackland et al., 2003; Arnason et al., 2004; Wisløff et al., 2004) are important in soccer performance.

6.2.3.1 Field-Based Tests

6.2.3.1.1 Anthropometric measurements

Body mass (Kg) (Seca, α 700 digital low form scale, Birmingham) and stature (m) (Seca, α 220 digital low form scale, Birmingham) were measured at the beginning and end of the intervention programme. Participants were required to be barefoot and wear the same light training clothing for these measurements. From this, body mass index (BMI) was calculated (body mass/stature^2) (Kg.m^{-2}).

6.2.3.1.2 Speed and Acceleration

The participants performed three 15m sprints from a split-stance, static standing start at 0m. Participants were instructed to adopt a forward lean at 0m, holding this position for a minimum of 3s before take-off on their own volition. No sway or counter-movement at the start was permitted. Participants received a full recovery (3mins) between each trial. Digital timing gates separated at 5m intervals were used to measure sprint performance (Brower Timing System, Draper, USA). The best time for each 5m interval was used as an indication of their acceleration (0-5m, 5-10m, 10-15m) and maximum running velocity (0-15m). These distances were chosen as they represent the physical demands of soccer (Rcilly, 2003c).

6.2.3.1.3 Agility

Change-of-direction movements in soccer are often referred to as 'agility' (Young et al., 2002). Although no valid and reliable method has been established for measuring soccer-specific agility, the T-Test has been established as the most valid and reliable method to measure linear to lateral agility (Pauole et al., 2000). The protocol consisted of a

10m sprint forward, side-step 5m left, side-step 10m right, side-step 5m left and backpedal 10m. Participants performed three T-Tests adopting the same starting and recovery strategies as the speed and acceleration test. A digital timing gate (positioned at 0m) was used to measure performance (Brower Timing System, Draper, USA). The aim was to complete the course in the fastest possible time with the best of three trials recorded.

6.2.3.1.4 Power

Each participant performed three separate counter-movement jumps (CMJ) using a digital vertical jump meter (Takei, 5105-Jump MD, Toyko). They were instructed to stand on the centre of a rubber mat with the jump meter tightly fitted around their waist. The belt was connected to the rubber plate by a cord. Before jumping, any slack was removed from the cord and participants were instructed to jump vertically using a counter-movement incorporating arm-swing. The best attempt (in centimetres) was recorded. Following this, participants completed three horizontal standing long jumps (SLJ) using a standing board (Metro Sports, Standing Long Jump Mat Intermediate, La Crosse, USA). Participants were instructed to stand with a square stance, feet hip-width apart and their toes positioned against a marker at 0m. Once positioned, they were required to incorporate arm-swing and counter-movement to perform a maximal effort, landing on both feet. The distance between the marker and the heel of the trailing foot was measured in metres. In both instances, the participants' received a full recovery (3mins) between trials with the best effort recorded and used for statistical analysis. These tests were thought to represent eccentric, concentric and isometric movements required in soccer (Chamari et al., 2004; Wisløff et al., 2004).

6.2.3.1.5 Dynamic Balance and Flexibility

Dynamic balance refers to the ability to execute movements and maintain balance while in motion. It was measured using a modified version of the Bass Test of Dynamic Balance (Johnson and Nelson, 1986; Blackburn et al., 2000). Participants were required to hop and land on a pattern of 10 markers ($5cm^2$) placed on the floor in a standardised manner with scores given for accuracy (Appendix J). Points of error included failing to stop on landing a given hop (i.e. requiring subsequent hops to regain balance), failing to cover the mark completely with the metatarsal heads and touching the floor with any other part of the body on landing reduced the overall score of the trial (maximum score 100). Participants were required to perform 3 trials which were filmed using a digital video-camera and scored using The Observer Version 5.0 video-analysis software (Noldus Technology, The Netherlands) with the best attempt recorded. In addition, 3 measurements of the frontal elevation of the right leg (with relaxed knee flexion) were taken to assess the flexibility of the hip joint using a goniometer (Bloomfield and Wilson, 1998). Participants were instructed to stand facing a wall and flex their left shoulder to 90° (sagittal plane), keeping the arm at full extension to support their body. Then, after maximally flexing their right hip and maintaining position for 3s, the measurement was taken. For both tests, the mean score was recorded and used for statistical analysis. These tests were thought to be important functional athletic abilities required for soccer performance (Blackburn et al., 2000; Ackland et al., 2003; Reilly and Doran, 2003).

6.2.3.1.6 Overall change measure

Finally, this study calculated the percentage change in physical performance based on the accumulative effect of the participants percentage difference from pre- to post-test on the following dependent variables: 0-5m, 5-10m, 10-15m Sprint, T-Test, Counter Movement Jump, Standing Long Jump, Dynamic Balance and hip flexibility.

6.2.3.2 Laboratory Based Tests

6.2.3.2.1 Peak Torque

Peak torque was assessed using an isokinetic dynamometer (Cybex norm, Nottingham, UK). The participants sat in an upright position on an adjustable chair and where secured with shoulder, pelvic, and thigh straps to minimize non-relevant body movements. The lateral femoral epicondyle was used to establish the axis of rotation of the knee with that of the lever arm of the dynamometer. The lower leg was being attached to the lever arm by means of shin pad at the level of the lateral malleoulus allowing full ankle dorsiflexion. Knee flexion and extension of the participant's dominant leg was performed with a protocol of one set of five repetitions at 60, 120 and 180 deg/s (three sets in total) with 1min recovery intervals. These relatively slow speeds were chosen as they provide higher reliability than faster isokinetic speeds (Coyle et al., 1981) with correlation coefficients between 0.93 and 0.99 (Bemben et al., 1989; Montgomery et al., 1989; Magnusson et al., 1990). Based on recommendations by Wilhite, Cohen and Wilhite (1992) the participants first completed the lowest velocity followed by the intermediate and finally the highest velocity. The trial with the greatest peak concentric torque was used for statistical analysis. The strength data where dimensionally scaled before statistical analysis according to recommendations by Wisloff et al. (1998). The highest peak torque at each speed was divided by the body mass $^{-0.67}$.

6.2.3.2.2 Turning

A 180° turning exercise was used to measure the ability to change direction (Young et al., 2002). The exercise required a 5m maximal acceleration and deceleration with the braking step positioned on the centre of a multi-component aluminum top plate measuring force platform (60cm x 40cm) (Kistler, Cambridge, UK) with the metatarsal heads parallel to the sides of the platform. Participants performed three 180° in each direction and adopted the same starting and recovery strategies as the speed and acceleration field-based test. The foot of the braking step determined the direction of the turn, that is, the right foot determined a left turn and left foot determined a right turn. Participants were instructed to minimise the ground contact of the braking step and accelerate out of the 180° turn, returning to the starting line. Three trials were taken for each foot with the quickest contact time for each braking step recorded and used in statistical analysis.

6.2.3.2.3 Reactive Strength

A 40cm depth jump from a box onto a force platform (Kistler, Cambridge, UK) was used to assess reactive strength. Bauersfeld and Voss (1992) suggest that the quality of a depth jump is the height the participant achieves. Furthermore, a correlation is sought between minimal ground contact and maximal height. However, if ground contact is too short, maximal height is compromised and similarly, if ground contact is too long the elastic potential from the stretch shortening cycle is lost and maximal height is also compromised. In correspondence, Bauersfeld and Voss (1992) have proposed a different variable: Effectivitaitskoeffizient des Absprungs (EKA) which is translated as 'effectiveness coefficient of the jump' (EKA = Flight time^2 / ground contact time). Participants were instructed to have their hands on their hips throughout and step down from the box, keeping the hips level and landing with both feet simultaneously on the centre of the force platform. Upon ground contact participants were required to perform a maximal vertical jump (without arm swing) landing once more on the force platform. This process would collect data concerning ground contact time (s) and flight time (s). Each participant performed three trials with participants receiving a full recovery between trials (3mins). The individual trial with the quickest contact time and longest flight time (i.e. highest EKA value) was recorded and used in statistical analysis.

In addition, inferential electromyography (EMG) was used to assess the activity of motor units within muscles of the lower limb of the dominant leg. After skin preparation (Winter, 1991), passive surface electrodes (AgAgCI) were positioned over the muscle bellies of tibialis anterior, gastocnemius (medial and lateral) and soleus (Clarys and Cabri, 1993). The positioning of electrodes was measured to satisfy repeatability of the tests and cables were taped to the skin to reduce connecting wire movement and cross-talk. A frequency of 1000 Hz was selected to provide accurate readings (μV) (Winter, 1991). The amplitude of the raw EMG was analysed from the mid point of take off for all muscles. The mean and peak (max) values from the three trials were recorded and used in statistical analysis in accordance with previous measurements (Clarys and Cabri, 1993). This would provide information towards the recruitment of muscle fibres and the rate of synchronicity.

6.2.3.2.4 Foot Speed

Bauersfeld and Voss (1992) identify movement frequency as an important aspect of maximal sprint performance. To measure foot speed, participants were required to perform a tapping test which is an indicator of the elementary character of the self-selected cyclical velocity without opposition (performed over 6 seconds). Participants were instructed to sit on a chair in a fixed position with 90° knee and hip flexion, the lower back supported and hands rested on their thighs. Before the test commenced, both feet began dorsi-flexed with the heels of each foot remaining on the ground, acting as a pivot and positioned 5cm from the edge of a force platform (Kistler, Cambridge, UK). The protocol was to strike the force platform with the metatarsal heads of each foot alternatively, using a full range of motion with the aim of making as many contacts as possible over a period of 6s (Bauersfeld and Voss, 1992; Weineck and Kostermeyer, 1998). Bauersfeld & Voss (1992) state that this elementary cyclical and acyclical velocity translates to the achievement of a maximal sprint performance (i.e. the product of stride length and stride frequency). This development of speed can be expressed in a speed coefficient (SQ) (SQ = leg tapping frequency/ground contact time (s) in a depth jump). Each participant performed 3 trials, receiving a full recovery between each trial (3mins), with the most number of ground contacts in an individual trial recorded and used in statistical analysis. Additionally, SQ was calculated using the trial with the most number of ground contacts and the quickest contact time. Finally, an overall improvement coefficient was calculated through the accumulated %increase of the pre-post field-based tests results.

6.3 Familiarisation and Establishing Error of Laboratory Tests

Each participant that was selected for laboratory-based test was first familiarised with each test protocol (peak torque, turning, reactive strength and foot speed) through a practical based workshop. Once the participant and tester were content that all the testing procedures were understood, a mean of three trials was recorded for the purposes of data collection towards assessment of reliability. These scores were then compared to the pre-test scores of the experiment which took place within 72hrs after the familiarisation session.

Reliability was evaluated using mean absolute error between first test (familiarisation) and the retest (pre-experimental test). Table 42 provides values of mean absolute error (MAE) where if a significant difference is found in the presence of MAE it is credible to take confidence in the result (Atkinson, 2002).

Table 42: Mean Absolute Error of laboratory-based measures.

