AN ANALYSIS OF THE PHYSICAL DEMANDS OF INTERNATIONAL FEMALE SOCCER MATCH-PLAY AND THE PHYSICAL CHARACTERISTICS OF ELITE PLAYERS

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A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Doctor of Philosophy

October 2016

ABSTRACT

The purpose of the thesis was to provide a detailed analysis of the physical demands of competitive international female soccer match-play and the physical characteristics of elite players. To date, the majority of research has focussed on sub-elite players with a lack of information available on international level competitors.

The aim of the first study (Chapter 4) was to analyse match physical performance using a computerised tracking system (Prozone Sports Ltd., Leeds, England). A total of 167 individual match observations from 122 players competing in competitive international matches during the 2011-2012 and 2012-2013 seasons were completed. Total distance and total high-speed running distances (>14.4 $km.h^{-1}$) were influenced by outfield playing position, with central midfielders completing the highest (10985 ± 706 m and 2882 ± 500 m) and central defenders (9489 ± 562 m and 1901 ± 268 m) the lowest distances, respectively. Greater total very high-speed running distances (>19.8 $km.h^{-1}$) were completed when a team was without (399 ± 143 m) compared to with (313 ± 210 m) possession of the ball. The majority of sprints (>25.1 $km.h^{-1}$) were over short distances with 95 % being less than 10 m. This study provides novel findings regarding the physical demands of different playing positions in competitive international female match-play and important insights for physical coaches preparing elite female players for competition.

The aim of the second study (Chapter 5) was to determine the incidence and nature of repeated sprint and high-speed activity in match-play. Repeated sprint activity (a minimum of two efforts (>25.1 $km.h^{-1}$) with 20 s or less recovery between efforts) was found to be rare during international female match-play with 1.1 ± 1.1 bouts per match. Repeated high-speed activity (a minimum of two efforts (>19.8 km.h^{-1}) was influenced by playing position; with attacking-based players completing more bouts (37-40 bouts per match) than defensive players (22-33 bouts per match). Repeated sprint and high-speed bouts frequently comprised two efforts per bout, with a maximum of three and six efforts respectively. Collectively, this study provides physical coaches with useful data for replicating the demands of repeated high-speed activity and an understanding of the positional demands in order to aid the specificity of training.

The aim of the third study (Chapter 6) was to attempt to apply a suitable approach for determining speed zones and to evaluate the application of specific zones to influence data outcome. Maximum match-play running speed in elite females was measured using Global Positioning System technology (STATSports, Viper, Ireland) in 230 individual match observations of 67 outfield players, during 19 international matches from 2011-2015. Female-specific speed zones and activity classifications were scaled appropriately to maximum match-play running speed. The resultant female-specific speed zones were on average 12.5 % lower than the standardised male zones, which if applied to the data in Chapter 4 would result in a small increases in total high-speed running (25 % to 28 %) and total very high-speed running (8 % to 9 %) relative to total distance. The calculated female-specific sprinting threshold (>22.0 km.h^{-1}) corresponds to 82 % of the average maximum female match-play running speed presently observed and consequently might be more representative than the standardised male sprinting threshold (>25.1 km.h^{-1}). However, as it was not possible to validate activity classifications in the current study it is suggested that the standardised thresholds should continue to be used to permit between playing position and gender comparisons, however, the activity classifications (e.g. walking, jogging, sprinting etc.) should be removed and replaced with the actual velocities.

The aim of the fourth study (Chapter 7) was to examine the reliability of both anthropometric and performance measures in elite female soccer players. The data suggest that both junior and senior elite female players are able to adequately reproduce a variety of anthropometric (coefficient of variation = 0.1-1.3 %) and performance (coefficient of variation = 0.6-7.7 %) related tests and that reliable measures can be obtained using the present protocols and one familiarisation session. The sample size estimations ($n<20$) provided important insights for the participant recruitment in Chapter 8 and also suggest that the anthropometric and performance assessments are suitable for the longitudinal tracking of the fitness status of elite female players.

The aim of the fifth study (Chapter 8) was to examine the physical characteristics of elite players, which were assessed in 471 national team players from 2011-2015. Anthropometric and performance variables improved with age; with large differences observed between U15s and seniors for body mass (53.9 ± 7.8 v 62.5 ± 5.8 kg), 30 m linear speed (4.78 ± 0.22 v 4.52 ± 0.17 s), countermovement jump (28.3 ± 4.0 cm v 33.4 ± 4.0 cm) and Yo Yo Intermittent Recovery Test Level 1 (1101 ± 369 m v 1583 ± 416 m). Similarities were observed for anthropometric and performance variables between the younger (U15 and U17) and older (U19 and senior) age groups. Goalkeepers generally exhibited inferior anthropometric and performance capabilities to outfield players. Faster linear speed times over short distances observed were in attackers (1.047 s v 1.061-1.077 s), greater repeated speed performance in wide midfielders and attackers (4.89-4.91 s v 4.92-4.99 s) and improved intermittent endurance performance in wide defenders (1483 m v 1260-1336 m) compared to other outfield playing positions. The normative physical characteristics presented, provide unique data for professionals involved in player recruitment and talent identification, whilst the positional differences in performance characteristics, coupled with an in-depth understanding of the demands of match-play can be applied to ensure training specificity.

Collectively, the present data provides the most in-depth description of the physical demands and physical characteristics of elite female soccer players to date. The data describing the demands of match-play provides valuable insights for physical coaches preparing elite female players for competition, whilst the normative physical characteristic data provides important information to professionals involved in player recruitment and talent identification and those responsible for physical development.

ACKNOWLEDGEMENTS

First and foremost I wish to express my sincere thanks to my director of studies Professor Warren Gregson, who has patiently supported me throughout the completion of this thesis. I will forever be grateful for the time and energy that he has invested not only in this thesis but also in me as a person. Completing this thesis whilst we have predominantly been on different continents has not always been easy but his flexibility and dedication has made it possible.

I would also like to thank my PhD supervisors, Professor Barry Drust and Dr Matthew Weston for their invaluable input, support and comments throughout the last four and a half years. It has been challenging to complete this thesis whilst working full-time in professional football but having such a knowledgeable and hard-working team behind me has made the journey much easier.

I am grateful to the players who participated in the study for their hard work and professionalism, without whom, this would not have been possible. I would also like to express my gratitude to my colleagues from the Football Association who assisted with aspects of the data collection process. The Football Association provided financial support throughout this process and I am particularly grateful to Dr Ian Beasley for offering the initial support and encouragement to commence this PhD.

I would also like to thank my friends who have provided endless support and motivation throughout this period. A special mention to Erika and Nikki for their advice and guidance on the general PhD process and kind offers of proof reading. Also, a special thanks to Amanda and Pete for their unwavering support throughout the whole process, I dread to think how many dinners they have cooked me to allow me extra time to work! Finally, a special thank you to my parents; Margaret and Jeremy and my sisters; Hannah and Ray for their love and encouragement to complete this thesis. I will forever be indebted to all my friends and family for being so understanding whilst I have been studying and for keeping me sane!

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

A	Attacker
CD	Central defender
CM	Central midfielder
cm	Centimetres
CMJ	Countermovement jump
CV	Coefficient of variation
ES	Effect size
GK	Goalkeeper
GPS	Global positioning system
HR_{max}	Maximum heart rate
HR_{peak}	Peak heart rate
HSR	High-speed running
ISAK	International Society for the Advancement of Kinanthropometry
kg	Kilogrammes
km	Kilometres
$km.h^{-1}$	Kilometres per hour
m	Metres
min	Minutes

MIPD	Minimum practically important difference
ml.kg-1	Millilitres per kilogramme
mm	Millimetres
mmol.L-1	Millimoles per litre
OCP	Oral contraceptive pill
RHSA	Repeated high-speed activity
RSA	Repeated sprint activity
SAQ	Speed, agility, quickness
s	Seconds
SEM	Standard error of measurement
TD	Total distance
THSR	Total high-speed running
TVHSR	Total very high-speed running
U15s	Under 15s
U17s	Under 17s
U19s	Under 19s
VO_{2max}	Maximal oxygen uptake
WD	Wide defender
WM	Wide midfielder

YYIE2	Yo Yo intermittent endurance test level 2
YYIR1	Yo Yo intermittent recovery test level 1
VHSA	Very high-speed activity
VHSRP	Very high-speed running with possession
VHSRWP	Very high-speed running without possession

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

An ergonomics model (Figure 1.1) for the analysis of soccer has previously been proposed (Reilly, 2005). The model highlights that match-play will impose a range of demands on players who must possess the necessary fitness to cope with these demands. Consequently, a comprehensive understanding of the demands of a sport is the basis for scientific support and physical development programmes. Extensive analysis of match-play to determine specific elements of a player's physical performance has previously been undertaken in elite level males using semi-automated camera systems (Bradley et al., 2011a; Di Salvo et al., 2013; Bush et al., 2015). However, to date only one study (Bradley et al., 2014a) has examined the demands of elite level female match-play using these contemporary techniques. The primary focus of the previous research (Bradley et al., 2014a) was to compare male and female match-play and as such a detailed examination of elite female match-play using contemporary techniques has yet to be presented. Some data are available regarding the demands of international female match-play (Krustrup et al., 2005; Gabbett and Mulvey, 2008; Mohr et al., 2008; Andersson et al., 2010a); however, this has been derived from relatively small samples (n = 13-19) using traditional video-based technology, which limits the depth of analysis that is possible.

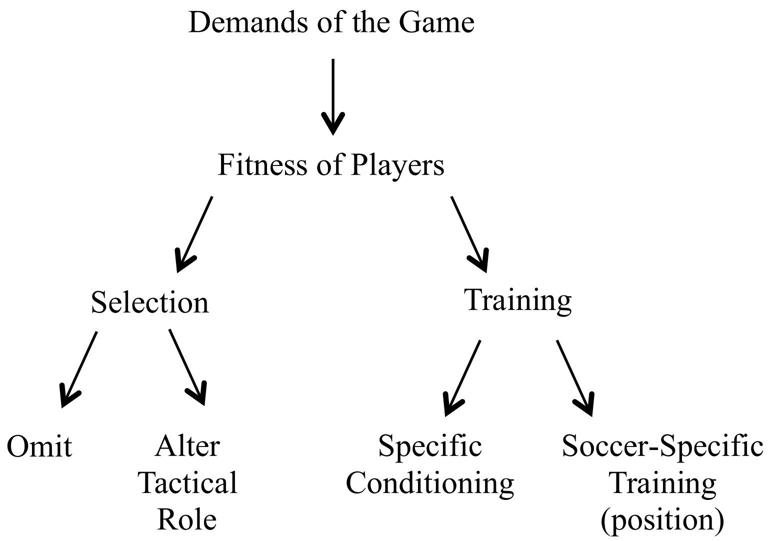

Figure 1.1 An ergonomics model for the analysis of soccer (Reilly, 2005)

Traditional video-based time motion analysis techniques often require an extensive time commitment and when using these methodologies there can be difficulties in distinguishing between some movement categories (Spencer et al., 2005). Consequently, previous studies have generally focussed on the overall demands of match-play as opposed to a detailed analysis of a specific physical element (Di Salvo et al., 2009). Contemporary technologies such as global positioning systems (GPS) and semi-automated camera systems such as Prozone represent more time efficient approaches to examining detailed aspects of match physical performance (Di Salvo et al., 2009). Despite the majority of match-play activity completed at low-speed (Bradley et al., 2014a), high-speed running and repeated high-speed efforts are deemed crucial elements of soccer performance (Mohr, Krustrup and Bangsbo, 2003; Gabbett and Mulvey, 2008). These aspects of match-play are often deemed critical to the outcome of matches (Stølen et al., 2005; Faude, Koch and Meyer, 2012) as these activities underpin the movements required to win the ball and go past defenders. Future work assessing the demands of elite female match-play, particularly high-speed activity is necessary in order to establish a more detailed understanding of the physical demands on players.

Fitness assessments of players including anthropometric and performance testing are important components of an elite player's development programme (Hulse et al., 2013; Manson, Brughelli and Harris, 2014). Data derived from such testing can be used to inform decisions in relation to talent identification, player selection, training monitoring and training periodisation (Hoare and Warr, 2000; Reilly et al., 2000; Svensson and Drust, 2005; Buchheit et al., 2012). Physiological profiling in elite male players has highlighted influences of age (Le Gall et al., 2010; Hulse et al., 2013) and playing position (Krustrup et al., 2006; Sporis et al., 2009; Carling and Orhant, 2010; Le Gall et al., 2010; Bradley et al., 2011b) on a range of physical characteristics. However to date, limited attention has focused on elite female players, with the majority of research focusing on sub-elite populations (Siegler, Gaskill and Ruby, 2003; Polman et al., 2004; Vescovi and McGuigan, 2008; McCurdy et al., 2010; Vescovi et al., 2011). Published reports of performance profiles for female national team players are rare with the majority of studies conducted to date focussing on a single physical characteristic (Castagna and Castellini, 2013; Bradley et al., 2014b; Haugen et al., 2014;). Furthermore, previous works have failed to extensively assess the influence of age (Mujika et al., 2009a; Bradley et al., 2014b) or playing position (Castagna and Castellini, 2013; Manson, Brughelli and Harris, 2014) with analyses only considering senior and junior age categories and generic playing positions (e.g. defenders, midfielders and attackers). Given the observations in male players coupled with the diverse nature of soccer (Hulse et al., 2013), it is necessary to examine a range of physical characteristics in elite female players and assess the influence of age, and playing position.

Despite the popularity and participation in female soccer increasing markedly in recent years (Fahmy, 2011) there is still a lack of female-specific research compared to the abundance of available literature regarding male players. Thus a comprehensive evaluation of the demands of international female match-play and the physical characteristics of elite players is necessary to inform decision making regarding the processes of player selection and physical development programmes.

1.2 INTRODUCTION TO RESEARCH STUDIES

Determination of the physical demands of international female soccer match-play and the characteristics of elite players will be achieved through a series of studies. A comprehensive understanding of the demands of match-play is necessary in order to develop a suitable programme of scientific support and to deliver effective physical development programmes. The physical demands of female match-play have rarely been evaluated using the contemporary techniques of GPS technology and semi-automated camera systems. The high costs associated with these technologies and the fact that female matches are seldom played in stadiums equipped with semi-automated camera systems often prohibit their use in female soccer. Available data suggests that standard of competition influences match physical performance as increased overall demands have been observed in European club football (10754 m) (Bradley et al., 2014a) compared to friendly international competition (9292 ± 175 m) (Hewitt, Norton and Lyons, 2014) and the nature of repeated high-speed efforts vary between national and international players and/or games (Gabbett, Wiig and Spencer, 2013). However, to date, contemporary techniques have not been used to analyse the demands of competitive international match-play, which represents the highest standard within the female game. Therefore, the aim of the first two studies is to provide a detailed analysis of the overall demands of international female soccer match-play and specifically the incidence and nature of repeated high-speed activity.

Recent commentary (Bradley and Vescovi, 2015) has questioned the suitability of transposing the speed zones commonly used to analyse male match-play data on to the performance of female players. It has been suggested that such methodologies will cause an underestimation of high-speed activities in female players and that female-specific speed zones should be applied to female match-play data. However, currently no consensus exists on the most appropriate methodology (Weston et al., 2012; Carling, 2013; Lovell and Abt, 2013; Hunter et al., 2014) for determining speed zones and as such the aim of the third chapter is to attempt to apply a suitable approach for determining speed zones and to evaluate the application of specific zones to influence data outcome.

Anthropometric and performance testing represent an important component of an elite soccer player’s development programme (Hulse et al., 2013; Manson, Brughelli and Harris, 2014) and information derived from such assessments can be used to inform decisions in relation to talent identification, player selection, training monitoring and training periodisation (Hoare and Warr, 2000; Reilly et al., 2000; Svensson and Drust, 2005; Buchheit et al., 2012). Although the benefits of assessing physical characteristics of players are apparent, limited information is currently available for elite female players with the majority of research focusing on sub-elite populations (McCurdy et al., 2010; Vescovi et al., 2011). Despite the widespread use of anthropometric and performance testing by researchers and practitioners the critical issues of validity and reliability are often overlooked (Pyne, Spencer and Mujika, 2014). Reliability refers to an acceptable level of agreement between repeated tests within a practically relevant timeframe (Atkinson and Nevill, 1998) and a test’s reliability should be evaluated before being applied to a given population. It is important to determine the reliability of a measure in order to assess its suitability to track changes in performance and avoid biased interpretations in future studies (Hopkins, 2000). Consequently, the aim of the final two studies is to assess the reliability of a set of anthropometric and performance assessments and then provide a detailed analysis of the physical characteristics of elite female players.

1.3 AIMS AND OBJECTIVES

Aims

To investigate the demands of international female soccer match-play and the physical characteristics of elite players.

Objectives

1. To quantify the demands of international female soccer match-play for different playing positions
2. To determine the incidence and nature of repeated high speed activity in international female soccer match-play
3. To attempt to apply a suitable approach for determining speed zones and to evaluate the application of specific zones to influence data outcome
4. To determine the reliability of a range of anthropometric and performance measures in elite female soccer players
5. To investigate the influence of age and playing position on the physical characteristics of elite female soccer players

CHAPTER 2

REVIEW OF LITERATURE

This literature review has been published:

Datson, N., Hulton, A., Andersson, H., Lewis, T., Weston, M., Drust, B. and Gregson, W. (2014). Applied physiology of female soccer: an update, *Sports Medicine,* **44** (9), 1225-1240

The aim of this review of literature is to provide the reader with information regarding the physical demands of international female soccer match-play and the physical characteristics of elite players. The initial section of the review examines match physical performance; this is followed by an assessment of the physiological demands of match-play, the physical capacity of players and the process of training. The final section of the review examines female differences, including phase of the menstrual cycle and oral contraceptive pill usage.

2.1 INTRODUCTION

The popularity of women's soccer has increased markedly in recent years with 29 million participants recorded in 2011, an increase of 34 % from 2000 (Fahmy, 2011). Coupled with the increase in participation there has also been a drive towards professionalism in the sport with players at the highest level now employed on a professional or semi-professional basis. Current elite players are exposed to greater training volumes and competition demands than ever before - consequently an in-depth understanding of the match physical demands and physical characteristics of players is necessary to inform the training process.

2.2 MATCH PHYSICAL PERFORMANCE

A comprehensive understanding of the demands of the game is necessary to apply a systematic approach to training (Reilly, 2005). The use of technologies such as GPS devices and semi-automated camera systems are now relatively commonplace within men's soccer. These technologies are more time efficient than the traditional video-based time motion analysis systems and offer greater objectivity and volume of information (Randers et al., 2010). Furthermore, more detailed evaluations of specific elements of a player's physical performance as opposed to generic time-motion analysis can be undertaken (Bradley et al., 2009; Di Salvo et al., 2009, 2010; Bradley et al., 2011a; Harley et al., 2011; Bush et al., 2015). Despite advancements in the understanding of match-play in elite male players, published research on elite female players using contemporary techniques is lacking (Vescovi, 2012a), which is predominantly due to stadium access and financial considerations.

Early data collected via video-tape (Davis and Brewer, 1993) (n = 7) showed national team players covered a total distance (TD) of 8.5 ± 2.2 km (mean ± standard deviation (SD)) and average sprint distances were 14.9 ± 5.6 m, although the velocity threshold for sprinting was not defined. More recent studies (Gabbett and Mulvey, 2008; Krustrup et al., 2008; Andersson et al., 2010a; Bradley et al., 2014a; Hewitt, Norton and Lyons, 2014), using larger sample sizes (n = 13-59) have reported higher TD covered (~10 km) for national team players when measured using video-tape, GPS technology and semi-automated camera systems. Whilst a trend exists for higher TD covered compared to early reports, these differences may also to some extent reflect differences in data collection methods (Randers et al., 2010). Total distance covered provides a global estimation of physical match-play but it is high-speed running (HSR) which is deemed to be more informative and reflective of the game (Bradley et al., 2009; Di Salvo et al., 2009). National team players have been reported to cover a distance of 1.5-1.7 km at high speeds (>15 km.h^{-1}) (Krustrup et al., 2008; Andersson et al., 2010a). Repeated sprint activity (RSA) has also been examined, with elite players performing 5 ± 5 repeated sprint and 31.2 ± 19 repeated high-speed bouts per game (Gabbett, Wiig and Spencer, 2013). Explosive events and game specific skill involvements are also deemed important markers of physical match performance yet these areas have been subject to little attention in the literature. Game specific skill involvements (including passing, dribbling, tackling and trapping) have been quantified as 76 ± 30 events per match (Gabbett and Mulvey, 2008) and specifically 11 ± 1 headers and 16 ± 1 tackles (Mohr et al., 2008) with players also undertaking 1326-1641 changes of activity or direction per match (Krustrup et al., 2005; Gabbett and Mulvey, 2008; Mohr et al., 2008; Andersson et al., 2010a).

The amount of HSR and sprinting undertaken by female players is higher at higher standards of competition. Players competing in international matches perform 28 % more HSR (1.7 ± 0.1 km v 1.3 ± 0.1 km; ES 4.00) and 24 % more sprinting (0.46 ± 0.02 km v 0.38 ± 0.05 km; ES 2.10) than those competing in domestic level matches (Krustrup et al., 2008). Players produce more repeated-sprint bouts during international matches compared to national league (5 ± 3 bouts v 1 ± 1 bout; ES 1.81 (Gabbett and Mulvey, 2008). Additionally, female players complete more HSR (13 %) and sprinting (14 %) when playing an international game compared to a domestic game (Andersson et al., 2010a). An overview of the demands of elite female match-play taken from recent studies is shown in Table 2.1.

Table 2.1 Match physical performance data for elite female soccer players (mean ± SD)

Source	n	Competition Level	Nationality / Region	Total Distance (km)	Activity Changes (number)	High Speed Bouts (number)	High Speed Running (km)	Sprinting (m) (>25km.h^{-1})	Sprinting Bouts (number) (>25km.h^{-1})	Data Capture Method
Bradley et al., 2014a	59	European Cup	European	10.8						Semi Automated Camera
Hewitt, Norton and Lyons, 2014	58	International	Australian	9.3 ± 0.2			2.4 ± 0.1*	338 ± 30		GPS
Andersson et al., 2010a	17	International	Scandinavian	9.9 ± 1.8	1641 ± 41	187 ± 15^	1.5 ± 0.1^	256 ± 57		Video Tape
	17	Domestic League		9.7 ± 1.4	1593 ± 30	168 ± 12^	1.3 ± 0.9^	221 ± 45		
Andersson, Ekblom and Krustrup, 2008b	21	Highest Division	Swedish	10.3			1.9^			Video Tape
Gabbett and Mulvey, 2008	13	v male youth teams	Australian	9.3 ± 0.8			1.9 ± 0.5^{+}			Video Tape
	13	National League	Australian	9.7 ± 0.5			2.0 ± 0.3^{+}			
	13	International	Australian	10.0 ± 1.1			2.5 ± 0.5^{+}			
Mohr et al., 2008	19	Highest Division	All	10.3 ± 0.2	1379 ± 34	154 ± 7^	1.7 ± 0.1^	460 ± 20	30 ± 2	Video Tape
	15	Domestic League	Scandinavian	10.4 ± 0.2	1326 ± 24	125 ± 7^	1.3 ± 0.1^	380 ± 50	26 ± 1	
Krustrup et al., 2005	14	Highest Division	Danish	10.3	1459	125^	1.3^	160	26	Video Tape