Variable	Mean Absolute Error
Peak Torque (Nm)	
Concentric Flexion (60°)	6.1
Concentric Flexion (120°)	7.2
Concentric Flexion (180°)	6.75
Concentric Extension (60°)	9.65
Concentric Extension (120°)	8.2
Concentric Extension (180°)	4.25
Turning	
180° Left (s)	0.0109
180° Right (s)	0.00615
Reactive Strength	
Depth Jump Contact Time (s)	0.01145
Depth Jump Flight Time (s)	0.0123
EKA	0.169
Mean µV (Tibilalis Anterior)	8.25
Mean µV (Gastrocnemius Lateral)	21.75
Mean µV (Gastrocnemius Medial)	19.45
Mean µV (Soleus)	11.65
Max µV (Tibilalis Anterior)	62.85
Max µV (Gastrocnemius Lateral)	29.55
Max µV (Gastrocnemius Medial)	72.8
Max µV (Soleus)	30.95
Foot Speed	
Number of Contacts	1.4
SQ	36.24

6.4 Data Analysis

6.4.1 Field Based Measurements

The main data set had 46 subjects and 32 dependents (16 pre and 16 post). All but 9 of these 32 passed the Shapiro Wilk test of normality (P>0.05) justifying use of a series of two-way ANOVA tests which were undertaken including group as a between subjects effect measured at 3 levels (PC, RC and NC) and gender as a between subjects effect measured at 2 levels (female and male). Each ANOVA test was applied to the pre-post difference of a dependent variable tested. Bonferroni adjusted post-hoc tests were applied in the instance of a significant condition main effect.

Two further series of two-way ANOVA tests were used to analyse the effect of using equipment within SAQ® conditioning and using the Sony Playstation2™ when not performing physical activity during the experimental period. Each of these series of ANOVA tests included group condition as a between subjects effect measured at 2 levels and gender as a between subjects effect measured at 2 levels. Again, each ANOVA test was applied to the pre-post difference of a dependent variable tested. Finally, correlations were calculated between the dependent variable for the pre-test data as well as for the post-test difference. The alpha level for significance for the present study was set at $P < 0.05$.

6.4.2 Laboratory Based Measurements

The laboratory data set was first screened for normality. The data set had 20 subjects and 44 variables (44 pre, 44 post and 44 difference variables (post-pre)). Shapiro Wilk test 58 of the 88 pre and post variables were normal enough according to Shapiro Wilk test, however of the post-pre difference variables, 26 out of 44 were normal cnough according to Shapiro Wilk tcst though duc to narrowcr majority and thc lowcr subject numbers (n=20), non-parametric tests were chosen. Log-transformed values were used for variables which had a skewed distribution. Kruskal Wallis H tests were conducted to the percentage change in the pre-post differences of the dependent variables tested. In the instance of a significant treatment effect, Mann-Whiney U tests were used to compare each pair of intervention groups. Pearson product-moment correlations were calculated between the dependent variable for the pre- and post-test data and for the difference score between pre- and post-test. The alpha level for significance for the present study was set at $P < 0.05$. Finally, correlations were calculated between the dependent variables.

6.5 Results

6.5.1 Field Based Assessment

The mean and standard deviations for the dependent variables for the three main conditions are presented in Table 42. The two-way ANOVA test applied to the pre-post differences showed a significant influence of condition on the dependent variables Body Mass, BMI, 0-5m, 5-10m and 0-15m speed, T-Test, standing long jump, dynamic balance and overall percentage. Post-hoc comparisons showed that the PC and RC conditions resulted in significantly greater weight loss (kg) and reduction in BMI in comparison to the NC condition. Also, the PC condition showed significantly greater improvements in 0-5m speed, 0-15 m speed, T-Test agility, standing long jump and dynamic balance in comparison to the RC and NC conditions. Additionally, the PC condition showed significantly greater improvements on 5-10m speed in comparison to the NC condition. No significant differences were found for the variables 10-15m speed, counter movement jump and hip flexibility. Finally, the PC condition showed a significantly greater percentage change in comparison to the RC and NC conditions. The percentage change in the RC condition was also significantly higher than that in the NC condition.

Table 43 illustrates the differences within PC conditioning as to the necessity of the use of specialised SAQ® equipment to perform SAQ® conditioning as a form of PC. It appeared that SAQ® conditioning was effectively performed with and without SAQ® equipment, no significant differences were found between the two groups. However, the significant interaction effect for the T-Test and follow-up post-hoc comparisons showed that the females in the specialist equipment condition showed greater improvements in the T-Test than the males in the specialist equipment condition and the females in the non-equipment condition. Table 44 indicates that there were no significant improvements in physical performance through interventions involving no physical conditioning. Overall, both control conditions did not show any significant improvement in physical performance.

Finally, tables 45 and 46 provide an overview of the correlations between the dependent variables for the for the pre-test scores and for the difference between the pre- and post-test performance. Improvements in dynamic balance are related to improvements in 0-5 m speed, 0-15 m speed, counter movement jump and standing long jump and flexibility. There is also a relationship between counter movement jump improvement and standing long jump improvcmcnt. Finally, thc improvcmcnt sccn in 0-15 m spccd is closcly related to improvements over the first 5 m.

Table 42: Effect of all conditioning interventions on field-based test performance (mean±sd).

Dependent Variable	Condition						ANOVA Results	
	PC-Pre *n = 14*	PC-Post *n = 14*	RC-Pre *n = 16*	RC-Post *n = 16*	NC-Pre *n = 16*	NC-Post *n = 16*	Condition F(2,40)	Condition X Gender F(2,40)
Body Mass (Kg)	65.64±7.15	63.57±7.41	71.63±12.17	70.06±12.10	68.69±11.07	68.88±11.09	18.2*** ^&	0.6
BMI ($Kg.m^{-2}$)	22.33±1.32	21.61±1.35	23.80±2.28	23.27±2.31	22.92±1.92	22.99±2.00	20.9***^&	1.9
0-5 (s)	1.18±0.20	1.05±0.12	1.20±0.15	1.19±0.13	1.22±0.15	1.26±0.15	6.2**$ ^	1.3
5-10 (s)	0.82±0.06	0.80±0.05	0.80±0.07	0.80±0.07	0.80±0.06	0.81±0.07	3.7*^	1.3
10-15 (s)	0.74±0.06	0.72±0.05	0.72±0.06	0.71±0.05	0.71±0.08	0.71±0.07	1.1	2.4
0-15 (s)	2.74±0.24	2.57±0.20	2.71±0.24	2.71±0.22	2.74±0.25	2.78±0.27	9.7*** $^	1.2
T-Test (s)	11.88±0.90	11.18±0.77	11.38±0.73	11.14±0.54	11.52±0.96	11.44±0.71	6.0** $^	0.4
CMJ (cm)	34.93±8.42	39.71±9.28	36.50±7.03	37.81±8.60	34.44±9.24	35.31±9.57	2.0	0.1
SLJ (m)	1.93±0.23	2.02±0.19	2.00±0.28	2.00±0.23	2.03±0.32	2.00±0.34	8.6** $^	1.0
Dynamic Balance (/100)	68.50±8.76	81.64±8.96	68.38±12.33	76.44±11.41	68.69±9.35	73.94±11.32	17.6*** $^	2.1
Hip Flexibility (degrees)	98.36±2.27	101.29±2.52	100.75±4.23	101.69±4.42	99.69±4.22	99.50±3.56	1.9	0.4
% Change	63.65±23.17		20.46±30.41		2.47±21.65		23.9***$^&	1.5

Key: Significant group effect (*P < 0.05, **P < 0.005, *** P < 0.001), Bonferroni adjusted post-hoc tests ($ Significant difference between PC and RC, ^ Significant difference between PC and NC, & Significant difference between RC and NC (p < 0.05)).

Table 43: Effect of using specialist equipment within SAQ® conditioning test performance (mean±sd).

Variable	Condition				ANOVA Results	
	With SAQ® Equipment Pre $n = 8$	With SAQ® Equipment Post $n = 8$	Without SAQ® Equipment Pre $n = 6$	Without SAQ® Equipment Post $n = 6$	Condition F(1,10)	Condition X Gender F(1,10)
Body Mass (Kg)	64.88±8.13	62.63±8.40	66.67±6.19	64.83±6.37	0.5	0.5
BMI (Kg.m^{-2})	22.08±1.45	21.29±1.44	22.67±1.15	22.04±1.22	0.5	0.5
0-5 (s)	1.25±0.17	1.06±0.10	1.09±0.21	1.04±0.15	2.4	1.1
5-10 (s)	0.81±0.06	0.80±0.06	0.83±0.06	0.79±0.04	2.6	0.0
10-15 (s)	0.77±0.06	0.73±0.05	0.71±0.04	0.71±0.06	3.0	0.9
0-15 (s)	2.83±0.19	2.59±0.19	2.63±0.27	2.54±0.23	3.2	0.8
T-Test (s)	11.96±1.07	11.16±0.63	11.79±0.71	11.19±0.99	1.4	8.2
CMJ (cm)	33.25±10.19	39.75±12.08	37.17±5.31	39.67±4.41	2.7	2.0
SLJ (m)	1.92±0.25	1.99±0.24	1.95±0.22	2.05±0.13	0.6	0.1
Dynamic Balance (/100)	71.13±9.20	85.13±9.95	65.00±7.43	77.00±4.98	1.0	1.7
Hip Flexibility (degrees)	97.88±2.36	100.00±2.07	99.00±2.19	103.00±2.10	1.7	0.1
% Change	73.27±22.01		50.81±19.27		0.1	0.7

Key: Significant effects (P < 0.05, ** P < 0.005, *** P < 0.001).

Table 44: Effect of using Sony Playstation2™ or no activity on test performance (mean±sd).

Variable	Condition				ANOVA Results	
	With Sony Playstation2™ Pre *n = 8*	With Sony Playstation2™ Post *n = 8*	Without Sony Playstation2™ Pre *n = 8*	Without Sony Playstation2™ Post *n = 8*	Condition F(1,12)	Condition X Gender F(1,12)
Body Mass (Kg)	72.88±8.76	72.63±8.60	64.50±12.08	65.13±12.74	1.4	0.7
BMI (kg.m^{-2})	23.48±1.36	23.41±1.45	22.36±2.31	22.56±2.46	1.4	0.7
0-5 (s)	1.16±0.13	1.17±0.08	1.28±0.15	1.35±0.17	0.1	1.5
5-10 (s)	0.77±0.05	0.78±0.06	0.83±0.07	0.85±0.06	0.9	0.9
10-15 (s)	0.67±0.07	0.67±0.07	0.75±0.07	0.76±0.05	0.0	0.0
0-15 (s)	2.60±0.19	2.61±0.17	2.88±0.24	2.95±0.24	0.2	0.4
T-Test (s)	10.95±0.51	11.06±0.53	12.09±0.98	11.81±0.69	0.2	0.5
CMJ (cm)	38.50±8.80	38.25±8.31	30.38±8.23	32.38±10.36	0.4	1.8
SLJ (m)	2.12±0.34	2.07±0.37	1.93±0.30	1.93±0.31	4.6	0.7
Dynamic Balance (/100)	71.38±8.48	76.88±10.93	66.00±9.94	71.00±11.63	1.3	4.7
Hip Flexibility (degrees)	101.50±4.28	100.38±4.37	97.88±3.52	98.63±2.50	5.2	4.8
% Change	0.40±28.29		5.14±9.51		0.4	0.5

Key: Significant effect (* P < 0.05, ** P < 0.005, *** P < 0.001)

Table 45: Pearson's correlation matrix for the pre-test performance scores of the participants collapsed over the three conditions.