** HSR threshold >12 km.h^{-1}, ^ HSR threshold >15 km.h^{-1}, $^{+}$ qualitative classification of HSR that includes all striding and sprinting activity*

An evaluation of the demands of different playing positions is essential to ensure specificity of training and potential talent identification of players. Despite an acknowledgement over two decades ago (Davis and Brewer, 1993) that further investigation of positional variations are warranted there still appears to be a lack of information in this area which is likely due to sample size constraints. Observations indicate that midfielders cover greater total distance (10.7 ± 1.3 km) compared to defenders (9.6 ± 1.2 km, ES 0.88) and attackers (9.6 ± 0.4 km, ES 1.14) (Gabbett and Mulvey, 2008). These findings have been confirmed by GPS technology with midfielders covering over 1000 m more than defenders (10.2 km v 8.8 km) and 800 m more than attackers (10.2 km v 9.4 km) (Hewitt, Norton and Lyons, 2014). Differences in high-speed activity also exist with defenders performing less HSR (1.3 ± 0.1 km) than both midfielders and attackers (1.7 ± 0.1 km, ES 4.00 and 1.6 ± 0.1 km, ES 3.00, respectively) (Mohr et al., 2008). Observations also show that defenders complete less HSR compared to midfielders (1.7 ± 0.1 km v 2.8 ± 0.2 km), during international friendly matches, however no differences were demonstrated between attackers and other playing positions (Hewitt, Norton and Lyons, 2014). Sprinting analysis has shown differences between playing positions with one study highlighting attackers complete greater distances than defenders (520 ± 30 m v 330 ± 50 m, ES 4.61) (Mohr et al., 2008), whereas another study observed midfielders completed more sprinting than defenders (392 ± 46 m v 188 ± 31 m) (Hewitt, Norton and Lyons, 2014). To date, only one study (Bradley et al., 2014a) has evaluated match physical performance using more specific positions (e.g. central defenders (CD), wide defenders (WD), central midfielders (CM), wide midfielders (WM) and attackers (A)) that are now commonly applied to research focussed on the male game (Bradley et al., 2009; Di Salvo et al., 2009). The primary focus of the previous research (Bradley et al., 2014a) was to compare male and female match-play and as such a detailed examination of elite female match-play using contemporary techniques has yet to be presented.

Changes in physical performance, particularly HSR within and between each 45-min half have often been used as a marker of progressive match fatigue, with results suggesting that players experience temporary fatigue during and towards the end of a game (Mohr, Krustrup and Bangsbo, 2003). Total distance covered has been shown to be consistent between halves (5.23 ± 0.09 km v 5.21 ± 0.08 km; ES 0.23); however, significant reductions in HSR (0.68 ± 0.06 km v 0.62 ± 0.04 km; ES 1.18) and sprinting (0.20 ± 0.03 km v 0.17 ± 0.02 km; ES 1.18) occur (Mohr et al., 2004). Some alterations in game specific skill involvements have also been demonstrated between halves with the number of tackles being greater in the first half compared to the second (Mohr et al., 2008). Reductions in RSA and repeated high-speed activity have not been observed between halves in elite players, however, an increased duration of low-speed recovery between efforts has been reported to occur (Gabbett, Wiig and Spencer, 2013). In an attempt to further examine the occurrence of fatigue, previous research has evaluated changes in physical performance within each half. Reductions in HSR distance have been reported with a 26-57 % decrement from the first to the last 15-min period of match-play (Krustrup et al., 2005; Mohr et al., 2008; Hewitt, Norton and Lyons, 2104). This reduction in HSR distance is even more pronounced when the same players compete at different levels of competition, with an 18 % and 40 % decline in the last to first 15-min of the second half for domestic and international competition, respectively (Krustrup et al., 2008). The 5-min subsequent to the peak 5-min period of HSR during match-play has frequently been used as an indicator of temporary fatigue and a 17 % decrement in HSR was apparent in top-level players but not moderate-level players (Mohr et al., 2008). These findings suggest a possible inability to maintain HSR and thus failure to perform at the required speed for the duration of the match. However, due to the tactical constraints of match-play these findings do not provide direct evidence of fatigue, as some reports suggest that player's produce increased physical outputs during the opening periods of a game in an attempt to engage with opponents and register their presence, and consequently the first 15-min of match-play may not be a suitable reference point (Bangsbo, Nørregaard and Thorsø, 1991). As such, a number of studies have assessed isolated physical performance parameters before and after match-play since these measures are not affected by tactical and technical decisions (Gregson et al., 2010). Decrements in speed (3.0 ± 0.5 %) (Andersson et al., 2008a), countermovement jump (CMJ) (4.4 ± 0.8 %) (Andersson et al., 2008a), repeated speed (4 %) (Krustrup et al., 2010), intermittent endurance as measured by the Yo Yo Intermittent Endurance Test level 2 (YYIE2) (62 %) (Krustrup et al., 2010), peak torque knee extension (7.1 ± 1.9 %) (Andersson et al., 2008a) and peak torque knee flexion (9.4 ± 1.8 %) (Andersson et al., 2008a) have been highlighted and these types of assessment may give a clearer indication of fatigue development following a game.

The published studies to date indicate differences in the motion analysis of soccer players based upon the level of competition, stage of the game and playing position. The majority of these studies have been conducted using traditional single camera time-motion analysis methods pioneered in the 1970s. Modern technologies such as GPS and semi-automated camera systems are able to provide more detailed information across large samples of players relative to video-based approaches (Spencer et al., 2005; Randers et al., 2010). Consequently, more comprehensive evaluations of the physical characteristics of elite female match-play using contemporary analysis methods and more specific playing position classifications are warranted.

2.3 SPEED ZONES

It is challenging to draw comparisons between high-speed activities in the literature due to methodological differences, notably the classification of speed zones that exist between studies. The most common approach to date has been the application of arbitrary zones in order to examine an individual's match physical performance profile. This methodology has been applied extensively in studies that have utilised semi-automated camera systems to analyse large anonymous datasets in male soccer (Bradley et al., 2013; Di Salvo et al., 2013; Bush et al., 2015). However, recent commentary (Bradley and Vescovi, 2015) has suggested that transposing the thresholds commonly used to analyse male match-play data on to the performances of female players will underestimate match-play demands by reducing the amount of high-speed activities completed by individuals. Consequently, female-specific zones have been suggested (Bradley and Vescovi, 2015) and applied to recent studies examining the demands of female match-play in soccer (Hewitt, Norton and Lyons, 2014) and other team sports (Clarke, Anson and Pyne, 2015). However, these female-specific HSR and sprint zones have been derived from small samples (n = 5-14) of non-elite players (domestic level players) (Krustrup et al., 2005; Dwyer and Gabbett, 2012) and as such their suitability for the analysis of elite female match-play is questionable. Consequently, the activity classifications derived from these zones may not be any more valid than the arbitrary male thresholds.

The use of individualised speed zones have become more common in recent years (Abt and Lovell, 2009; Lovell and Abt, 2013; Hunter et al., 2014), however, a precise methodology for obtaining individual zones is still to be agreed (Weston et al., 2012). Questions pertain as to the suitability of laboratory determined physiological thresholds derived from continuous exercise protocols (Akubat and Abt, 2011) and therefore, protocols that incorporate the unorthodox modes of motion (e.g. backwards and sideways running) of soccer (Reilly and Bowen, 1984) should be considered (Weston et al., 2012). Percentages of maximal running speed can also be used to classify match activity zones, however, no consensus currently exists as to the classification and justification of such zones (Weston et al., 2012). Furthermore, it is not possible to derive and apply individualised zones to large anonymous datasets that dominate the literature and therefore the use of arbitrary speed zones are presently more commonplace.

2.4 PHYSIOLOGICAL DEMANDS OF MATCH-PLAY

2.4.1 Aerobic

Heart rate measurement is often used as an indirect measure of intensity of exercise and the validity of heart rate monitoring in soccer has formerly been described (Helgerud et al., 2001). Several studies have determined heart rate during competitive female match-play and observed average and peak heart rate values of 86 ± 3 % of maximum heart rate (HR_{max}) and 98 ± 1 % HR_{max}, respectively (Krustrup et al., 2005; Andersson et al., 2010a, 2010b). The assessment of heart rate and subsequent use of pre-established heart rate and maximal oxygen uptake (VO_{2max}) relationships are frequently used to estimate the aerobic contribution to match-play (Reilly, 1997). Average VO_2 during match-play in elite female players has been estimated at 77-80 % of VO_{2max} (Mohr et al., 2004; Krustrup et al., 2005), with peak values of 96 % of VO_{2max} (Krustrup et al., 2005). These values for heart rate and VO_2 suggest the aerobic energy system is highly taxed throughout female soccer match-play with periods of near maximal exertion exhibited (Krustrup et al., 2005). It should be noted, however, that heart rate values during match-play might overestimate the actual physical demands as factors such as isometric contractions, thermal and emotional stress can elevate heart rate beyond the normal HR-VO_2 relationship (Bangsbo, 1994a; 1994b; Andersson et al., 2010b).

Heart rate responses to match-play do not appear to vary for position during domestic competition with average heart rates of 86-88 % of peak heart rate (HR_{peak}) reported for defenders, midfielders and attackers (Krustrup et al., 2005). Slightly lower (82 ± 3 % HR_{peak}) average heart rate values were reported during an international friendly (Andersson et al., 2010b). Peak heart rate values achieved during match-play have been shown to be similar for international (97 ± 3 % HR_{peak}) and domestic games (97 ± 2 % HR_{peak}), despite differences in workload as measured by HSR (Andersson et al., 2010a). Heart rate values in females are reported as similar during the first and second halves or indeed in any 15-min period of the game (Krustrup et al., 2010). Furthermore, match-play heart rate was not found to correlate with VO_{2max}, which is likely due to the limitations of heart rate for assessing exercise-intensity during match-play (Andersson et al., 2010a). Indeed, heart rate has been shown to lack the required sensitivity to accurately relate to measures of external load such as HSR and sprinting (Weston, 2013).

2.4.2 Anaerobic

Still little information exists on the anaerobic energy contribution to female match-play. Traditionally anaerobic capacity has been evaluated using blood lactate with elite female players exhibiting mean blood lactate concentrations of 5.1 ± 0.5 $mmol.L^{-1}$ and 2.7 ± 0.4 $mmol.L^{-1}$ following the first and second halves respectively (Krustrup et al., 2010). Decreased blood lactate concentrations following the second half have been attributed to a reduction in distance covered and intensity (Stølen et al., 2005). However, it is important to highlight that blood lactate concentration depends largely on the activity pattern of the player in the minutes preceding blood sampling and consequently may over or underestimate the overall demands (Stølen et al., 2005).

2.5 PHYSICAL CAPACITY

Identifying the physical capacity of an individual player represents a central component of the ergonomics model discussed by Reilly (2005) (Figure 1.1). A comprehensive understanding of a player's strengths and weaknesses informs selection, tactical decisions and ultimately the specifics of a detailed training programme. Moreover, the testing of physical capacity can help identify talent and differentiate between standards of competition (Hoare and Warr, 2000).

2.5.1 Anthropometry

Female national team players and those competing in the highest domestic leagues are on average 20-27 years old, 1.61-1.70 m in stature, weighing 57-65 kg and with a body fat percentage of 14-20 % (Table 2.2). Height and body mass of elite female players remains comparable to earlier reports (Davis and Brewer, 1993), however, percentage body fat is now lower than previously observed (20-22 %) (Davis and Brewer, 1993). These alterations in body composition likely reflect greater training volume and improved access to support staff such as nutritionists.

Table 2.2 Basic anthropometric characteristics for elite female soccer players (mean ± SD)

Source	n	Competition Level	Nationality / Region	Age (years)	Height (m)	Body Mass (kg)	Body Fat Content (%)
Bradley et al., 2014b	92	National Team Players / Highest Division	European	23 ± 2	1.68 ± 0.07	61.9 ± 5.6	
Haugen et al., 2014	76	National Team Players	Norwegian	22.8 ± 3.5	1.69 ± 0.06	63.2 ± 5.5	
Hewitt, Norton and Lyons, 2014	15	National Team Players	Australian	23.5	1.70	64.9	
Manson, Brughelli and Harris, 2014	15	National Team Players	New Zealand	23.3 ± 4.9	1.68 ± 0.08	64.1 ± 5.4	
Castagna and Castellini, 2013	21	National Team Players	Italian	25.8 ± 3.9	1.67 ± 0.04	59.9 ± 3.8	
Gravina et al., 2011	14	Highest Division	Spanish	25 ± 5		61.0 ± 7.4	15.5 ± 2.9*
Ingebrigtsen, Dillern and Shalfawi, 2011	29	Highest Division	Norwegian	20.8 ± 3.7	1.66 ± 0.05	60.7 ± 6.6	
Andersson et al., 2010a	17	National Team Players	Scandinavian	27 ± 1	1.68 ± 0.02	61.0 ± 1.4	
Andersson et al., 2010b	16	Highest Division	Scandinavian	22 ± 3	1.67 ± 0.05	64.0 ± 2.0	
Krustrup et al., 2010	23	Highest Division	Danish	23	1.69	60.1	18.5*
Mujika et al., 2009a	17	Highest Division	Spanish	23.1 ± 2.9	1.65 ± 0.04	56.8 ± 5.7	
Sedano et al., 2009	100	Highest Division	Spanish	22.1 ± 1.1	1.61 ± 0.06	57.7 ± 7.5	20.1 ± 5.5^
Krustrup et al., 2005	14	Highest Division	Danish	24	1.67	58.5	14.6*
Bunc and Psotta, 2004	14	Elite	Czech	25.3 ± 4.8	1.65 ± 0.06	64.5 ± 9.9	14.9 ± 5.7*
Can, Yilmaz and Erden, 2004	17	Highest Division	Turkish	20.7 ± 2.1	1.62 ± 0.06	56.6 ± 5.0	19.8 ± 0.7$^+$
Mohr et al., 2004	18	Highest Division	Scandinavian	24	1.68	61.0	15.0*

** method of percentage body fat determination not stated; $^+$determined from sum of skinfolds (Jackson and Pollock, 1985); ^determined from sum of skinfolds (Faulkner, 1968)*

The small variation in anthropometric measures (1.61-1.70 m and 56.8-64.9 kg) highlights the relative homogeneity of the elite female soccer population. Height and body mass have previously been reported to be similar between playing positions in elite Norwegian (Ingebrigtsen, Dillern and Shalfawi, 2011) and North American (Vescovi, Brown and Murray, 2006) players with trends for defenders to be taller than attackers (Vescovi, Brown and Murray, 2006; Ingebrigtsen, Dillern and Shalfawi, 2011). However, some differences were noted in high-level Spanish players with CD being taller than all outfield positions and goalkeepers (GK) being heavier than WD, midfielders and A (Sedano et al., 2009). Goalkeepers were reported to have the highest fat mass, which could be attributed to reduced energy expenditure in training and games (Sedano et al., 2009) and suggests inappropriate conditioning and/or dietary practices. Wide defenders were found to have the lowest body fat percentage and highest muscle mass (Sedano et al., 2009) which may be related to differing physical demands of their playing position as preliminary match analysis literature has suggested increased HSR demands for WD relative to their CD counterparts (Bradley et al., 2014a). Conversely, older studies (Todd, Scott and Chisnall, 2002; Wells and Reilly, 2002) found no significant differences in body fat percentage between outfield playing positions. It can be speculated that the positional differences demonstrated in recent studies are a result of increased training specificity for playing positions or indeed that player's with particular anthropometric characteristics are assigned to certain playing positions.

The basic physical characteristics of female players across a spectrum of playing standards have been documented within the literature. Researchers have described anthropometric characteristics of high school (Siegler, Gaskill and Ruby, 2003), university (Vescovi, Brown and Murray, 2006; McCurdy et al., 2010; Sjökvist et al., 2011), lower division domestic league (Mujika et al., 2009a), higher division domestic league (Mujika et al., 2009a; Krustrup et al., 2010; Ingebrigtsen, Dillern and Shalfawi, 2011) and national team players (Andersson et al., 2010b; Hewitt, Norton and Lyons, 2014; Manson, Brughelli and Harris, 2014). However, the anthropometric profile of elite youth players has yet to be fully examined. Some information exists regarding differences in anthropometric variables based on the level of competition, with differences in body mass and body fat percentage being demonstrated between elite and non-elite players (Todd, Scott and Chisnall, 2002; Sedano et al., 2009). Specifically, elite Spanish players were found to be lighter and have lower percentage body fat than their non-elite counterparts (Sedano et al., 2009).

2.5.2 Maximal Aerobic Power

As previously stated, the average VO_2 during match-play in elite female players (77-80 % of VO_2 max) (Mohr et al., 2004; Krustrup et al., 2005) highlights that the aerobic system is highly stressed during soccer match-play (Stølen et al., 2005). The direct measurement of VO_{2max} in female soccer players has been reported in a number of studies with values for elite players ranging from 49.4-57.6 $ml.kg^{-1}.min^{-1}$ (Table 2.3). Some studies (Tumilty and Darby, 1992; Tamer et al., 1997; Tumilty, 2000; Manson, Brughelli and Harris, 2014) have estimated VO_{2max} using equations derived from distances achieved in either the multistage fitness test (Ramsbottom, Brewer and Williams, 1988) or the 30:15 intermittent fitness test (Buchheit, 2008). However, the predictive power of the multistage fitness test to estimate VO_{2max} in young women soccer players has recently been questioned (Castagna et al., 2010). A summary of direct and indirect values for VO_{2max} values in elite female soccer players is shown in Table 2.3.

Table 2.3 Maximal oxygen uptake data for elite female soccer players (mean ± SD)

Source	**n**	**Competition Level**	**Nationality / Region**	**Maximal Oxygen Uptake (ml.kg.min^{-1})**	**Estimated Maximal Oxygen Uptake (ml.kg.min^{-1})**
Haugen et al., 2014	76	National Team Players	Norwegian	56.6	
Manson, Brughelli and Harris, 2014	15	National Team Players	New Zealand		50.3 ± 2.9
Ingebrigtsen, Dillern and Shalfawi, 2011	29	Highest Division	Norwegian	51.9 ± 5.1 (Defenders) 55.4 ± 5.7 (Midfielders) 52.9 ± 3.2 (Attackers) 50.7 ± 5.0 (Goalkeepers)	
Andersson et al., 2010b	16	Highest Division	Scandinavian	54.0 ± 3.0	
Krustrup et al., 2010	23	Highest Division	Danish	52.3 ± 1.3	
Andersson et al., 2008a	8 9	Highest Division	Scandinavian	55.4 ± 3.6 53.8 ± 2.3	
Gabbett and Mulvey, 2008	13	Scholarship Holders / National Team Players	Australian	51.4 ± 5.4	
Krustrup et al., 2005	14	Highest Division	Danish	49.4	
Bunc and Psotta, 2004	14	Elite	Czech	53.9 ± 5.7	
Mohr et al., 2004	18	Highest Division	Scandinavian	49.5 ± 1.0	
Tumilty, 2000	17	National Team Players	Australian		50.3 ± 5.1
Tamer et al., 1997	22	Elite	Turkish		43.2 ± 4.1
Davis and Brewer, 1992	14	National Team Players	English	52.2 ± 5.1*	
Evangelista et al., 1992	12	Elite	Italian	49.8 ± 8.3	
Jensen and Larsson, 1992	10	National Team Players	Danish	57.6*	
Tumilty and Darby, 1992	20	National Team Players	Australian		48.5 ± 4.8

* *following an intervention*

Similar VO_{2max} levels have been observed between outfield playing positions (Ingebrigtsen, Dillern and Shalfawi, 2011) although midfielders often record higher values than those in other positions (Ingebrigtsen, Dillern and Shalfawi, 2011). Goalkeepers generally have lower VO_{2max} values compared to outfield positions, particularly midfielders (Haugen et al., 2014). When using the multistage fitness test to estimate VO_{2max} the findings are equivocal with some studies showing no differences in aerobic capacity between playing positions (Todd, Scott and Chisnall, 2002; Vescovi, Brown and Murray, 2006), whereas one study highlighted significant differences between midfielders and defenders (Wells and Reilly, 2002). The VO_{2max} of female players has been reported by a number of researchers at various levels of competition and descriptions for university (Rhodes and Mosher, 1992; Vescovi, Brown and Murray, 2006; Sjökvist et al., 2011) and lower division domestic league players (Polman et al., 2004) generally show a lower capacity than higher division domestic league (Mohr et al., 2004; Krustrup et al., 2005) and national team players (Davis and Brewer, 1992; Jensen and Larsson, 1992). In addition, a positive correlation ($r = 0.81$) has been demonstrated between VO_{2max} and the amount of HSR completed during a match (Krustrup et al., 2005). However, when VO_{2max} for international and regional English players was directly compared, no significant differences were reported (Todd, Scott and Chisnall, 2002). The failure to discriminate between standards of competition in this study may be a result of both groups being non-professional at this time and therefore the differentiation between weekly training volume and intensity may have been slight. Furthermore, the specificity of VO_{2max} for soccer performance has been questioned (Krustrup and Bangsbo, 2001; Castagna, Abt and D'Ottavio, 2005), consequently more intermittent based assessment tools are now commonly used.

2.5.3 High-Intensity Endurance Capacity

It has previously been described (Davis and Brewer, 1993) that to be successful a player must have the capacity to recover rapidly from high-intensity exercise. The use of the Yo Yo Intermittent Recovery Test level 1 (YYIR1) (Castagna et al., 2006a) and YYIE2 (Bradley et al., 2014b) are now commonplace in field-based testing protocols for team sports. An overview of published literature can be found in Table 2.4.

Table 2.4 High-intensity intermittent endurance capacity data for elite female soccer players (mean ± SD)

Source	n	Competition Level	Nationality / Region	YYIR1 (m)	YYIE2 (m)
Bradley et al., 2014b	92	National Team Players	European		1774 ± 532
	46	Highest Domestic Division			1261 ± 449
	42	U20 National Team Players			1490 ± 447
Scott and Andersson, 2013	27	National Team Players	England		2182 ± 89
Krustrup et al., 2010	23	Highest Division	Danish		1265 ± 133
Mujika et al., 2009a	17	Highest Division	Spanish	1224 ± 255	
	17	Second Division		826 ± 160	
Krustrup et al., 2005	14	Highest Division	Danish	1379	

Data for national team female players shows distance of 1774 ± 532 m (Bradley et al., 2014b) and 2182 ± 89 m (Scott and Andersson, 2013) being attained for the YYIE2. There appears to be no published data for national team players using the YYIR1, however, domestic players from the Danish and Spanish leagues cover 1379 m (600-1960 m) (Krustrup et al., 2005) and 1224 ± 255 m (Mujika et al., 2009a), respectively. Some positional differences in YYIE2 have been identified (Bradley et al., 2014b), with senior WM covering more distance than CD and A, similarly, WM and CM covered more distance than CD at U19 level.

Moreover, large differences (48 %, ES 1.87) in YYIR1 performance have been demonstrated between first and second division female Spanish players (Mujika et al., 2009a). These large differences can likely be attributed to female players in lower leagues operating at a recreational level with a lower training volume.