	0-5 (s)	5-10 (s)	10-15 (s)	0-15 (s)	T-Test (s)	CMJ (cm)	SLJ (m)	Dynamic Balance (/100)
5-10 (s)	-0.008							
10-15 (s)	-0.028	-0.141						
0-15 (s)	0.910**	0.195	0.231					
T-Test (s)	-0.028	0.274	0.315*	0.161				
CMJ (cm)	-0.226	-0.147	0.158	-0.174	-0.307*			
SLJ (m)	-0.146	-0.278	-0.074	-0.208	-0.453**	0.402**		
Dynamic Balance (/100)	-0.344*	-0.249	-0.141	-0.400**	-0.278	0.323*	0.435**	
Hip Flexibility (degrees)	-0.121	-0.251	0.022	-0.166	-0.278	0.299*	0.260	0.433**

Key: Significant effect (* $p < 0.05$, ** $p < 0.01$)

Table 46: Pearson's correlation matrix for pre-post differences for the selected dependent variables.

	0-5 (s)	5-10 (s)	10-15 (s)	0-15 (s)	T-Test (s)	CMJ (cm)	SLJ (m)	Dynamic Balance (/100)
5-10 (s)	0.206							
10-15 (s)	0.397**	0.633**						
0-15 (s)	0.886**	0.571**	0.709**					
T-Test (s)	0.360*	0.789**	0.760**	0.661**				
CMJ (cm)	-0.503**	-0.725**	-0.694**	-0.740**	-0.786**			
SLJ (m)	-0.395**	-0.680**	-0.697**	-0.652**	-0.788**	0.781**		
Dynamic Balance (/100)	-0.288	-0.516**	-0.312*	-0.447**	-0.455**	0.394**	0.532**	
Hip Flexibility (degrees)	-0.064	-0.285	-0.232	-0.193	-0.256	0.125	0.151	0.075

Key: Significant effect (* $p < 0.05$, ** $p < 0.01$)

6.5.2 Laboratory Based Assessment

Due to missing data and participant drop-out data where available for 7 participants in PC and RC and 6 in NC. The mean±sd for the dependent variables for the three groups during the pre- and post-test are presented in Table 47. Table 48 provide the results of the statistical analysis. Significant differences where found for isokinetic concentric strength at flexion and extension at 60 deg/sec^{-1}, mean µV gastronemicus mediallis and for 180° right turn (using the left foot). Follow-up Mann Whitney U tests revealed that PC provided significantly greater % increases in isokinetic concentric strength at flexion and extension at 60 deg/sec^{-1} than RC and NC ($P<0.05$). Additionally, RC showed a significant reduction in the contact time for the left foot in the 180° right turn in comparison to both the RC and NC conditions.

Table 49 presents correlations between the dependent variables before and after the intervention showed that the participants 15m sprint time was highly correlated with their time over the first 5m as well as with most dynamic strength measures (excluding flexor 180 deg/sec^{-1}) and the depth jump flight time. As expected the depth jump flight time was positively correlated with the maximal power generated by the extensor muscles at 60, 120 and 180 deg/sec^{-1} as well as the number of taps. Tapping performance, on its turn was correlated with mean output of the tibialis anterior muscle during the depth jump.

The correlations calculated for the change in the dependent variables from pre- to post-test revealed that improvements in both the 0-5 and the 0-15m sprint time was associated with similar decreases in contact time for the turning exercise. Additionally, faster sprinting times were associated with increased mean and peak output for the tibialis anterior during the depth jump. Turning performance for the left leg (turning to the right) was not only correlated with the decrease in 0-5 and 0-15 m sprint time but also with increased flexor output at 60 and 120 deg/sec^{-1} and the mean output for the tibialis anterior and the lateral and medial gastocnemius. The correlations indicated that those participants who shorten their contact time improved their mean muscular output whereas those who showed an increase in their contact time showed a decreased mean output during the depth jump. Finally, the decrease in depth jump contact time was significantly correlated with both an increase in mean and peak tibialis anterior muscular output.

Table 47: Mean and standard deviations for the pre- and post-test scores for the dependent variables.

Dependent Variable	PC-Pre $n = 7$	PC-Post $n = 7$	RC-Pre $n = 7$	RC-Post $n = 7$	NC-Pre $n = 6$	NC-Post $n = 6$
Speed and Acceleration						
0 - 5 m (s)	1.21±0.21	1.08±0.14	1.19±0.17	1.15±0.13	1.24±0.14	1.240.16
0 - 15m (s)	2.77±0.25	2.58±0.19	2.71±0.25	2.65±0.18	2.80±0.28	2.77±0.30
Peak Torque (Nm)						
Concentric Flex (60°)	110.9±35.9	144.1±40.2	120.0±32.1	132.0±33.5	98.7±16.1	112.8±22.6
Concentric Flex (120°)	96.6±32.8	116.6±26.9	106.2±36.4	111.9±31.5	101.7±14.5	113.3±23.2
Concentric Flex (180°)	93.4±55.1	142.0±42.5	110.3±31.0	138.3±63.4	96.2±17.6	105.3±18.0
Concentric Ext (60°)	162.1±57.5	193.3±49.2	183.8±44.6	189.6±31.7	159.2±27.9	172.2±42.0
Concentric Ext (120°)	126.0±44.2	151.4±37.8	138.0±41.4	151.6±30.8	144.8±20.5	159.3±21.8
Concentric Ext (180°)	101.0±41.2	123.1±34.8	117.0±76.9	146.3±61.7	137.8±64.3	132.0±43.6
Reactive Strength						
Contact Time (s)	0.37±0.11	0.33±0.10	0.29±0.08	0.29±0.08	0.34±0.09	0.35±0.07
Flight Time (s)	0.45±0.05	0.46±0.05	0.48±0.06	0.56±0.10	0.50±0.08	0.50±0.07
EKA (s)	0.61±0.28	0.68±0.23	0.83±0.27	0.75±0.10	0.84±0.39	0.78±0.31
Mean µV (Tib. Ant.)	191.3±98.1	139.7±44.1	132.2±52.0	126.3±27.2	177.2±61.1	164.8±26.9
Mean µV (Gast. Lat.)	182.4±73.4	226.9±35.3	231.5±80.1	229.3±41.9	264.7±111.9	266.0±109.7
Mean µV (Gast. Med.)	240.3±137.6	351.1±174.7	254.7±140.2	243.3±98.5	304.5±130.4	319.5±141.1
Mean µV (Soleus)	168.7±59.5	212.3±44.4	234.0±72.7	241.0±115.8	246.8±64.7	236.5±55.2
Max µV (Tib. Ant.)	108 4.9±546.8	893.9±373.1	756.2±262.4	856.6±328.9	1263.3±390.1	1131.0±348.7
Max µV (Gast. Lat.)	926.4±293.9	1123.6±271.1	1294.8±342.0	1342.0±336.6	1264.8±357.5	1639.8±745.8
Max µV (Gast. Med.)	1242.1±531.1	1378.9±458.6	1170.0±413.6	1147.4±351.3	1215.3±634.2	1752.2±381.1
Max µV (Soleus)	1174.1±379.3	984.6±322.3	1469.7±525.5	1452.9±395.7	1587.5±740.3	1357.3±221.1
Turning						
180° Left (s)	0.49±0.07	0.68±0.19	0.56±0.10	0.46±0.08	0.54±0.11	0.57±0.09
180° Right (s)	0.52±0.07	0.62±0.22	0.46±0.08	0.51±0.11	0.56±0.09	0.54±0.09
Foot Speed						
Number of Taps	48.6±13.0	50.6±6.6	48.7±7.5	54.4±6.8	51.0±7.5	50.0±8.8
SQ	24.50±12.40	27.34±9.33	30.03±6.50	28.60±5.33	27.42±9.37	25.48±9.11

Table 48: Pre-Post % increase of all conditioning interventions on test performance (mean±sd), and results of the statistical analysis.

Dependent Variables	Pre-Post % Increase			
	PC $n = 7$	RC $n = 7$	NC $n = 6$	H_2, P
Speed and acceleration				
0 - 5 m (s)	9.53±12.66	2.60±5.36	-0.8±16.04	1.66, $P = 0.44$
0 – 15 m (s)	6.36±5.41	2.06±3.31	1.28±6.53	2.40, $P = 0.30$
Peak Torque (Nm)				
Concentric Flex (60°)	31.9±16.1	11.0±16.0	14.6±14.0	5.9, $P = 0.05$
Concentric Flex (120°)	24.8±16.7	7.1±20.1	11.1±12.5	3.4, $P = 0.18$
Concentric Flex (180°)	99.2±121.4	21.0±47.7	10.4±10.7	1.7, $P = 0.42$
Concentric Ext (60°)	24.0±26.3	4.7±16.0	7.6±14.7	6.1, $P < 0.05$
Concentric Ext (120°)	24.9±22.9	11.0±18.3	10.5±9.7	3.4, $P = 0.18$
Concentric Ext (180°)	28.2±27.5	9.6±20.4	0.2±13.4	4.0, $P = 0.18$
Reactive Strength				
Contact Time (s)	-5.5±32.5	14.1±18.3	5.8±19.0	2.1, $P = 0.35$
Flight Time (s)	2.9±10.1	3.1±9.1	0.6±2.3	0.4, $P = 0.83$
EKA	24.1±45.9	-3.7±23.0	-1.7±17.7	2.4, $P = 0.30$
Mean μV (Tibialis Ant.)	9.1±48.0	9.3±30.0	-2.3±16.9	2.3, $P = 0.32$
Mean μV (Gastroc. Lat.)	51.9±84.5	16.9±43.1	1.3±8.0	2.5, $P = 0.29$
Mean μV (Gastroc. Med.)	67.0±70.2	13.2±36.1	5.6±11.7	6.7, $P < 0.05$
Mean μV (Soleus)	46.6±75.5	12.1±54.9	-3.6±7.4	2.5, $P = 0.29$
Max μV (Tibilalis Ant.)	-10.6±26.3	23.0±49.5	-8.6±21.2	2.2, $P = 0.34$
Max μV (Gastroc. Lat.)	32.7±53.4	16.6±49.3	32.2±54.7	0.8, $P = 0.66$
Max μV (Gastroc. Med.)	25.8±58.9	4.1±39.1	195.3±424.2	4.0, $P = 0.13$
Max μV (Soleus)	-10.0±35.6	0.7±19.1	-6.0±22.6	0.7, $P = 0.70$
Turning				
180° Left Foot (s)	39.7±32.4	-17.1±24.5	6.0±11.4	8.1, $P < 0.05$
180° Right Foot (s)	19.4±39.3	12.8±32.5	-3.4±3.5	1.0, $P = 0.61$
Foot Speed				
Number of Taps	7.5±16.4	9.3±19.5	-1.5±12.5	2.7, $P = 0.26$
SQ	11.6±	-4.76±	-7.07±	0.7, $P = 0.71$

Table 49: Correlation matrix for the relationship between the selected variables before the start of the experiment (above the diagonal) and at the end of the intervention (below the diagonal).