2.5.4 Speed

A plethora of studies (Tumilty and Darby, 1992; Hoare and Warr, 2000; Tumilty, 2000; Siegler, Gaskill and Ruby, 2003; Polman et al., 2004; Spencer et al., 2005; Vescovi, Brown and Murray, 2006; Vescovi and McGuigan, 2008; Gabbett, 2010; Krustrup et al., 2010; McCurdy et al., 2010; Sjökvist et al., 2011; Haugen, Tønnessen and Seiler, 2012) have undertaken speed testing across a range of performance levels in female soccer players, however, the use of different assessment protocols limits comparison. For example, the distance that a player stands before the first timing gate is variable with 0 cm (Gabbett, 2010; McCurdy et al., 2010) and 88 cm (Andersson et al., 2008a) being used in the literature. Nevertheless, Table 2.5 highlights the studies to date that have described speed characteristics of elite female players. When the same testing protocol was adopted to evaluate sprinting performance in Australian national team players in 1992 and 2000 (Tumilty and Darby, 1992; Tumilty, 2000), an increase in performance was demonstrated in the more recent assessment (ES 0.56). Further improvements (ES 1.90) in 20 m speed were demonstrated when a greater distance between the start line and the first timing gate was used (Andersson et al., 2008a).

Table 2.5 Linear speed data for elite female soccer players (mean ± SD)

Source	n	Competition Level	Nationality / Region	Time 5 m (s)	Time 10 m (s)	Time 20 m (s)	Distance before first timing gate (m)
Haugen, Tønnessen and Seiler, 2012	85	National Team Players	Norwegian		1.67 ± 0.07		N/A (pressure pad)
Andersson et al., 2008a	8	Highest Division	Scandinavian			3.18 ± 0.03	0.88
	9	Highest Division				3.17 ± 0.03	
Tumilty, 2000	20	National Team Players	Australian	1.14 ± 0.04	1.91 ± 0.04	3.26 ± 0.06	1.00
Tumilty and Darby, 1992	20	National Team Players	Australian			3.31 ± 0.11	1.00

Limited information exists on the differences in speed characteristics between playing positions. Vescovi, Brown and Murray (2006) evaluated differences in speed variables (10-40 yard sprints) and they concluded there were no significant differences between playing positions, despite a trend for defenders to be slower. It has been proposed that sprint performance can distinguish between standards of competition (Hoare and Warr, 2000; Vescovi, 2012b). Selected players from trials for an American professional soccer league were between 0.5 and 0.8 km.h^{-1} faster than their non-selected equivalents (Vescovi, 2012b). Similar findings were reported during an Australian talent identification project with selected players recording faster times over 5 m, 10 m and 20 m, respectively than the non-selected players (Hoare and Warr, 2000).

2.5.5 Repeated Sprint Activity

Repeated sprint activity has long been acknowledged as an important aspect of team sports (Spencer et al., 2005; Rampinini et al., 2007; Gabbett, Wiig and Spencer, 2013). However, recent research (Schimpchen et al., 2016) has questioned both the importance of RSA in match-play and also the construct validity of traditional RSA tests. Very few studies have reported assessments of RSA in female soccer players. Furthermore, the published papers to date (Rhodes and Mosher, 1992; Polman et al., 2004; Gabbett, 2010) have used different protocols, making comparison difficult. One study (Polman et al., 2004) adopted a method that involved players completing a 34.2 m sprint course seven times with 25 s rest between sprints (Bangsbo, 1994a). The reported mean sprint time to complete the course ranged from 8.79-9.13 s following a training intervention. Gabbett (2010) designed a repeated sprint test specifically to reflect the demands of international female soccer. The test involved 6 repetitions of a 20 m maximal sprint, on a 15 s recovery cycle which represents the most extreme repeated-sprint demands of the international game (Gabbett and Mulvey, 2008). The total sprint time was found to be reliable (1.5 % typical error of measurement) and able to discriminate between elite and sub-elite players and thus this protocol could be used in future to advance research in this area.

2.5.6 Power and Strength

The assessment of jumping capability is an accepted functional measure of power in soccer players (Stølen et al., 2005). Furthermore, a significant relationship has been demonstrated between team success and average jump height and leg extension power, thus demonstrating the importance of this physical component for soccer-specific performance (Arnason et al., 2004). There are numerous reports within the literature detailing the power performance of female players across differing competition levels; university (Vescovi, Brown and Murray, 2006; McCurdy et al., 2010; Sjökvist et al., 2011), high school (Vescovi and McGuigan, 2008; Vescovi et al., 2011), lower division domestic league (Polman et al., 2004; Mujika et al., 2009a), higher division domestic league (Andersson et al., 2008a; Sedano et al., 2009; Krustrup et al., 2010), national team youth (Castagna and Castellini, 2013) and senior national team players (Jensen and Larsson, 1992; Tumilty and Darby, 1992; Gabbett and Mulvey, 2008; Haugen, Tønnessen and Seiler, 2012; Castagna and Castellini, 2013). As with the other components of physical fitness previously described; the ability to compare data between studies is hindered by the different protocols and equipment adopted by researchers. A summary of results for vertical jump ability in elite players can be found in Table 2.6.

Table 2.6 Vertical jump data for elite female soccer players (mean ± SD)

Source	**n**	**Competition Level**	**Nationality**	**Squat Jump (no arms) (cm)**	**Drop Jump (no arms) (cm)**	**CMJ (no arms) (cm)**	**CMJ (with arms) (cm)**
Castagna and Castellini, 2013	21	National Team Players	Italian	30.1 ± 3.7		31.6 ± 4.0	
	20	U19 National Team		32.8 ± 2.9		34.3 ± 3.9	
	21	U17 National Team		28.2 ± 2.5		29.0 ± 2.1	
Haugen, Tønnessen and Seiler, 2012	85	National Team Players	Norwegian			30.7 ± 4.1	
Krustrup et al., 2010	23	Highest Division	Danish			35.0 ± 1.0	
Mujika et al., 2009a	17	Highest Division	Spanish			32.6 ± 3.7	38.0 ± 4.8
Sedano et al., 2009	100	Highest Division	Spanish		25.3 ± 5.6	26.1 ± 4.8	
Andersson et al., 2008a	8	Highest Division	Scandinavian			30.5 ± 1.2	
Krustrup et al., 2008	12	National Team Players	Scandinavian			35.0 ± 1.0	
Can, Yilmaz and Erden, 2004	17	Highest Division	Turkish			34.5 ± 7.1[+]	
Tumilty, 2000	20	National Team Players	Australian			51.0 ± 5.0	
Jensen and Larsson, 1992	10	National Team Players	Danish			37.8[*,^]	
Tumilty and Darby, 1992	20	National Team Players	Australian			40.5 ± 4.5[+]	

* *recorded as "vertical jump" but assumed to be countermovement jump*

^ *jump height estimated from flying time*

[+] *following an intervention*

Playing position does not seem to be a distinguishing factor relating to performance in jumping assessments (Haugen, Tønnessen and Seiler, 2012). However, trends are apparent with GK recording the lowest scores (Vescovi, Brown and Murray, 2006; Sedano et al., 2009) and midfielders and attackers recording greater scores than defenders (Vescovi, Brown and Murray, 2006). Vertical jump performance has been shown to differentiate between age groups (Castagna and Castellini, 2013). Specifically, U19 Italian national team players produced higher CMJ and squat jumps than their U17 counterparts (Castagna and Castellini, 2013). Additionally, an improvement in CMJ performance has been described until players reach an age of 15-16 years and then a plateau in performance is shown until 21 years of age (Vescovi et al., 2011). The data regarding competitive standard and jumping performance show no apparent differences between Spanish (Sedano et al., 2009) or English (Todd, Scott and Chisnall, 2002) elite and sub-elite players.

Insightful recommendations have been made within the literature regarding the specifics of protocols that should be adopted for female players. It has been suggested that a drop jump may not be appropriate as drop jump values have been shown to be lower than CMJ scores despite the increased activation of muscle fibres resulting in increased force production (Sedano et al., 2009). Justifications for this finding include the increased technical requirement with a drop jump compared to a CMJ, furthermore the CMJ has been described as being more similar to physical skills executed within soccer (Sedano et al., 2009). Consequently, consideration should be given before including the drop jump in a testing protocol (Sedano et al., 2009). Unilateral jump performance has a stronger correlation with sprint performance than bilateral jump performance and is a useful tool for assessing asymmetries; therefore the inclusion of unilateral jumps in a testing protocol is warranted (McCurdy et al., 2010). Castagna and Castellini (2013) have attempted to describe thresholds of acceptable vertical jump values for elite females using the data gathered from Italian national team players. The authors have suggested scores over 34.4 cm and 32.9 cm for CMJ and static jump should be regarded as superior vertical jump abilities. In addition, a CMJ of 29.8 cm should be considered a threshold measure for discriminating between competitive levels in elite female players. This work could be expanded to include thresholds for different playing positions and age groups.

Investigations into muscle strength in female players are limited and the methods of data collection appear varied, thus making comparisons difficult. Limited recent (Krustrup et al., 2010; Manson, Brughelli and Harris, 2014) and historical (Davis and Brewer, 1992) isokinetic data is available for national team players but the majority of research has been conducted using sub-elite and recreational players to examine injury risk. The scarcity of information available in this area is surprising, as female players have been regularly completing this component of training for many years.

2.6 TRAINING

Effective conditioning programmes that carefully balance training and recovery are the cornerstone of athletic development. Moreover, in soccer, those that can integrate both physical and tactical/technical training are considered superior in enhancing the effectiveness of the available training time. The issue of managing a player’s training load is important for the elite player to ensure optimal preparation for performance and potentially reduce the susceptibility to injury (Rhea et al., 2009).

2.6.1 Training Interventions

Due to the high demand placed on the aerobic system during match-play (~80 % of VO_2 max) (Stølen et al., 2005), many soccer training programmes serve to increase the ability to repeatedly perform high-intensity exercise (Little and Williams, 2006). The volume of female specific training literature is sparse but two recent studies (Rhea et al., 2009; Clark, 2010) have shown increased VO_{2max} using interval training methodologies. Specifically, an 8-week mixed-intensity interval programme significantly improved VO_{2max} capacity (49.69 ± 1.15 ml.kg.$^{-1}$ to 62.13 ± 0.96 ml.kg.$^{-1}$) (Clark, 2010). Interval training sessions lasted between 12-36-min with work durations of between 30-90 s, sessions were repeated three times per week. Similarly, a 12-week individualised interval training programme consisting of intervals of between 5–120 s increased mean values for VO_{2max} (13 %), anaerobic threshold (17 %) and 1-min heart rate recovery (37 %) (Rhea et al., 2009). However, the participants in these two studies were recreational players and therefore large increases in physical markers would be expected when adhering to an organised training regime. Currently no information is available regarding high-intensity training interventions for elite female players, which is likely due to the difficulties in manipulating elite player's training schedules for research purposes.

It is recognised that to be successful in soccer, an individual must be able to cover short distances quickly (Upton, 2011), as high-speed activities are most often associated with decisive moments in a game (Davis and Brewer, 1993; Faude, Koch and Meyer, 2012). To date, few studies (Polman et al., 2004; Bartolini et al., 2011; Upton, 2011) have examined components of speed training using a female soccer population. Polman (2004) evaluated the use of the Speed, Agility, Quickness (SAQ) method of training and demonstrated improved mean performances in sprint to fatigue (12 %), 25 m sprint (4 %), left and right side agility (5

% and 4 %, respectively) and vertical and horizontal power tests (19 % and 8 %, respectively) following 12 weeks of SAQ training compared to a control group. The concept of assisted and resisted sprint training has been assessed and these methods were found to be more effective than traditional sprint training (Upton, 2011). Furthermore, assisted sprint training was more suitable for improving acceleration (≤13.7 m) and resisted sprint training for improving maximum velocity (≥13.7 m). Bartolini and colleagues (2011) highlighted that when completing overspeed training (2 maximal sprints) with an elastic cord, sprint times were lowest following the use of 30 % body weight assistance over distances up to 15 yards. The studies to date have examined sub-elite and collegiate level players and have expressed benefits of various forms of speed training on physical testing values. As with the high-intensity endurance training there appears to be limited available research on the interventions regarding the elite player and this is an area requiring further examination.

Explosive strength is an important determinant of high-level performance in soccer and plyometric activity is cited as a suitable training modality for improving jumping performance and explosiveness (Sedano Campo et al., 2009). Specifically, elite female players who completed 12 weeks of plyometric training three times per week had mean increases of 3.3 cm and 4.5 cm for CMJ and drop jump, respectively (Sedano Campo et al., 2009). Furthermore, female players completing combined plyometric, resistive and anaerobic programmes twice per week also experienced improvements in time to fatigue during a simulated soccer running test (Siegler, Gaskill and Ruby, 2003), a reduction in mean 20 m sprint time (0.10 s) (Siegler, Gaskill and Ruby, 2003) and a significant decrease in the percentage of VO_{2peak} at a set running speed (Grieco et al., 2012). Plyometric training has also been shown to have a role in injury prevention for female soccer players by enhancing the functional joint stability in the lower extremity (Chimera et al., 2004). These studies highlight the potential advantages of including plyometric-based activity as part of a training programme, however, as with the aforementioned training techniques further investigation using elite players is required.

2.7 FEMALE DIFFERENCES

There are some physiological areas of research that are exclusive to females. A full appraisal of these topics is beyond the scope of this literature review and in some instances has already been conducted (Burrows and Peters, 2007; Renstrom et al., 2008; Alentorn-Geli et al., 2009; Oosthuyse and Bosch, 2010; Vescovi, 2011). However, the importance of these variables to female soccer players and the potential impact on training, performance and injury risk should not be underestimated.

2.7.1 Menstrual Cycle

Women aged ~13-50 years, experience a circa-mensal rhythm termed the menstrual cycle (Reilly, 2000). Alterations in the cycle can occur and cause menstrual disturbances (Loucks, 1990). High training loads can have an adverse effect on the normal menstrual cycle. Young females with low body mass and body fat levels who undertake intense training may experience delayed menarche (Reilly, 2000; Warren and Perlroth, 2001). Similarly, menstruating athletes with high training loads, low body mass, low body fat levels and/or energy imbalance (Reilly, 2000) may suffer secondary amenorrhea, although this is uncommon in soccer players.

Physiological responses may be influenced by the variations in endocrine hormones that occur according to menstrual cycle phase (Reilly, 2000). As women train and compete at all stages of their menstrual cycle the possible effect on performance should be considered.

These effects have received a limited amount of research attention and the findings to date have been unclear. VO_{2max} appears to be largely unaffected by the phase of the menstrual cycle (De Souza et al., 1990; Beidleman et al., 1999). However, some studies have shown increased minute ventilation (Williams and Krahenbuhl, 1997; Stachenfeld et al., 2000; Wells and Reilly, 2002; Janse de Jonge et al., 2012), heart rate (Hessemer and Bruck, 1985; Pivarnik et al., 1992; Janse de Jonge et al., 2012) and rating of perceived exertion (Pivarnik et al., 1992; Janse de Jonge et al., 2012), during the luteal phase, which could be attributed to an increased core temperature (0.3-0.5 °C) during this phase (Janse de Jonge et al., 2012). Lactate threshold findings are equivocal with some reports of stable values throughout the cycle (Dean et al., 2003; Smekal et al., 2007), whilst others describe lower blood lactate concentrations in the luteal phase during moderate-intensity activity (Zderic et al., 2001). Sprint performance as measured via power output seems unaffected by menstrual cycle phase (Tsampoukos et al., 2010). Investigations into muscle contractile strength during the cycle have produced conflicting results; however, when methodological shortcomings are addressed it appears that fluctuations in female steroid hormones do not affect muscle strength and fatigability (Janse de Jonge, 2003). Limited soccer-specific research exists but one study showed no performance differences in high-intensity intermittent shuttle running throughout the menstrual cycle (Sunderland and Nevill, 2003), although differences in core temperature were not found in this study that may explain these findings. At present there are a number of conflicting reports within the literature, methodological concerns and a lack of specificity to team sports, specifically soccer activity.

2.7.2 Oral Contraceptive Pill

The oral contraceptive pill (OCP) is available in single (progesterone only) and combined (oestrogen and progesterone) formulations. Non-contraceptive benefits include cycle control and reductions in dysmenorrhoea, iron deficient anaemia and bone mineral density loss (Maia and Casoy, 2008). In recent years there has been an increase in the use of OCP by the athletic population with reports stating 83 % of elite athletes use an OCP (Rechichi et al., 2009).

Despite the increased prevalence of OCP usage in athletic populations there is still limited research regarding its effects on athletic performance (Rechichi and Dawson, 2009). Aerobic performance as measured by VO_{2max} has been shown to reduce by 5-15 % in trained and active women using a triphasic OCP (Casazza et al., 2002; Lebrun et al., 2003), however, research remains equivocal when considering the monophasic pill (Burrows and Peters, 2007). Anaerobic performance, high-intensity intermittent performance and strength appear to be largely unaffected by OCP, however, more well-controlled studies are required (Burrows and Peters, 2007; Rechichi et al., 2009). During an investigation in to the effects of OCP on team sport athletes, reactive strength index as measured during a drop jump was significantly lower during the withdrawal phase, i.e. when exogenous oestrogen and progesterone were at their lowest. The mechanism for this finding could not be fully explained but it was suggested that increased endogenous oestrogen might have a negative impact on neuromuscular timing, muscle activation and performance (Rechichi and Dawson, 2009). It is clear that further studies are necessary to ascertain the effects of OCP on soccer-specific performance.

2.8 SUMMARY

The findings of this review of literature highlight that women's soccer has changed dramatically in the last two decades (Davis and Brewer, 1993). The increased professionalism within the sport is represented by the increased physicality of match-play as TD covered has increased from ~8.5 km (Davis and Brewer, 1993) to ~10 km (Gabbett and Mulvey, 2008; Krustrup et al., 2008; Andersson et al., 2010a; Bradley et al., 2014a; Hewitt, Norton and Lyons, 2014). Differences in time-motion analysis have also been identified between standards of competition (Gabbett and Mulvey, 2008), playing position (Krustrup et al., 2008; Mohr et al., 2008; Bradley et al., 2014a; Hewitt, Norton and Lyons, 2014) and at different time-points within a match (Mohr et al., 2004, 2008; Krustrup et al., 2005, 2008). However, the majority of time-motion studies in female soccer to date have used traditional single camera analysis methods as such the ability to examine specific physical elements in detail are limited (Spencer et al., 2005; Di Salvo et al., 2009). Consequently, more comprehensive evaluations into the physical characteristics of elite female match-play using contemporary analysis methods and greater positional differentiation are warranted.

The physical capacity of female players is probably the most thoroughly researched area to date. Data is available for most components of physical fitness in sub-elite players; however, research on elite players and the influence of age and playing position on performance characteristics is still lacking. A comprehensive understanding of the physical characteristics of elite players will help to inform the design of specific training drills and conditioning programmes.

CHAPTER 3

GENERAL METHODOLOGY

The aim of this general methods section is to provide the reader with specific information regarding the procedures undertaken to fulfil the aims of the thesis. The initial section of the methods describes the semi-automated multi-camera system used (Prozone Sports Ltd., Leeds, UK) to quantify the demands of match-play and the frequency of repeated high-speed activity (Aims 1 and 2). An overview of the Prozone system is provided and the pertinent issues of validity and reliability are also discussed. The second section of the methods describes in detail the anthropometric and performance measures used to evaluate the influence of age and playing position on the physical characteristics of players (Aim 5). The specific details of each test procedure, including warm-up activity are outlined in this section.

3.1 MATCH PHYSICAL PERFORMANCE DATA COLLECTION

3.1.1 System Overview

Match physical performance data was collected via Prozone (Prozone Sports Ltd., Leeds, UK). The Prozone system is a third party post-match analysis service provider, that collects match performance data using computerised semi-automatic multi-camera image recognition technology. Multiple cameras that are positioned in each of the stadiums that use the Prozone system capture physical match data. The data was collected and processed independently by Prozone using predefined speed zones to generate match physical performance data (Prozone, 2009). All physical match performance data were exported using the Prozone Trend database (Prozone Sports Ltd., Leeds, UK) and data were provided in 1-min time periods. Exported data were provided in CSV format and were then analysed using custom designed Excel spreadsheets (Microsoft, Redmond, USA).

3.1.2 Video Capture Process

The Prozone system and capturing process used in this thesis is consistent with previous investigations analysing match physical performances of male players (Bradley et al., 2011a; Di Salvo et al., 2013; Bush et al., 2015). All players' movements were captured using eight colour cameras (Vicon surveyor dome SVFT-W23, Oxford, UK) that were positioned at roof height in each of the stadiums. Cameras 1-3 were positioned in one corner of the stadium, with cameras 4-6 positioned diagonally opposite. Camera 7 and camera 8 were positioned diagonally opposite one another in the remaining corners. Each camera was individually positioned and fixed for optimal zoom and field of vision to guarantee long-term stability of the camera system (Bradley et al., 2009). The position of the cameras allowed for every area of the pitch to be covered by at least two cameras to address issues of accuracy, occlusion, resilience and resolution (Di Salvo et al., 2006).

The eight individual video files created from the cameras were analysed using Prozone Stadium Manager (Prozone Sports Ltd., Leeds, UK) to determine image coordinates and continuous trajectories for each player. Once the automatic tracking was completed, the eight video files were automatically combined to produce a single dataset and Kalman filters were applied to ensure object speed and directional data. Any erroneous objects (i.e. debris on the field) were corrected or removed. Each player's trajectory (every 0.1 s) was then delimited by x and y coordinates measured in meters from the centre spot on the pitch. Using Pythagoras theorem and the average velocity over a 0.5 s period, the distance covered within each 0.1s trajectory was computed from the distance covered over time (Di Salvo et al., 2009). The completed match physical performance data were then compiled in to a Prozone application and made available for export at a minimum reporting unit of 0.5 s.

All individual movement trajectories derived through Prozone are subject to verification by quality control processes as during periods of congestion in small areas (e.g. collisions, set pieces and goal celebrations) it is possible that the automatic tracking system may lose players or confuse individuals with one another. The automated tracking system is visually verified until point of failure, then at this time an operator will perform manual tracking until the automated tracking reappears (Di Salvo et al., 2009). The amount of occlusion can range from 38-97 % of a match (average of 58 %) and therefore a player's trajectory is almost always derived as a consequence of both the automatic tracking system and the subsequent manual correction by quality control personnel.

3.1.3 Validity and Reliability

It was not possible to independently determine validity and reliability of the Prozone system for the purpose of this thesis due to financial restrictions. However, the Prozone system has previously been validated (Di Salvo et al., 2006, 2009; Buchheit et al., 2014) by quantifying the displacement velocities during match-related activities relative to data obtained using electronic timing gates. Di Salvo et al. (2009) demonstrated that there were no significant differences (coefficient of variation (CV) = 0.4 %) when average velocity was measured using Prozone or electronic timing gates and differences were independent of mode of running (linear or non linear) and running velocity (7.5-25.2 km.h^{-1}) (Di Salvo et al., 2009). A more recent study examined the validity of Prozone for determining distance run at different speeds (7.2, 14.4 and 19.8 km.h^{-1}) and peak velocity (Buchheit et al., 2014). Results highlighted that Prozone moderately overestimated the distance run at each of the three speeds (e.g. +47 m over a 200 m reference distance at a speed of 14.4 km.h^{-1}), however the magnitude of overestimation was constant.

Reliability of the Prozone system has previously been determined by measuring sprint time over 40 m during two repetitions, (Buchheit et al., 2014) as well as two separate analyses of the physical match performance for an entire match (Di Salvo et al., 2009). Prozone was found to be reliable when measuring peak velocity during a 40 m sprint with CV's between 1-3 % for each 10 m interval (Buchheit et al., 2014). Prozone was also found to be reliable when measuring physical match performance with CV's of less than 5 % reported when data were analysed for two outfield players, on two separate occasions separated by seven days, by two different Prozone quality control personnel. However, it should be noted that reliability decreased as speed increased, with values of ~ 1.5 % and ~ 4.8 % for walking and sprinting respectively. Collectively, this data demonstrates that Prozone is an accurate system for quantifying match-related displacement velocities in soccer (Di Salvo et al., 2009).