Dependent variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. 0-5 m speed	–	.89**	-.58*	-.54*	-.10	-.38	-.38	-.51*	-.03	-.39	-.21	.14	-.10	-.30	-.15
2. 0-15 m speed	.93**	–	-.75**	-.73**	-.30	-.60**	-.59**	-.65**	.10	-.57**	-.42	.26	.06	-.32	-.26
3. concentric flex 60^0	-.71**	-.79**	–	.94**	.46*	.86**	.80**	.56*	.15	.35	.29	.09	-.02	.31	.29
4. Concentric flex 120^0	-.64**	-.78**	.89**	–	.53**	.89**	.88**	.65**	-.12	.48*	.36	.09	.06	.32	.26
5. Concentric flex 180^0	-.26	-.26	.20	.28	–	.52*	.55*	.54*	-.22	.35	.28	-.06	-.01	.17	.22
6. Concentric ext 60^0	-.36	-.57**	.71**	.77**	.39	–	.88**	.56**	-.24	.48*	.41	.00	-.14	.35	.35
7. Concentric ext 120^0	-.32	-.53*	.67**	.82**	.31	.83**	–	.73**	-.23	.57**	.51*	.08	.06	.34	.35
8. Concentric ext 180^0	-.39	-.57**	.54*	.73**	.39	.48*	.64**	–	-.14	.70**	.49*	-.17	-.13	-.49*	.30
9. Depth jump contact time	-.13	-.03	.15	-.04	-.24	-.24	-.17	-14	–	-.32	-.76**	-.06	.27	.41	-.87**
10 Depth jump flight time	-.23	-.48*	.37	.53*	.03	.44	.43	.58**	-17	–	.81**	-.26	-.26	.46*	.45*
11. EKA	-.35	-.54*	.36	.53*	.01	.51*	.50*	.39	-46*	.73**	–	-.10	-.21	.45*	.79**
12 180^0 left turn	.08	.18	-.02	-.11	.06	-.31	-.23	-.26	.32	-.48*	-.46*	–	.28	-.38	-.11
13. 180^0 right turn	-.08	-.11	.29	.23	-.13	.27	.36	.08	.23	-.29	-.04	.12	–	-.02	-.09
14. Number of taps	.13	-.01	.08	.17	.07	.28	.07	.01	-.48*	.22	.41	-.16	-.11	–	.75**
15. SQ	-.19	-.26	.18	.29	.06	.35	.27	.04	-.58**	.10	.70**	-.18	.19	.69**	–

6.6 Discussion and Conclusions

6.6.1 Field Based Assessment

This study compared the efficacy of two conditioning programmes on selected physical performance variables relevant to soccer performance in novice participants. Two separate groups received physical conditioning delivered in the form of programmed (PC) and random (RC) methods and a third control group performed no physical conditioning (NC). PC used SAQ® conditioning and in RC supervised small-sided soccer games were played. The overall percentage change indicated that both conditioning groups increased physical performance significantly more than the NC condition. Additionally, the PC and RC conditions showed significant decreases in body weight and BMI. However, the PC methods appeared to be significantly more effective than the RC method. In particular, PC had a superior effect on 0-5m and 0-15m speed, T-Test, standing long jump, dynamic balance and the overall summation of % increases when compared to RC. Secondly, this study found that the use of specialised SAQ equipment was not a requirement to observe significant improvements. No differences in performance were observed between the programmed SAQ conditions with and without equipment.

Recent studies on conditioning in soccer have mainly used highly skilled soccer players and have particularly emphasised the importance of improving player's aerobic capacity (Wisløff et al., 1998; Helgerud et al., 2001; Hoff et al., 2002). This has provided evidence that optimising endurance capacity is associated with increased distance covered during a match, increased number of sprints and involvement with the ball, and with position in the league (Wisløff et al., 1998; Helgerud et al., 2001). Although it is undeniable that players aerobic capacity will be important in maintaining a high level of intensity throughout a game of soccer, it is the speed by which purposeful movements are executed that is of the highest importance. The present study suggests that these physical capabilities are best trained by incorporating specific, programmed conditioning sessions. SAQ training principles, in this respect, appears to be a more efficient method of improving these physical capabilities assumed to be relevant to soccer performance than RC in the form of small sided games. Additionally, these significant improvements in the RC took place over a relatively short period of time.

The findings of the present study provide support for the conditioning methods of Verheijen (2004) whereby the speed, agility and quickness conditioning of the Korean National soccer team in preparation for the FIFA World Cup 2002 was deliberately performed separately, in a programmed fashion and in supplement to random conditioning methods of soccer-specific aerobic and repeat sprint conditioning (using small sided games).

A possible explanation why PC in the present study resulted in greater improvements on the selected tests in comparison to RC is that, fundamentally, the nature of PC and RC expose the participants to different bioenergetic demands. In this respect, RC could have incorporated a higher aerobic yield due to the nature of the match-play and this may have compromised the quality of the speed, agility and quickness conditioning. Hence, in a recent study by Hoff et al. (2002) it was found that participants who played small sided games worked at 91.3% of maximal heart rate or 84.5% of maximal oxygen uptake. It was suggested that small sided games could be a suitable way to improve soccer player's endurance capacity when actively coached during such session. So, in contrast to PC, RC participants might have regularly received inadequate recoveries to replenish ATP-PC stores and subsequently performed the speed, agility and quickness parameters relevant to soccer at a submaximal intensity. Alternatively, RC provided fewer participants with a sufficient level of overload within each individual conditioning session which perhaps also relates to the level of motivation and intensity of effort of an individual on any particular day. This could have occurred despite active coaching during these sessions. To this end, future studies could include heart rate monitoring to establish actual exercise intensity during small sided games (Hoff et al., 2002) as well as a test to assess participant's changes in maximal oxygen uptake. The latter would provide evidence whether small sided games are more suitable to improve player's aerobic capacity. The structure provided by PC, on the other hand, ensured that all participants received at least a minimal level of overload in each conditioning session regardless of levels of motivation. This also lends support as to the necessity for a controlling figure to command, promote motivation and intensity of effort in all conditioning sessions.

Within PC conditioning, it appears SAQ® conditioning is effective in conditioning the ability to start quickly and efficiently (0-5m speed), move effectively in multi-directions (T-Test) and prepare to change direction or stop quickly (dynamic balance, standing long jump) (Wisløff et al., 1998; Helgerud et al., 2001). In this respect, SAQ® conditioning particularly emphasises the ability to accelerate with changes in 0-5m values strongly correlated to 0-15m speed and dynamic balance (note, 0-15m speed is mostly influenced through the increase in 0-5m performance). This partially supports some of the claims of the licensed SAQ® commercial organisations who associate increases in performance through SAQ® conditioning with the development of acceleration and speed over short distances, deceleration and changes in direction, footwork patterns, movement responses, arm action, as well as linear, lateral, diagonal, and vertical movements (Wisløff et al., 1998; Helgerud et al., 2001).

The PC condition was beneficial in increasing the participant's horizontal power. The ability to generate high power has been found to be important for successful soccer performance (Wisløff et al., 1998). Hence, during a game of soccer players engage in activities like jumping, tackling, kicking and turning which successful execution is dependent on the player's maximal strength as well as the rate of force development. The results of the present study suggest that the exercises used in PC facilitated the improvement of horizontal power which benefited the participant's performance on the T-Test. The significant correlation between standing long jump and counter movement jump suggest that there is a cross-component effect between horizontal and vertical power (Polman et al, 2004). Finally, improvements in dynamic balance appear to be associated with a number of variables. That is, improvements in 0-5m and 0-15m speed, horizontal and vertical power as well as hip flexibility where associated with improvements in dynamic balance.

In a similar study by Polman et al., (2004), it was suggested that improvements seen in performance in the SAQ conditions could have been due to a placebo effect. Hence, participants in this study either received the novel, structured SAQ training programme from a new instructor which might have enhanced their motivation in comparison to the group who received their regular conditioning by their current coach. The fact that all participants in the present study where new to the instructor and activities suggests the absence of such an effect.

This study found that PC in the form of SAQ® exercises can be effectively performed with and without the use of specialised SAQ® equipment. Similar findings where obtained in a study by Polman et al. (2004) using elite female soccer players. SAQ principles can be implemented by soccer coaches without the necessity of purchasing additional equipment. Also, SAQ training can be implemented during whole team training sessions in a structured fashion allowing coaches to optimize the time spent on such physical conditioning activities.

6.6.2 Laboratory Based Assessment

The PC group showed significantly larger improvements in comparison to the RC and NC groups in maximal isokinetic concentric strength at 60 deg/sec^{-1} for both the flexor and extensor muscles. Additionally, the gastronemicus mediallis showed increased mean output during the depth jump. The programmed conditioning group also showed significantly lower contact time when turning on the left foot. The correlational analysis identified relationships between dependent variables before the start and at the end of the intervention as well as relationships associated with changes over the duration of the training program.

The nature of the exercises conducted in PC and the emphasis on appropriate movement technique for executing these exercises might explain that significant strength benefits were only observed at 60 deg/sec^{-1}. That is, initially participants executed the exercises at low speeds to ensure the development of appropriate technique and this was built-up only slowly maintaining emphasis on the appropriate executing of these movements.

The nature of the exercises conducted during PC suggests that the improvements seen in isokinetic concentric strength are most likely to be the consequence of improved neuromuscular functioning rather than muscular hypertrophy (Almasbakk and Hoff, 1996). Extending the duration of the intervention program allowing the participants to execute the exercises correctly at maximal speeds could potentially result in adaptations and improvements at higher peak torque velocities.

It is generally believed that concentric muscle force produced at the knee is an important variable in the execution of a sprint stride (Mann and Hagy, 1980). This study found a significant relationship between the participant's isokinetic concentric strength and their 0-15 m sprint and depth jump flight time performance. That is, for both the pre- and post-test data faster sprint times for this distance where associated with higher peak torque scores ($N \cdot m \cdot kg^{-67}$) in the extensor and flexor muscles at 60, 120 and 180 deg/sec^{-1} and a longer flight time during the depth jump. This finding support recent findings by Wisloff et al (2004) and Newman et al. (2004). The former study obtained a strong relationship between maximal strength in half squats and vertical jump height with sprint performance ($r = 0.94$ and $r = 0.71$ for maximal strength in half squats with 10 and 30m sprint performance respectively and $r = 0.78$ for jumping height and sprint performance) in elite soccer players whereas the latter study found a strong correlation between isokinetic knee strength and single sprint performance (with the strongest correlations at 240 deg/sec^{-1} $r = -0.714$). However, the current study differed in that the strongest correlation where found for the lower speeds (flexor muscles in particular) and that the stronger and significant correlations where found between maximal strength and 0-15 m sprint performance rather than 0-5 m performance. The latter has a larger acceleration component and would expected to be stronger correlated to the participants maximal isokinetic concentric strength (Newman et al., 2004). The fact that stronger correlation where found for lower speeds might be partially due to the notion that at lower speed generally more accurate readings are obtained.

Although there does not appear to be a standardised protocol to assess maximal strength doubt has been raised about the use of the isokinetic method. Hence, this method isolates a particular muscle and forces it to move in isolation at a constant speed. Such a movement is rather detached from those performed in real world sporting situations. Therefore, it has been suggested that tests using free weights are more likely to accurately reflect the functional strength in soccer (Wisloff et al., 2004). However, caution should be taken considering this statement. The familiarity of participants of training with free weights (learning effect) might have a significant influence on their 1 RM.

As expected the participant's depth jump flight time was also significantly correlated with sprint performance (0-15 m) and maximal isokinetic concentric strength of the extensor muscles at all 3 speeds. This finding is also in line with previous studies in soccer which have found similar relationships (Newman et al., 2004; Wisloff et al., 2004 & 1998).

Maximal strength, in this respect, is an important variable that influences power. Hence, an increase in maximal strength is accompanied by an increase in relative strength and subsequent power capabilities (Hoff and Helgerud, 2004). Improvements in strength, therefore, have the potential to improve soccer specific activities like acceleration, sprinting and turning. The current study found some evidence for this assertion. Improvements in concentric strength for the flexor muscles was associated with improved sprinting performance (0-15 m) and reduced contact time for turning on the left foot.

It is well established that maximum speed, acceleration and agility are relatively independent qualities (Buttifant et al., 1999; Little and Williams, 2005; Mayhew et al., 1989). The present study found low, non-significant correlations between sprint performance and the turning task partially supporting the independence of these abilities.