3.2 PHYSICAL CHARACTERISTICS DATA COLLECTION

3.2.1 Anthropometric Measures

An International Society for the Advancement of Kinanthropometry (ISAK) accredited anthropometrist performed all anthropometric measurements and ISAK guidelines were followed (Jones et al., 2006).

3.2.1.1 Height

Height was measured using a portable stadiometer (Seca 217, Germany) and the stretch stature method was adopted (Jones et al., 2006). Participants were required to stand with their feet together and with their heels, buttocks and upper part of the back touching the back of the stadiometer. The head was placed in the Frankfort plane, with the orbitale (lower edge of the eye socket) in the same horizontal plane as the tragion (the notch superior to the tragus of the ear). The measurer placed their hands along the jaw line of the participant in to a position that ensured upward pressure was transferred through the mastoid processed. The participant was instructed to take and hold a deep breath whilst the measurer applied a gentle upward lift through the mastoid processes, whilst keeping the head in the Frankfort plane. The recorder then placed the headboard firmly down on the vertex, crushing the hair as much as possible. The recorder further assisted by watching that the feet did not come off the floor and that the position of the head was maintained in the Frankfort plane. The participant's height to the nearest 0.05 cm was taken at the end of a deep inward breath. The measurement of height was repeated and providing the values were within 1.5 % of one another, a mean of the two measurements was recorded. A third measurement was taken if the values were outside the acceptable range of 1.5 % and in this instance the median of the three measurements was taken.

3.2.1.2 Body Mass

Body mass was measured using calibrated digital scales (Seca 876, Germany) and participants were weighed in minimal clothing (shorts and t-shirt). The scales were placed on a firm and flat surface and were reset to zero prior to each participant's assessment. The participant was instructed to stand in the centre of the scales without support and with their weight distributed evenly on both feet. The scales were routinely calibrated (every three months) against known weights totaling at least 150 kg (Jones et al., 2006).

3.2.1.3 Skinfolds

Skinfolds (mm) were taken as an estimate of adiposity and were measured at eight sites using skinfold calipers (Harpenden, UK). Prior to skinfold measurement, the required anatomical landmarks were identified. An anthropometric tape (Lufkin, USA) and dermographic pen (ComEd, USA) were used to mark the landmarks on each participant. All measurements were taken on the right side of the body irrespective of the preferred side of the participant. Skinfolds measurements were taken in sequence (biceps, triceps, subscapular, iliac crest, supraspinale, abdominals, front thigh and medial calf) and a complete dataset was obtained before repeating measurements for the second time. Each skinfold measurement was repeated and providing the values were within 5 % of one another, a mean of the two measurements was recorded. A third measurement was taken if the values were outside the acceptable range of 5 % and in this instance the median of the three measurements was taken.

The information below describes in detail the location and technique for measuring each skinfold.

- *Biceps Skinfold* - the caliper was applied 1 cm distally from the left thumb and index finger raising a vertical fold at the marked mid-acromiale-radiale line on the anterior surface of the right arm.
- *Triceps Skinfold* - the caliper was applied 1 cm distally from the left thumb and index finger raising a vertical fold at the marked mid-acromiale-radiale line on the posterior surface of the right arm.
- *Subscapular Skinfold* - the caliper was applied 1 cm distally from the left thumb and index finger, raising a fold oblique to the inferior angle of the scapula in a direction running obliquely downwards in a lateral direction at an angle of about 45° from the horizontal along the natural fold (Langer line).
- *Iliac Crest Skinfold* - The caliper was applied 1 cm anteriorly from the left thumb and index finger raising a fold immediately superior to the iliac crest at the mid-axillary line (i.e. above the crest on the mid-line of the body). The fold runs anteriorly downwards and usually is progressively smaller as one moves in this direction away from the designated site.
- *Supraspinale Skinfold* - the caliper was applied 1 cm anteriorly from the left thumb and index finger raising a fold at the intersection of the border of the ilium and a line from the spinale to the anterior axillary border (armpit). The fold follows the natural fold lines running medially downwards at about a 45° angle from horizontal.
- *Abdominal Skinfold* - the caliper was applied 1 cm inferiorly to the left thumb and index finger, raising a vertical fold on the right side 5 cm lateral to, and at the level of, the omphalion (midpoint of the navel).

- *Front Thigh Skinfold* - the caliper was applied 1 cm distally to the left thumb and index finger, raising the fold on the anterior of the right thigh, along the long axis of the femur, when the leg is flexed to a 90° at the knee by placing the foot on a box. The mid-thigh position for this measure is the estimated half-distance between the inguinal crease and anterior patella.
- *Medial Calf Skinfold* - the caliper was applied 1 cm distally to the left thumb and index finger, raising a vertical fold on the relaxed medial right calf at the estimated level of the greatest circumference

3.2.2 Performance Measures

3.2.2.1 Warm-Up

Prior to commencing the physical assessments, a standardised warm-up was completed, consisting of generic warm-up activity (Table 3.1). Specific warm-ups were also completed prior to each of the performance tests (Tables 3.2-3.4), which included activities specifically related to the performance assessment. To ensure consistency between testing occasions, National federation staff coached the warm-up activity. The generic warm-up consisted of approximately 8-mins of activity, which largely incorporated running activity and hip/lumbar mobility exercises (Table 3.1). Following the generic warm-up, the players completed a 3-5-min jump specific warm-up (Table 3.2). Prior to commencement of the linear speed and repeated speed assessments, the players completed a 15-min specific warm-up comprising dynamic stretches, lunge drills and foot drills (Table 3.3). Similar warm-up activity was also undertaken before the YYIR1 test, with players instructed to complete 5-min dynamic warm-up plus 3-min dynamic stretching (Table 3.4).

Table 3.1 An outline of the generic warm-up activity to be completed prior to performance assessments

	Time	Reps	Distance
Generic Warm-Up: Total Time	8-mins		
Pulse Raiser	5-mins		
Jogging, side steps, carioca etc.			20 m
Hip/Lumbar Mobility	3-mins		
4 point kneeling			
- Cat camel		8	
- Hip drops		10	
Lying flat on back			
- Knee drop outs		10	
- Straight leg raise		10 each leg	

Table 3.2 An outline of the jump-specific warm-up activity to be completed prior to CMJ assessments

	Time	Reps	Distance
Jump-Specific Warm-Up: Total Time	3-5-min		
Squats		10	
Lunges		5 each leg	
Deep squat with lateral weight shifts		10	
Static jump		3	
Countermovement jump		3	
Repeated countermovement jump x3		2	
Hop and holds (increasing distance)		6 each leg	
Skater hops		8	
Calf jumps		10	
Single calf skips		1	10 m

Table 3.3 An outline of the speed-specific warm-up activity to be completed prior to linear speed assessments

	Time	Reps	Distance
Speed-Specific Warm-Up: Total Time	15-min		
Dynamic Warm-Up	3-min		
A-skips		3	20 m
Side steps – high and big		2	10 m
Side steps – low and quick		2	10 m
Carioca		2	20 m
Cross steps		2	10 m
Spiderman crawls (elbow outside and inside)		8	
Inchworms with extension		8	
Hamstring sweeps		8	
Back rolls (forwards, back and lateral)		10	
Dynamic Stretches	3-min		
Neural hamstrings (starter stretch)		10 each leg	
Leg swings (backwards and forwards)		10 each leg	
Leg swings (side to side)		10 each leg	
Walking hip flexor stretch (5-s holds)		2 each leg	
Kneeling quad stretch (5-s holds)		2 each leg	
Lunge Drills	2- min		
Forward lunge (reach forward)		2 each leg	
Forward lunge (reach up)		2 each leg	
Forward lunge (rotate)		2 each leg	
Lateral lunge		10	
Foot Drills	7-min		
Frappier foot speed (forwards, backwards and side)		4	5 m
Line run overs into 10 m sprint		2	10 m
Hip swivels into 30 m sprint		2	30 m
Sprint 5 m		2	5 m
Sprint 10 m		1	10 m
Sprint 10 m, back 5 m		1	15 m
Sprint 10 m, back 5m, out 10 m		2	25 m

Side step out 5 m and back 5 m, sprint out to 10 m		2	20 m
20 m builds		2	20 m
30 m max		1	30 m

Table 3.4 An outline of the YYIR1-specific warm-up activity to be completed prior to YYIR1 assessments

	Time	**Reps**	**Distance**
YYIR1-Specific Warm-Up: Total Time	8-min		
Dynamic Warm-Up	5-min		
A-skips		3	20 m
Side steps – high and big		3	10 m
Side steps – low and quick		3	10 m
Carioca		3	20 m
Cross steps		3	10 m
Spiderman crawls (elbow outside and inside)		8	
Inchworms with extension		8	
Hamstring sweeps		8	
Back rolls (forwards, back and lateral)		10	
Dynamic Stretches	3-min		
Neural hamstrings (starter stretch)		10 each leg	
Leg swings (backwards and forwards)		10 each leg	
Leg swings (side to side)		10 each leg	
Walking hip flexor stretch (5-s holds)		2 each leg	
Kneeling quad stretch (5-s holds)		2 each leg	

3.2.2.2 Countermovement Jump (without arms)

An estimation of a player's lower limb muscular power was assessed via a CMJ on a jump mat (KMS Innervations, Australia). The jump mat was placed on a firm, concrete surface at the edge of the third generation turf (indoor arena). The jump mat was connected to a laptop computer via the USB port and the KMS application was opened. Following the generic and jump-specific warm-up activity the player was permitted an additional practice jump on the mat before performing three recorded trials. The player was instructed to step on to the mat and place their feet in the middle of the mat (a comfortable distance apart) and with their hands on their hips. Whilst the player was stood stationary on the mat, the tester ensured that the mat had been reset and was ready to record. The player started from an upright position and was instructed to jump as high as possible whilst keeping their hands on their hips. Players were instructed to keep their legs straight whilst in the air and refrain from bringing their legs into a pike position or flicking their heels. The highest jump height recorded to the nearest 0.1 cm was used as the criterion measure of performance.

3.2.2.3 Linear Speed

Linear speed times were evaluated using electronic timing gates (Brower TC Timing System, USA) over distances of 0-30 m. A 50 m steel tape measure (Stanley, UK) was used to measure the 30 m distance and markers were placed at 0, 5 m, 10 m, 20 m and 30 m, in addition, a marker was placed 1 m behind the zero line. Tripods were placed directly over each marker at a height of 87 cm above ground level and a timing gate (transmitter) was fitted to each tripod. Opposite each tripod, at a distance of 2 m, another tripod and timing gate (receiver) was positioned. All timing gates were switched on and any necessary adjustments were made to ensure transmitters and receivers were appropriately lined up.

Following the speed-specific warm-up activity, the player was permitted an additional practice sprint through the course before performing three recorded trials. Each sprint was separated by a 3-min recovery period. The player commenced each sprint with their preferred foot on a line 1 m behind the first timing gate. The fastest time at each distance to the nearest 0.001 s was used as the criterion measure of performance.

3.2.2.4 Repeated Speed

Repeated speed times were evaluated using electronic timing gates (Brower TC Timing System, USA) over a distance of 30 m. The setup protocol was identical to the linear speed assessments, except the timing gates were only placed at 0 and 30 m.

If the time between completion of the linear speed assessment and the commencement of the repeated speed test was greater than 10-min, the player completed the ‘foot drills’ section of the warm-up. However, if the duration was less than 10-min, then no rewarm-up activity was undertaken. Each player completed 7 x 30 m sprints with a 30 s recovery between efforts. Players commenced each sprint with their preferred foot on a line 1 m behind the first timing gate. On completion of the 30 m sprint, the player had 30 s to return to the start line, which could be achieved by either a fast walk or a slow jog. The mean of the seven sprint times to the nearest 0.001 s was used as the criterion measure of performance.

3.2.2.5 Yo-Yo Intermittent Recovery Test Level 1

To estimate high-intensity endurance capacity, each player performed the YYIR1 which involved a series of repeated 20 m shuttle runs with progressively increasing speed (10-19 km.h^{-1}), interspersed with 10 s rest intervals (Krustrup et al., 2003). A 50 m steel tape measure (Stanley, UK) was used to measure the 20 m shuttle distance and markers were placed at 0 and 20 m, in addition a marker was placed 5 m behind the zero line. Flat disc cones were used as markers and each player had an individual, 1 m wide running lane. Following the YYIR1-specific warm-up, players positioned themselves on the zero line and listened to the test instructions (1 min 54 s) on the official audio track. The players then commenced the test, which required them to start, turn and stop on each 'bleep'. The running speed was determined by the official audio track and started at 10 km.h^{-1}, with speeds increasing in 0.5 km.h^{-1} increments. After each shuttle (2 x 20 m) there was a 10 s recovery, in which players walked 10 m. The players then returned to the start line and stood stationary prior to the next shuttle. When a player failed to make a turn on the 'bleep' they were issued with a warning, after two consecutive warnings the player was withdrawn from the test and the level was recorded in metres to the nearest 20 m shuttle.

3.3 STATISTICAL ANALYSIS

Data were analysed using linear mixed modeling to account for the repeated measures nature of each study (Statistical Package for Social Sciences, Version 21). Linear mixed modeling can be applied to repeated measures data from unbalanced designs, which was the case in each of our studies since players differed in terms of the number of matches or testing sessions they participated in. Linear mixed modeling can also cope with the mixture of random and fixed level effects that occur with performance analysis data (Cnaan, Laird and Slasor, 1997) as well as with missing data and 'nested' (hierarchical models). Main effects were followed up with Bonferroni-corrected multiple contrasts. Then, using the mean difference, degrees of freedom and standard deviation derived from the linear mixed model, standardised mean differences (effect sizes) were calculated and subsequently classified as trivial (<0.20), small (>0.20-0.60), moderate (>0.60-1.20), large (>1.20-2.00) and very large (>2.00) (Hopkins et al., 2009).

CHAPTER 4

MATCH PHYSICAL PERFORMANCE OF ELITE FEMALE SOCCER PLAYERS DURING INTERNATIONAL COMPETITION

This study was presented at the World Conference on Science and Soccer

(Portland, USA, June 2014)

4.1 INTRODUCTION

A comprehensive understanding of the physical demands of match-play is necessary in order to apply a systematic approach to training and testing protocols (Reilly, 2005). As a consequence, GPS technology and semi-automated camera systems have been extensively used to provide a detailed analysis of specific elements of a player's physical performance in men's soccer (Bradley et al., 2013; Di Salvo et al., 2013; Bush et al., 2015). Despite advancements in the understanding of the physical demands of match-play in elite male players, limited research currently exists on elite female players. This predominantly reflects the fact that female matches are rarely played in stadiums equipped with semi automated camera systems. Furthermore, the high financial costs that are associated with other contemporary technologies often prohibit their use in female soccer (Datson et al., 2014; Hewitt, Norton and Lyons, 2014). Consequently, a large proportion of the research undertaken to date has been derived from relatively small samples (n = 13-19) using traditional video-based technology (Krustrup et al., 2005; Gabbett and Mulvey, 2008; Mohr et al., 2008; Andersson et al., 2010a). Collectively, these factors limit the depth of analysis possible; therefore, it is important that further information relating to female match-play is derived to better inform female-specific training prescription and testing protocols.

Available data on female match-play indicates that the standard of competition influences physical performance with greater TD observed in European club football (10.7 km) (Bradley et al., 2014a) compared to friendly international competition (9.3 km) (Hewitt, Norton and Lyons, 2014). Furthermore, greater high-speed running (28 %) and sprinting (24 %) have also been observed in international match-play compared to domestic club matches (Krustrup et al., 2008). However, to date, no information utilising contemporary techniques exists on the demands of competitive international match-play, which represents the highest standard within the female game. Furthermore, due to the limited sample sizes available, the majority of studies examining the influence of playing position on match physical performance have been restricted to more generic assessments (e.g. defenders, midfielders and attackers) with only one study (Bradley et al., 2014a) further differentiating between central and wide positions. Bradley and colleagues (2014a) presented activity profiles for female match-play across five playing positions; however, the primary focus of their research was to compare male and female match-play and as such detailed female positional comparisons were lacking. Therefore, the aim of the current investigation was to provide a detailed analysis of the physical demands of different playing positions during competitive international female match-play.

4.2 METHODS

4.2.1 Experimental Approach to the Problem

To quantify the demands of competitive international female match-play, physical performance data were collected during the 2011-2012 and 2012-2013 seasons. Data were derived from ten matches, featuring thirteen teams playing in different stadiums across Europe.

4.2.2 Participants

A total of 167 individual match observations were undertaken on 122 players with a median of two matches per player (range = 1-4). Data were only included for those players completing entire matches (i.e. 90-min). Data were collected as a condition of employment in which player performance is routinely measured during match-play (Winter and Maughan, 2009). Therefore, usual appropriate ethics committee clearance was not required.

Nevertheless, to ensure team and player confidentiality, all physical performance data were anonymised before analysis. Permission to publish this data was granted by Prozone (Prozone Sports Ltd., Leeds, UK). As data were anonymised it was not possible to obtain descriptive information such as height and body mass for each player, nor was it possible to obtain details regarding the player's menstrual cycle and/or use of the OCP, which are acknowledged limitations.

4.2.3 Procedures

Match physical performance data were collected using a computerised semi-automated multi-camera image recognition system (Prozone Sports Ltd., Leeds, UK). This system provides valid (Di Salvo et al. 2006) and reliable (Di Salvo et al. 2009) estimations of a variety of match performance indices. A detailed description of the Prozone system can be found in the general methodology (Chapter 3). Players were categorised by playing position; GK (n = 19 match observations), CD (n = 35 match observations), WD (n = 34 match observations), CM (n = 40 match observations), WM (n = 20 match observations) and A (n = 19 match observations) to determine the influence of playing position on match physical performance. The influence of playing position on the difference in activity between the first and second half periods was undertaken. Within half changes in physical performance were also assessed by examining 15 and 5-min time periods.

The following activity classifications were used: TD, walking (0.7-7.1 $km.h^{-1}$), jogging (7.2-14.3 $km.h^{-1}$), running (14.4-19.7 $km.h^{-1}$), HSR (19.8-25.1 $km.h^{-1}$) and sprinting (>25.1 $km.h^{-1}$) distance. Total high-speed running (THSR) (>14.4 $km.h^{-1}$) and total very high-speed running (TVHSR) (>19.8 $km.h^{-1}$) were also computed (Bradley et al., 2009).

Total very high-speed running (>19.8 km.h^{-1}) was expressed as both TVHSR distance completed when the respective player's team were in possession (VHSRP) or were without possession (VHSRWP) of the ball. Further analysis of sprinting activity (>25.1 km.h^{-1}) was also considered, with the distance covered and the type of sprint classified. Sprints were classed as either explosive or leading sprints. An explosive sprint was defined as the attainment of sprint speed from standing, walking, jogging or running with time spent in the HSR category less than 0.5 s. Conversely, a leading sprint was defined as the attainment of sprint speed from standing, walking, jogging or running whilst entering the HSR category for a minimum of 0.5 s (Di Salvo et al., 2009).

4.2.4 Statistical Analysis

Data are presented as mean ± SD, to two significant digits (Hopkins et al., 2009). Data were analysed using factorial linear mixed modeling with playing position and time as fixed effects and a random intercept to account for the repeated measures nature of our design (Statistical Package for Social Sciences, Version 21). More detail regarding the statistical approach can be found in the general methodology (Chapter 3). Main effects were followed up with Bonferroni-corrected multiple contrasts. Then, using the mean difference, degrees of freedom and standard deviation derived from the linear mixed model, standardised mean differences (effect sizes) were calculated for the effect of playing position and time and subsequently classified as trivial (<0.20), small (>0.20-0.60), moderate (>0.60-1.20), large (>1.20-2.00) and very large (>2.00) (Hopkins et al., 2009).

4.3 RESULTS

4.3.1 Total Match Performance

Physical match-play characteristics per playing position, along with between playing position differences are shown in Tables 4.1 and 4.2. For the majority of physical match-play characteristics, the between playing position differences were generally very large between GK and outfield playing positions, large between CD and other outfield playing positions and moderate to trivial between all other playing positions. The physical match-play characteristics were similar between wide players (WD and WM) and A with generally small and trivial differences observed.

Very large differences were observed between GK and all outfield-playing positions for each activity classification (except walking). The magnitude of the between playing position differences highlighted that CD covered less TD than all outfield positions, with very large differences observed relative to CM, large differences observed relative to both WD and WM and moderate differences observed relative to A. Moderate differences for TD were also observed in CM compared to both WD and A. All other between outfield playing position differences for TD were small and trivial.

Central defenders covered less THSR than all other outfield playing positions, with very large differences observed compared to both CM and WM and large differences observed compared to both WD and A. Moderate differences for THSR were also observed in CM relative to both WD and A. All other between outfield playing position differences for THSR were small and trivial. Central defenders also covered less TVHSR than all other outfield playing positions, with very large differences observed compared to A and large differences observed compared to all other outfield playing positions. Moderate differences for TVHSR were also observed in CM relative to both WD and A. All other between outfield playing position differences for TVHSR were small and trivial.

Central defenders covered less VHSRP than all other outfield playing positions, with very large differences observed compared to both A and WM and large differences observed compared to both WD and CM. Attackers and WM completed more VHSRP than both WD and CM with large and moderate differences observed respectively. All other between outfield playing position differences for VHSRP were small and trivial.

Attackers covered less VHSRWP than all other outfield playing positions, with large differences observed compared to both CM and WD and moderate differences observed compared to both CD and WM. Moderate differences for VHSRWP were also observed in CM compared to both CD and WM. All other between outfield playing position differences for VHSRWP were small and trivial.

Table 4.1 Match physical performance data for elite female players per playing position, along with inferential statistics (effect size) for the between playing position differences (mean ± (SD)

	GK	CD	WD	CM	WM	A	All Outfield	Qualitative Inferences for all Contrasts
TD (m)	5094 (746)	9489 (562)	10250 (661)	10985 (706)	10623 (665)	10262 (798)	10321 (859)	**Very Large:** CM, WM, WD, A, CD v GK (**8.11, 7.83, 7.32, 6.69, 6.66**), CM v CD (**2.34**) **Large:** WM, WD v CD (**1.84, 1.24**) **Moderate:** A v CD (**1.12**), CM v WD (**1.07**), CM v A (**0.96**) **Small:** WM v WD (**0.56**), CM v WM (**0.52**), WM v A (**0.49**) **Trivial:** A v WD (**0.01**)
Walking (m)	3465 (420)	3401 (142)	3301 (190)	3224 (183)	3328 (182)	3449 (214)	3326 (194)	**Moderate:** A, CD, GK v CM (**1.13, 1.08, 0.74**), A v WD, WM (**0.73, 0.61**), CD v WD (**0.60**) **Small:** WM v CM (**0.57**), GK v WD (**0.50**), CD, GK v WM (**0.45, 0.42**), WD v CM (**0.41**), A v CD (**0.27**) **Trivial:** GK v CD (**0.21**), WM v WD (**0.15**), GK v A (**0.05**)
Jogging (m)	1276 (310)	4158 (457)	4382 (426)	4857 (451)	4488 (445)	4202 (606)	4448 (537)	**Very Large:** CM, WM, WD, CD, A v GK (**9.25, 8.38, 8.35, 7.38, 6.08**) **Large:** CM v CD, A (**1.54, 1.23**) **Moderate:** CM