It remains unclear as to the precise underlying mechanisms that explain the increase in several field-based test performances. Nevertheless, it appears that an increase in peak torque occurs (particularly at 60 deg/s) through SAQ® conditioning which would suggest that concentric and eccentric leg strength is increased and demonstrated predominatly in acceleration or leg power exercises (depth jump, EKA, CMJ, SLJ). Furthermore, the increase in leg strength may be due to an increase in neuromuscular control of movement. To this end, SAQ® conditioning produced the highest increases in mean μV values signifying either a higher recruitment of muscle fibres or increased rate of synchronicity of muscular contraction (Basmajian, 1978; Clarys and Cabri, 1993).

SAQ® conditioning would suggest the development of superior neuromuscular strategies for dealing with movement complexity than RC. However, the essence of motor learning and physical conditioning is the principle of specificity (Henry, 1968; Barnett et al., 1973; Saltin et al., 1977; Sale and MacDougall, 1981; Holloszy and Coyle, 1984; Wolpaw and Carp, 1990; Morrissey et al., 1995). In this respect, it is critical to identify the specificities of soccer performance in order to design appropriate functional conditioning programmes (See Chapter five). The main issue is if the improvements seen in training can be transferred to the soccer pitch. In this respect, does this conditioning positively effect performance such as capacity for faster dribbling with ball (future studies could include soccer specific tests to establish this) or does it also transfer to a chain of actions?

RC also had some positive effects in speed, agility and quickness conditioning with superior increases in tests of 180° turning and the tapping test. However, the increases in the depth jump through PC provided a higher increase in speed coefficient (SQ). Bauersfeld & Voss (1992) state that SQ is strongly correlated to sprint performance although only low non-significant correlations were found between these parameters in this study. This was also observed in a similar study conducted on adolescent athletes although the measurements for this study were taken on different days which might have significantly influenced the results obtained (Van der Loo and van Rossum 2000). Bauersfeld & Voss (1992) also explain that improvements in speed can be obtained by special as well as competition like exercises and highlight the importance of specificity. In this respect, specific exercise has to have relevance to the actual movements made during competiton. They may involve use of lighter or smaller equipment, assistance when executing movements, changes of the competition situation (e.g. size of the pitch, size of the goal) and other forms of PC (e.g. treadmill).

It was observed that no significant improvements in physical performance occurred through interventions involving no physical conditioning. Although minimal, improvements were made overall, it may be noted that participants who were engaged in video gaming using the Sony Playstation2™ made slight improvements in 0-5m speed. Really there is no difference. This suggest at the moment that central issues are less important in comparison to peripheral changes.This also lends support as to the necessity for a controlling figure to command, promote motivation and intensity of effort in all conditioning sessions.

6.7 Limitations

One limitation of the current study is that it did not investigate whether the improvements on the selected physical performance variables resulted in improved soccer performance (See Di Salvo and Pigozzi, 1998; Polman et al., 2004 for similar limitations). To this end additional research is required to establish whether the progress seen in programmed SAQ conditioning would also result in improved soccer performance. An important concept to keep in mind when doing this is that of specificity of learning and training (Henry, 1968; Barnett et al., 1973; Sale and MacDougall, 1981). That is, will improvements seen in training be transferred to the soccer field? Earlier studies have investigated the effect of endurance-based training and have found improvements in soccer performance relevant to this parameter (e.g., distance covered, number of sprints). More relevant to the current study would be to investigate the effects of SAQ training on activities like dribbling or driving a soccer ball or shooting power. Future studies, in this respect, could be enhanced by including soccer specific tests to investigate this relationship.

The present study did not observe any significant improvements in physical performance in the no physical conditioning groups (NC). This suggests that central issues are less important in comparison to peripheral changes for the improvement in physical performance observed in the present study. However, the field based test used in the present study may have been too generic in nature to detect possible benefits of engagement in fine motor skills (computer games) on physical performance.

Finally, the specificity of exercises conducted in the programmed condition and the fact that this group received drills to improve movement mechanics might have resulted in the development of more functional and relevant motor programmes that control the complex intramuscular coordination of associated activities like sprinting and jumping. Secondly, there are some obvious relationships between some of the variables measured in this study. For example, improvements in power were associated with faster sprinting times (Young et al., 2002). Increases in power in the present study can result in the reduction of contact time with the surface and the production of higher forces at faster rates. The improvement observed in 0-5m speed (and 0-15 m speed) therefore could be partially due to the improvements seen in vertical power (Polman et al, 2004).

6.8 Practical Implications

The practical implications of the current research would be that in order to condition soccer players in the most effective way possible in the often limited time available a combination of both programmed and random exercises would be recommended (Verheijen, 2004). If there is a need of specific increase in a particular aspect of physical performance than programmed conditioning using SAQ® principles might be the preferred option to relatively quickly obtain improvements. For example, this might be the case in pre-season training or after sustaining an injury. However, the principle of specificity has always to be kept in mind when designing conditioning programmes.

Secondly, the findings of this study would recommend the presence of a fitness specialist in speed, agility and quickness conditioning to lead, direct and control PC, in particular the specificity and overload, is of superior benefit to the laissez-faire approach of RC to improve aspects like speed, power and agility.

Finally, SAQ principles can be implemented by soccer coaches without the necessity of purchasing additional equipment. Also, SAQ training principles can be implemented during whole team training sessions in a structured fashion optimising the time available for physical conditioning.

CHAPTER SEVEN: EPILOGUE

7.1 Aims and objectives

The aim of this research programme was to examine the physical aspects of high performance soccer and provide an up-to-date analysis with greater depth through new investigations into three interrelated areas. This involves the physical characteristics of players, physical demands of match-play and effective physical conditioning. The objective of these investigations was to supply valuable information to assist with the development of soccer players in preparation for FA Premier League match-play. This thesis would be of interest to both applied practitioners and sport science researchers as it provides information on the requirements of FA Premier League players and new methodologies to make on-going player assessment.

7.2 Study 1: Analysis of Age, Stature, Body Mass, BMI and Quality of Elite Soccer Players from four European Leagues

The purpose of Study 1 was to identify normative values of 2085 elite players for age (years), stature (m), body mass (kg) and body mass index (BMI) ($kg.m^{-2}$) and quality using the FIFA World Ranking (FWR) of the international players' nations. Players competed in either the English FA Premier League, the Spanish Premiera Division (La Liga), the German Bundesliga or the Italian Serie A in the season 2002/03. Differences were examined firstly between positions (goalkeeper, defender, midfielder, forward) and secondly by European League. This is an important issue because even small changes in these physical characteristics of players could result in a large reduction in the pool of people to draw from in the general population who have the suitable physical characteristics to be successful in soccer, an issue already identified in rugby (Olds, 2001). Furthermore, comparison of players in different leagues and in different positions provides some valuable insights into the different demands placed on soccer players in different leagues (Reilly et al., 2000a; Rienzi et al., 2000; Strudwick et al., 2002).

7.3 Study 2: The 'Bloomfield Movement Classification': Motion Analysis of Individual Soccer Players

The purpose of Study 2 was to develop a methodology based on computerised time-motion analysis in order to investigate the physical demands of FA Premier League soccer match-play. To date, fewer than 8 modes of motion have often been chosen in time-motion investigations. However it is arguable that this does not provide a high enough degree of specificity to detail the physical demands of an intermittent, stochastic and dynamic sport such as soccer. This new approach included 14 modes of timed-motion, 3 'other' non-timed movements, 14 directions, 4 intensities, 5 turning categories and 7 'On the Ball' activity classifications known as the 'Bloomfield Movement Classification' (BMC). The BMC is a highly specific, accurate and reliable method for analyzing soccer performance. This novel and detailed approach will provide researchers and practitioners useful addition data which can be used to optimize assessment, conditioning, nutritional and recovery strategies.

7.4 Study 3: Physical demands of outfield positions in FA Premier League soccer

The purpose of study 3 was to investigate the physical demands of high level soccer performance through use of the BMC. The aims were to provide detail regarding intermittent patterns of Purposeful Movement (PM) and Recovery (R), performed by players of three different positions (defender, midfielder and striker), to investigate the reoccurrence of bouts of PM and R within selected time phases and finally provide detailed time-motion analysis of the PM. As the majority of soccer-related time-motion analysis studies have reported findings macroscopically, greater detail into the intermittent nature of the sport provides better knowledge regarding the specific physical demands.

PM and R were collected concerning 373 professional soccer players from 63 matches in the FA Premier League 2003-2004 season. No substitutes were selected. Repeated bouts of PM and R (RPMB - any period of 2 or more PMs separated by recoveries of 15s or less) were investigated. The BMC was then employed to detail the PMs of 55 players (18 defenders, 18 midfielders, 19 forwards). This study showed that match-play differences exist between striker, midfield and defending players. Furthermore, differences appear to exist between the bioenergetic demands for each position with strikers requiring a high anaerobic capacity for repeated bouts of short, high intensity movement and defenders and midfielders requiring a higher VO_{2max} for longer repeated bouts of movement. This would indicate that physical conditioning, assessment, recovery and nutritional programs need to be tailored to specific positions in soccer or preferably even for individual players (Di Salvo and Pigozzi, 1998).

7.5 Study 4: Effective conditioning for soccer match-play

The interaction of multiple dynamic physical activities often produces a hybrid of physiological and biomechanical stresses. Higher levels of soccer require increased levels of physical fitness through increased demands from high intensity activity (O'Donoghue et al., 2001; Strudwick and Reilly, 2001; Mohr et al., 2003). Therefore, increased ability to perform complex chains of movement skills (agility) in conjuncture with speed (both acceleration and deceleration) and quickness (overcoming inertia) are relative to high level performance (Withers et al., 1982; Bangsbo, 1992; Reilly, 1994a). In this respect, two main methods of conditioning (programmed and random) have been identified (see: Bangsbo, 1994b, c) and recognised as credible methods of conditioning for soccer (Hoff et al., 2002). The purpose of study 4 was to investigate differences between these two different types of physical conditioning methods. Both interventions were aimed at conditioning aspects of speed, agility and quickness specific for soccer. The aim was to investigate differences in performance variables with a secondary objective of establishing the necessity for the use of specialised conditioning equipment to perform the conditioning. A total of 46 participants (m=25, f=21) performed six weeks of physical conditioning with a battery of field and laboratory tests completed pre and post intervention. Participants were randomly assigned to one of three main groups (programmed, random, control) with each split into two sub-groups. Programmed conditioning (PC) included SAQ® conditioning with and without specialised equipment. Random conditioning (RC) included small-sided games separated into males and female groups. The control group performed no physical conditioning with one sub-group operating a Sony Playstation2™ and the other continuing a daily routine of no formal exercise. Field tests to measure speed and acceleration, agility, power, dynamic balance and flexibility were completed by all participants. Laboratory tests to investigate peak torque, reactive strength turning and foot speed were selected incorporating use of isokinetic dynamometry, force platform analysis and electromyography. The key finding of the study was that PC conditioning is a more effective method of enhancing speed, agility and quickness qualities than RC conditioning. To this end, SAQ® conditioning is proven to be effective in increasing performance, particularly in terms of acceleration over short distances. This can be performed both with and without equipment, although the use of specialised SAQ® equipment is preferred.

7.6 Applied Implications

The findings from the first study imply that FA Premier League practitioners should be encouraged to select players with appropriate physical characteristics to suit a desired system and style of play. Alternatively, it is useful to investigate the physical characteristics of opposing teams to predict a particular system and style of play. In this respect, taller players with international experience are sought in the FA Premier League, particularly for the positions of goalkeeper and striker. In turn, this desire also influences the identification and development of talented young players. In addition, a player's date of birth has an influence on selection to play at higher levels and should also be considered (although not as an ultimatum) when searching for new talent.

Through investigation of the physical demands of match-play, it appears that distinct differences exist between different positions. This would suggest that positional specific physical conditioning, assessment, recovery and nutritional programs should be adopted. In these regards, strikers require a high anaerobic capacity for repeated bouts of short, high intensity movement and defenders and midfielders requiring a higher VO_{2max} for slightly longer repeated bouts of movement. Furthermore, the use of time-motion analysis appears to be the most effective method of quantifying match-play energy expenditure in soccer. Due to the randomisation of intermittent activity of varying intensities during match-play, physiological analyses and measurements of distance covered appear to supply inaccurate quantifications (e.g. heart rate data provides an overestimation of energy cost). Consequently, highly detailed information gained from time-motion analysis can be translated into specific conditioning and assessment practices and used as a useful method of monitoring physical exertion.

The practical implications of study 4 would be that in order to condition soccer players in the most effective way possible in the often limited time available a combination of both programmed and random exercises would be recommended (Verheijen, 2004). If there is a need of specific increase in a particular aspect of physical performance than programmed conditioning using SAQ® principles might be the preferred option to relatively quickly obtain improvements. For example, this might be the case in pre-season training or after sustaining an injury. However, the principle of specificity has always to be kept in mind when designing conditioning programmes. Secondly, the findings of this study would recommend the presence of a fitness specialist in speed, agility and quickness conditioning to lead, direct and control PC, in particular the specificity and overload, is of superior benefit to the laissez-faire approach of RC to improve aspects like speed, power and agility.

Finally, SAQ principles can be implemented by soccer coaches without the necessity of purchasing additional equipment. Also, SAQ training principles can be implemented during whole team training sessions in a structured fashion optimising the time available for physical conditioning.

7.7 Future Research

Due to the evolving physical nature of soccer, research in this area should be constantly on-going. For example, as has been indicated, if small changes in physical characteristics of players occur, they could result in a large reduction in the pool of people in the general population from which to draw from who have the suitable physical characteristics to be successful in soccer. A similar effect has been witnessed in rugby since the game turned professional in 1996 (Olds, 2001). Therefore, it is important to regularly re-assess the physical characteristics of players of different positions and of interest to investigate what is sought of players competing in different leagues.

Also, time-motion analysis research has indicated that the physical demands of match-play have appeared to increase over the last few decades (1976 – 2005). However, the reporting of the findings of time-motion analysis investigations has involved a holistic approach (e.g. totals, means±sd, and frequencies) and has ignored any interaction between and within motions, movements and playing activities. Therefore, it is important to also perform temporal pattern (T-pattern) detection to identify hidden patterns within a time-motion data set (Borrie et al., 2002). The identification of patterns that are not identifiable through simple observation has great benefit not only in match-play but also in establishing the physical performance demands. It is therefore desirable to perform the T-pattern analysis with the player movement to uncover further specific demands of physical performance.

Another requirement for research into the physical demands of match-play is that of significant events and phases of play. A significant event may include a sending off or the scoring of a goal. In this respect, the effect of score-line on team strategy and physical effort also merits thorough investigation. It is commonly accepted that players fatigue towards the end of a match and this has an influence on a higher number of goals scored in the final period of the match (Reilly, 2003c). In contrast, it has also been shown that there were no significant differences in the quantity of high intensity activity during different phases of FA Premier League match-play, although score-line did briefly influence work rates. It is therefore also necessary to perform detailed studies in these areas (Bloomfield et al., 2004d).

Additional research is also required to establish whether the progress seen in programmed SAQ conditioning would also result in improved soccer performance. An important concept to keep in mind when doing this is that of specificity of learning and training (Henry, 1968; Barnett et al., 1973; Sale and MacDougall, 1981). That is, will improvements seen in training be transferred to the soccer field? Earlier studies have investigated the effect of endurance-based training and have found improvements in soccer performance relevant to this parameter (e.g., distance covered, number of sprints). More relevant to the current study would be to investigate the effects of SAQ training on activities like dribbling or driving a soccer ball or shooting power. Future studies, in this respect, could be enhanced by including soccer specific tests to investigate this relationship.

7.8 Conclusion

The four studies suggest that there are abundant differences in the physical aspects of high performance soccer. These include the physical characteristics of the players and the demands of match-play. In addition, this also appears to be relative to the league that the players compete in as observed through investigation of the FA Premier League, La Liga, Serie A and Bundesliga players. These differences suggest alternatives in playing style from league to league which may be influential in European soccer competitions. Additionally, there appear to be desirable characteristics of players for each league with teams in all four leagues seeking such players. Furthermore, the advancements in time-motion analysis research presented in this thesis provide greater detail and depth into the specificities of the physical demands of match-play. To this end, this would indicate that physical conditioning, assessment, recovery and nutritional programs need to be tailored to specific positions in soccer and ideally for individual players.

Finally, in order to condition soccer players in the most effective way possible in the often limited time available a combination of both programmed and random exercises would be recommended (Verheijen, 2004). If there is a need of specific increase in a particular aspect of physical performance than programmed conditioning using SAQ® principles might be the preferred option to relatively quickly obtain improvements. However, the principle of specificity has always to be adhered when designing conditioning programmes. In addition, the presence of a fitness specialist in speed, agility and quickness conditioning is recommended to lead, direct and control specificity and overload and is of superior benefit to a laissez-faire approach.

Finally, SAQ principles can be implemented by soccer coaches without the necessity of purchasing additional equipment. Also, SAQ training principles can be implemented during whole team training sessions in a structured fashion optimising the time available for physical conditioning.

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APPENDICES

APPENDIX A

Selected workings of Study 1: Analysis of Age, Stature, Body Mass, BMI and Quality of Elite Soccer Players from four European League.

It was important to discover a source that provided a comprehensive database concerning elite soccer players and their physical characteristics. Relatively few textbooks supplied these statistics, though the Rothmans Football Yearbook Series (Rollin and Rollin, 2002) provided sufficient information regarding FA Premier League players. However, to make European comparisons and tests for reliability, further sources were necessary. Alternative sources were then sought on the internet with a search engine selecting the following soccer statistics websites:

- http://www.soccerassociation.com/
- http://www.soccerbase.com/
- http://www.soccerbot.com/
- http://www.soccer-stats.com/
- http://www.wsoccer.com/

The website <http://www.soccerassociation.com/> provided a publication (Wilson, 2003) from a private service that required a subscription fee. The organisation also included staff members verifying and validating the statistics of each player. In addition, it was made aware that scouts working in high performance soccer also regularly referred to this source. Table A provides an example of data that was collected in order to create the database used in the present study.

Table A: Biographic and anthropometric data concerning the 25 tallest players in the four leagues

Rank	Position	Club	League	Nationality	Origin	FIFA World Rank	Age	Stature (m)	Body Mass (kg)	BMI ($kg.m^{-2}$)	Int. Caps	Int. Goals
1	FWD	Borrussia Dortmund	German	Czech Republic	Eastern Europe	14	28	2.02	99	24.26	27	15
2	GK	SC Freiburg	German	Germany	Central Europe	10	33	1.99	95	23.99		
3	DEF	Fulham	English	England	UK and Ireland	12	21	1.98	86	21.94		
4	GK	West Ham United	English	Trinidad & Tobago	N. America	34	33	1.98	77	19.64	7	0
5	FWD	Arsenal	English	Nigeria	Central Africa	32	25	1.97	80	20.61	11	4
6	GK	Chelsea	English	Holland	Central Europe	9	35	1.97	76	19.58	31	0
7	GK	Fulham	English	Holland	Central Europe	9	31	1.97	85	21.90		
8	GK	Roma	Italian	Italy	Southern Europe	4	21	1.96	88	22.91		
9	GK	Bayer Leverkusen	German	Australia	Oceania	49	28	1.96	96	24.99	2	0
10	FWD	Kaiserslautern	German	Czech Republic	Eastern Europe	14	28	1.96	88	22.91	43	5
11	GK	1. FC Köln	German	Germany	Central Europe	10	31	1.96	90	23.43		
12	GK	TSV München 1860	German	Germany	Central Europe	10	25	1.96	96	24.99		
13	GK	Arsenal	English	England	UK and Ireland	12	21	1.95	78	20.51		
14	GK	Fulham	English	Northern Ireland	UK and Ireland	92	30	1.95	86	22.62	19	0
15	GK	Southampton	English	England	UK and Ireland	12	22	1.95	103	27.09		
16	GK	West Ham United	English	Sweden	Northern Europe	16	38	1.95	93	24.46		
17	GK	West Ham United	English	Canada	N. America	74	34	1.95	88	23.14	52	0
18	FWD	Málaga	Spanish	Spain	Southern Europe	7	27	1.95	80	21.04		
19	DEF	Valencia	Spanish	Spain	Southern Europe	7	21	1.95	77	20.25		
20	FWD	Valencia	Spanish	Norway	Northern Europe	30	22	1.95	92	24.19	25	9
21	GK	Inter	Italian	Italy	Southern Europe	4	30	1.95	88	23.14	19	0
22	DEF	Udinese	Italian	Denmark	Northern Europe	19	22	1.95	88	23.14		
23	MID	Udinese	Italian	Denmark	Northern Europe	19	27	1.95	86	22.62		
24	DEF	Hertha BSC Berlin	German	Croatia	Southern Europe	23	24	1.95	89	23.41		
25	GK	Kaiserslauten	German	Germany	Central Europe	10	30	1.95	95	24.98		

APPENDIX B

Selected workings of Study 2: The 'Bloomfield Movement Classification': Motion Analysis of Individual Soccer Players.

The Bloomfield Movement Classification (BMC) was created after the movements of individual players in dynamic team sports were thoroughly observed and notated. Classifications for motion, direction, turns, unorthodox movement and soccer activity were chosen and further brainstormed (Table B).

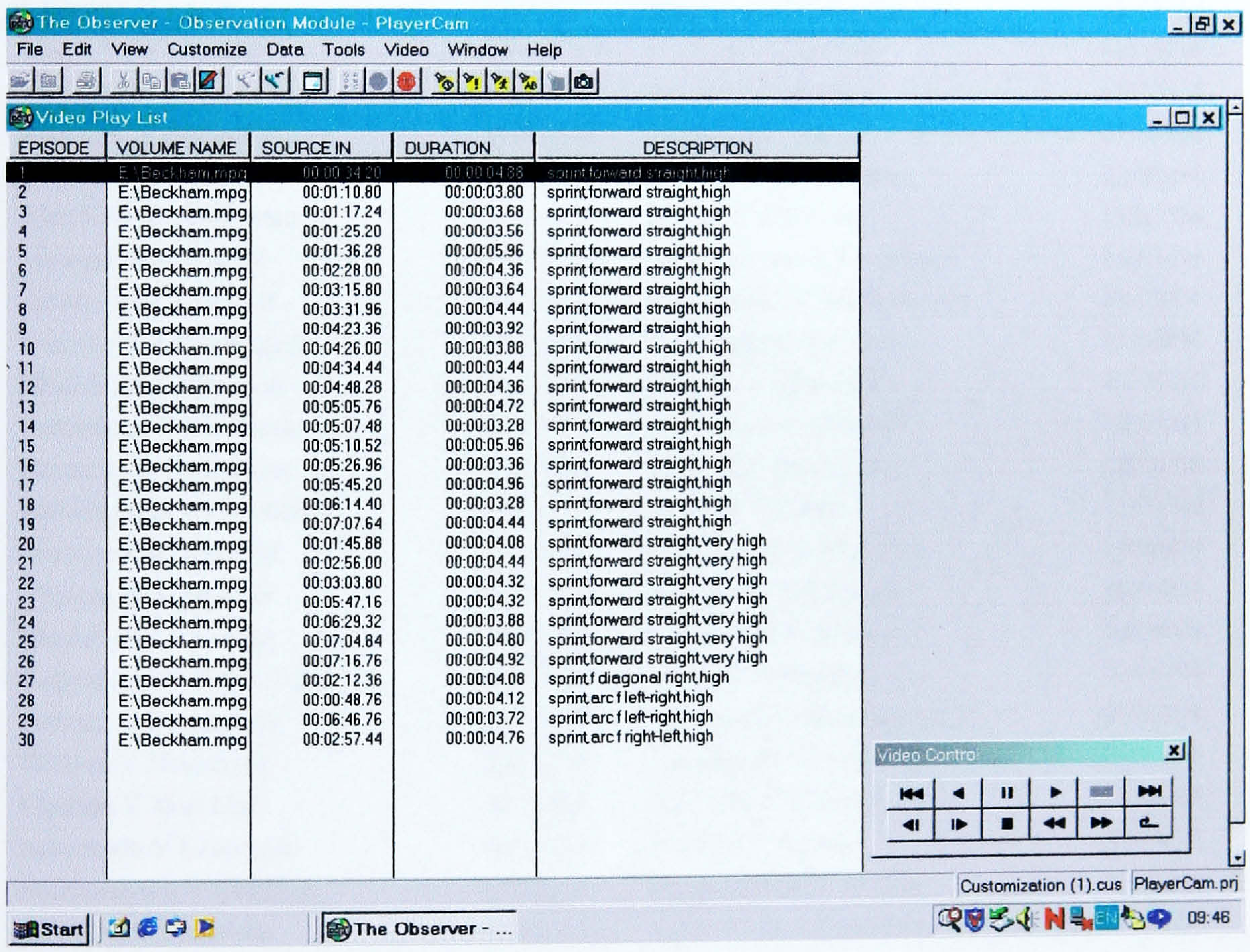
Table B: Brainstorm of classifications aided to compose the BMC.

DIRECTIONS	
1. FORWARD	9. ARC RUN FORWARDS LEFT-RIGHT
2. FORWARD DIAGONALLY RIGHT	10. ARC RUN FORWARDS RIGHT- LEFT
3. SIDEWAYS RIGHT	11. ARC RUN BACKWARDS LEFT-RIGHT
4. BACKWARD DIAGONALLY RIGHT	12. ARC RUN BACKWARDS RIGHT- LEFT
5. BACKWARD	13. ARC RUN SIDEWAYS RIGHT FW - BK
6. BACKWARD DIAGONALLY LEFT	14. ARC RUN SIDEWAYS RIGHT BK - FW
7. SIDEWAYS LEFT	15. ARC RUN SIDEWAYS LEFT FW - BK
8. FORWARD DIAGONALLY LEFT	16. ARC RUN SIDEWAYS LEFT BK - FW
TURNS	
17. SPIN/TURN/PIVOT RIGHT 0-45°	26. SPIN/TURN/PIVOT LEFT 0-45°
18. SPIN/TURN/PIVOT RIGHT 0-90°	27. SPIN/TURN/PIVOT LEFT 45-90°
19. SPIN/TURN/PIVOT RIGHT 90-135°	28. SPIN/TURN/PIVOT LEFT 90-135°
20. SPIN/TURN/PIVOT RIGHT 135-180°	29. SPIN/TURN/PIVOT LEFT 135-180°
21. SPIN/TURN/PIVOT RIGHT 180-225°	30. SPIN/TURN/PIVOT LEFT 180-225°
22. SPIN/TURN/PIVOT RIGHT 225-270°	31. SPIN/TURN/PIVOT LEFT 225-270°
23. SPIN/TURN/PIVOT RIGHT 270- 315°	32. SPIN/TURN/PIVOT LEFT 270-315°
24. SPIN/TURN/PIVOT RIGHT 315-360°	33. SPIN/TURN/PIVOT LEFT 315-360°
25. SPIN/TURN/PIVOT RIGHT 360°+	34. SPIN/TURN/PIVOT LEFT 360°+
UNORTHADOX MOVEMENT	
35. JUMP VERTICAL	45. GET UP
36. JUMP FORWARDS	46. STUMBLE
37. JUMP SIDEWAYS RIGHT	47. COLLISION
38. JUMP SIDEWAYS LEFT	48. DODGE RIGHT – LEFT
39. JUMP BACKWARDS	49. DODGE LEFT – RIGHT
40. LAND	50. PLANT/HALT/STOP
41. FALL	51. FOOT SHUFFLE LEFT
42. DIVE HEAD FIRST	52. FOOT SHUFFLE RIGHT
43. DIVE FEET FIRST	53. FOOT SHUFFLE FORWARD
44. SLIDE	54. FOOT SHUFFLE BACKWARD

SOCCER ACTIVITY	
55. DRIBBLE (TOUCHES)	101. TACKLED
56. DUMMY PASS	102. SUCCESSFUL INTERCEPTION
57. DUMMY SHOT	103. UNSUCCESSFUL INTECEPTION
58. HEAD – SHOT	104. CLEARANCE
59. HEAD – PASS	105. CROSS (RF)
60. HEAD – FLICK ON	106. CROSS (LF)
61. CHEST – CONTROL	107. SHOOT (RF)
62. CHEST – PASS	108. SHOOT (LF)
63. LOB	109. SHOT ON TARGET
64. SCOOP	110. SHOT OFF TARGET
65. DEFLECT	111. GOAL
66. CHIP	112. OWN GOAL
67. BACKHEEL (RF)	113. SAVED
68. BACKHEEL (LF)	114. HIT POST
69. STEP OVER (RF)	115. HIT CROSSBAR
70. STEP OVER (LF)	116. HALF VOLLEY (RF)
71. TRICK/HIGH LEVEL SKILL	117. HALF VOLLEY (LF)
72. FEINT LEFT	118. VOLLEY (RF)
73. FEINT RIGHT	119. VOLLEY (LF)
74. CRUYFF (LF)	120. SIDE VOLLEY (RF)
75. CRUYFF (RF)	121. SIDE VOLLEY (LF)
76. PLAY BEHIND SUPPORT LEG (LF)	122. OVERHEAD KICK (RF)
77. PLAY BEHIND SUPPORT LEG (RF)	123. OVERHEAD KICK (LF)
78. DRAG BACK (LF)	124. CAUGHT OFFSIDE
79. DRAG BACK (RF)	125. FOUL CONCEDED
80. SIDEWAYS BALL ROLL (LF)	126. YELLOW CARD
81. SIDEWAYS BALL ROLL (RF)	127. RED CARD
82. FORWARD BALL ROLL (RF)	128. FREE KICK WON (I.E. FOULED)
83. FORWARD BALL ROLL (LF)	129. PENALTY CONCEDED
84. JUGGLE (TOUCHES)	130. PENALTY WON
85. PASS RIGHT FOOT (RF)	131. CORNER CONCEDED
86. PASS LEFT FOOT (LF)	132. CORNER WON
87. PASS SUCCESSFUL	133. THROW IN CONCEDED
88. PASS UNSUCCESSFUL	134. THROW IN WON
89. RECEIVE (RF)	135. GOAL KICK CONCEDED
90. RECEIVE (LF)	136. GOAL KICK WON
91. RECEIVE THIGH/KNEE (R)	137. INJURY
92. RECEIVE THIGH/KNEE (L)	**MOTIONS**
93. BRING DOWN (LF)	ADD A FOR SKIPS
94. BRING DOWN (RF)	ADD B FOR LOW JUMP
95. TRAP (RF)	ADD C FOR HIGH JUMP
96. TRAP (LF)	ADD D FOR X-OVER STEPS (when not stated)
97. SUCCESSFUL BLOCK	ADD E FOR SIDE STEPS (when not stated)
98. UNSUCCESSFUL BLOCK	
99. SUCCESSFUL TACKLE	
100. UNSUCCESSFUL TACKLE	

Table B was then used to the BMC. This was done through pilot study in The Observer Version 5.0 (Noldus Information Technology, The Netherlands). It took several attempts to ensure that each behaviour and modifier could account for any possible movements or match-play scenarios. Once this had been achieved, 8 observers performed a reliability study and provided an inter- and intra-observer agreement revealing kappa values of between 0.64 and 0.78 and 0.79 and 0.92 respectively. This is interpreted as a good to very high level of agreement (Altman, 1991). Further manual checks of quality were made using The Observer 5.0 video play list which provides visual highlights of entered data by recalling specified entries in the Event Log (See Figure A).

Figure A: Manual checks of quality for coding of sprints using The Observer 5.0 video play list.



APPENDIX C

Selected workings of Study 3: Physical demands of outfield positions in FA Premier League soccer.

Table C: FA Premier League matches that were used for analysis.

Match	Date	Match	Date
Portsmouth V Aston Villa	16/08/03	Leeds V Fulham	14/12/03
Liverpool V Chelsea	17/08/03	Tottenham V Man Utd	21/12/03
Middlesbrough V Arsenal	24/08/03	Charlton V Chelsea	26/12/03
Newcastle V Man Utd	23/08/03	Southampton V Arsenal	29/12/03
Blackburn V Man City	25/08/03	Aston Villa V Portsmouth	06/01/04
Man Utd V Wolves	27/08/03	Chelsea V Liverpool	07/01/04
Everton V Liverpool	30/08/03	Man Utd V Newcastle	11/01/04
Birmingham V Fulham	14/09/03	Chelsea V Birmingham	18/01/04
Leicester V Leeds	15/09/03	Man Utd V Southampton	31/01/04
Man City V Arsenal	31/08/03	Chelsea V Charlton	08/02/04
Wolves V Chelsea	20/09/03	Leicester V Bolton	10/02/04
Man Utd V Arsenal	21/09/03	Chelsea V Arsenal	21/02/04
Arsenal V Newcastle	26/09/03	Tottenham V Leicester	22/02/04
Man City V Tottenham	28/09/03	Bolton V Chelsea	13/03/04
Liverpool V Arsenal	04/10/03	Southampton V Liverpool	14/03/04
Aston Villa V Bolton	05/10/03	Portsmouth V Southampton	21/03/04
Everton V Southampton	19/10/03	Birmingham V Leeds	27/03/04
Blackburn V Charlton	20/10/03	Arsenal V Man Utd	28/03/04
Tottenham V Middlesbrough	26/10/03	Newcastle V Arsenal	12/04/04
Leicester V Blackburn	02/11/03	Fulham V Blackburn	12/04/04
Birmingham V Charlton	03/11/03	Arsenal V Leeds	17/04/04
Liverpool V Man Utd	09/11/03	Portsmouth V Man Utd	17/04/04
Chelsea V Newcastle	09/11/03	Newcastle V Chelsea	24/04/04
Blackburn V Everton	10/11/03	Tottenham V Arsenal	24/04/04
Tottenham V Aston Villa	23/11/03	Arsenal V Birmingham	01/05/04
Fulham V Portsmouth	24/11/03	Liverpool V Middlesbrough	01/05/04
Wolves V Newcastle	29/11/03	Portsmouth V Arsenal	04/05/04
Chelsea V Man Utd	30/11/03	Man Utd V Chelsea	08/05/04
Newcastle V Liverpool	06/12/03	Fulham V Arsenal	08/05/04
Southampton V Charlton	07/12/03	Southampton V Arsenal	15/05/04
Man Utd V Man City	13/12/03	Aston Villa V Man Utd	15/05/04

APPENDIX D

RISK ASSESSMENT SUMMARY /FORM

Faculty/School - Leeds Metropolitan University/School of Sport and leisure Studies ....

Researcher - Jonathan Bloomfield ....

Director of Studies - Dr Remco Polman ....

Director of Studies should identify areas of work in the following risk categories:

A = Those where work may not be undertaken without direct Supervision;
B = Those where work may not be started without Supervisor's advice and approval;
C = Those with risks (other than categories A & B) where extra care must be observed, but where it is considered that workers are adequately Trained and competent in the procedures involved;
D = Those where the risks are insignificant and carry no special supervision considerations.

The nature of the risks should be defined, ie toxicity, explosion, high-voltage, lasers, flammability etc.
Instructions and advice should include the method of work and the safeguards to be used.
The person who is to supervise A and B risks should be identified

Nature and Method of Work	Hazards/Risks	Safeguards	Category Assigned
Physical conditioning and field-based testing of untrained participants	**Physical injury**	**Physical conditioning delivered by an accredited practitioner** **Accredited and fully equipped First Aid personnel on site**	**C**
Laboratory-based testing	**Skin allergy (EMG)** **Sharps phobia (EMG)**	**Tester fully trained and practiced in all testing and safety procedures** **Testing completed in a fully equipped Laboratory**	**C**

Director of Studies Signature: Dr Remco Polman .... Signature of Student: Jonathan Bloomfield.............

APPENDIX E

LIFESTYLE QUESTIONNAIRE (CONFIDENTIAL)

***** PLEASE ANSWER ALL QUESTIONS *****

Name:____

Age:____

Male/Female:____________________________________

Contact telephone:________________________________

Email:____

Please circle

1. Do you take part in regular exercise? **Yes** **No**
2. How often do you exercise per week?____________________
3. How many minutes on average is each of your exercise workouts? ______
4. Do you own/have access to a video games console and football game? **Yes** **No**
5. Have you played video games regularly in the past 12 months? **Yes** **No**
6. Do you consider yourself to be in good health? **Yes** **No**

If no, details:____________________________________

____

____

7. Can you commit to the entire programme? **Yes** **No**

SIGNED ....

DATE ....

APPENDIX F

MEDICAL HISTORY QUESTIONNAIRE

NAME: ______________________________ **D.O.B:** ___/___/___

Any information contained herein will be treated as confidential.

**** Please answer all questions. Circle appropriate answer. ****

1. Have you recently suffered from a cold, cough, sore throat, flu symptoms or other minor ailments? **YES NO**

2. Did you have to consult your doctor about it? **YES NO**

3. Do you, or have you ever suffered from:

Asthma	**YES NO**
High Blood Pressure	**YES NO**
Heart Disease	**YES NO**
Lung Disease	**YES NO**
Diabetes	**YES NO**
Epilepsy	**YES NO**
Thyroid Disease	**YES NO**
Heart Murmur	**YES NO**
Other	**YES NO**

If YES, please give details:____________________________________

____

4. Are you presently taking any form of medication for any of these illnesses? **YES NO**

If YES, please give details:____________________________________

____

5. Do you ever suffer from clamminess, rapid breathing, rapid heartbeat, nausea and dizziness? **YES NO**

If YES, please give details:______________________________________

____

6. Is there a history of heart disease in your family? **YES NO**

7. Do you currently have any form of muscle or joint injury? **YES NO**

8. Have you had any reason to suspend your normal activity in the past two weeks? **YES NO**

9. Do you suffer from a needle phobia or fear of sharp implements? **YES NO**

If YES, please give details:______________________________________

____

10. Is there anything to your knowledge that may prevent you from successfully completing the task(s) that have been explained to you? **YES NO**

If YES, please give details:______________________________________

____

Signature of Subject:____

Date:____

Signature of Test Supervisor:___________________________________

Date:____

Please supply the name, address and telephone number of an emergency contact

____

____

____

APPENDIX G

INFORMED CONSENT FORM

FITNESS TESTING

The tests are being carried out to provide you with an objective assessment of specific aspects of your current fitness status. This information will help to evaluate the effectiveness of your training programme.

(To be completed by the participant)

1. Have you been informed about the test(s) to be carried out? **YES NO**

2. Have you been able to ask questions about the procedure(s)? **YES NO**

3. Are you fully aware of any discomfort or risks, which may be associated with the testing procedure(s)? **YES NO**

4. Have you been informed about the medical and emergency support which is available? **YES NO**

5. Have you been informed that all information about your person will be treated as strictly confidential and will not be made available to a third party without your written consent? **YES NO**

FITNESS TRAINING (Declaration from participant)

1. I have a full understanding of what is involved in my intervention group. **YES NO**

2. I have had the opportunity to ask questions and discuss the intervention. **YES NO**

3. I am satisfied with the answers to my questions. **YES NO**

4. I understand that I am free to withdraw from the study at any time without giving a reason. **YES NO**

5. I agree to take part in this research study. **YES NO**

DECLARATION BY THE PARTICIPANT

I fully understand what is involved in taking part in this assessment and do so of my own free will. I am aware that I may withdraw from the test(s) at any time without the need for explanation.

Signed:____________________________________

Name: ____________________________________
(Block Capitals)

Date:____________________________________

DECLARATION BY THE ASSESSOR

I confirm that I have informed the participant of the nature and effects of the testing procedure(s) to be administered and the participants' consent has been given freely and voluntarily.

Signed:____________________________________

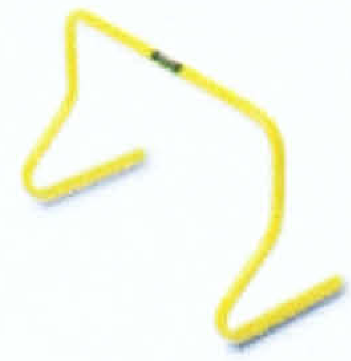
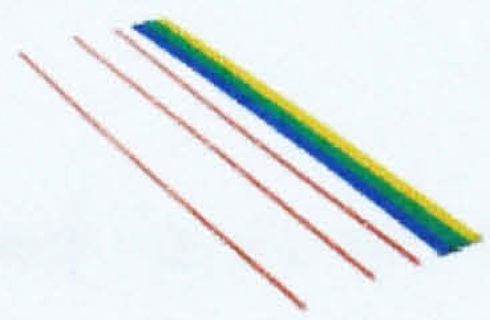
Name: ____________________________________
(Block Capitals)

Date:____________________________________

APPENDIX H

Selected workings of Study 4: Effective conditioning for soccer match-play.

Table D: SAQ® conditioning equipment used in the study.

 **Indoor Ladder**	 **Micro Hurdle**	 **Macro Hurdle**
 **Reaction Ball**	 **Viper Belt**	 **Flexicord**
 **Breakaway Belt**	 **Marker Spots**	 **Peripheral Stick**
 **Sprint Resistor**	 **Stride Canes**	 **Visual Acuity Ring**
 **Traditional Coaching Equipment**		

APPENDIX I

Selected workings of Study 4: Effective conditioning for soccer match-play.

The Borg Scale (1998) of Perceived Exertion

6 No exertion at all

7 Extremely light

8

9 Very light - (easy walking slowly at a comfortable pace)

10

11 Light

12

13 Somewhat hard (It is quite an effort; you feel tired but can continue)

14

15 Hard (heavy)

16

17 Very hard (very strenuous, and you are very fatigued)

18

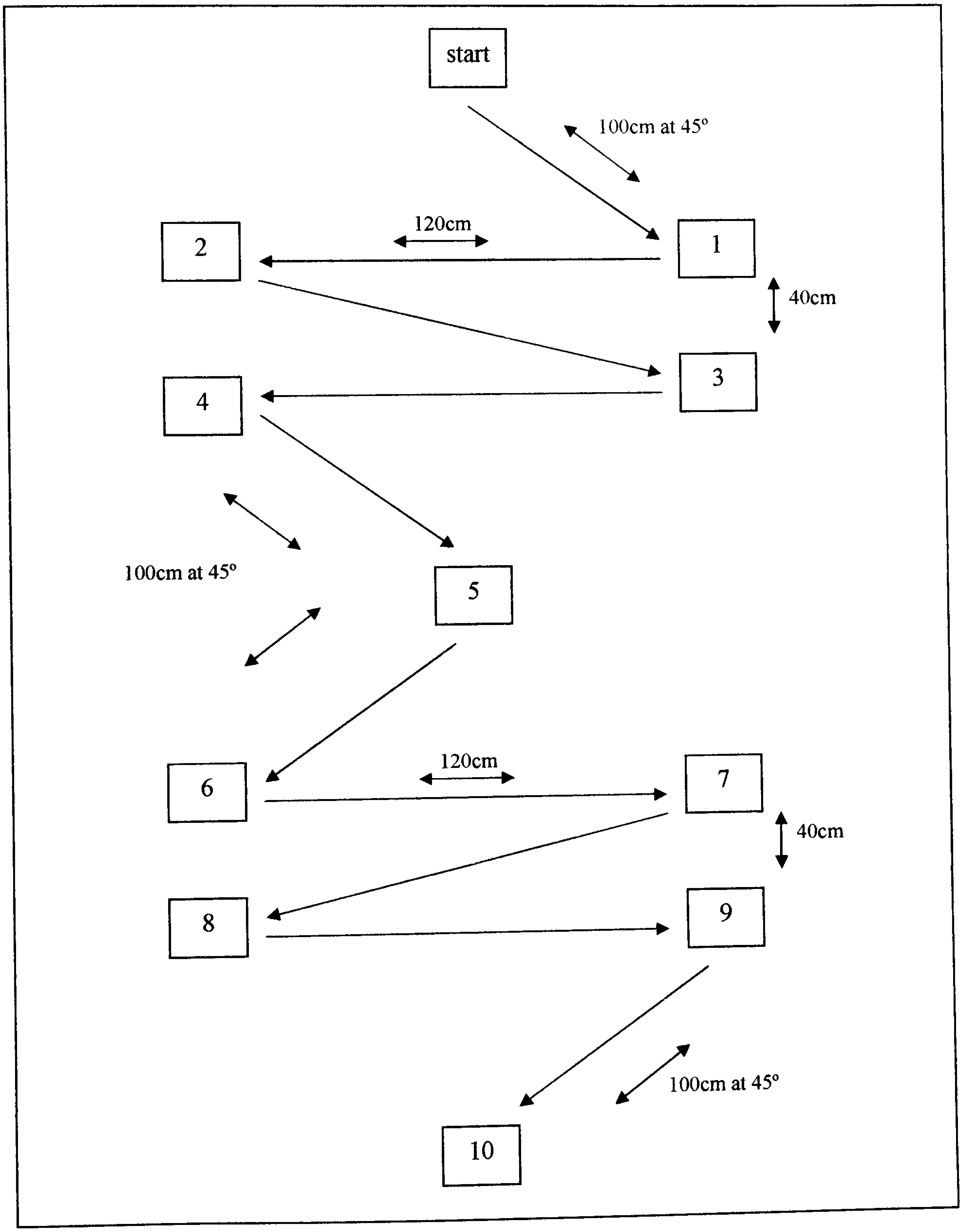
19 Extremely hard (You can not continue for long at this pace)

20 Maximal exertion

APPENDIX J

Selected workings of Study 4: Effective conditioning for soccer match-play.

A Modified version of the Bass Test of Dynamic Balance (Blackburn et al., 2000).



Notes: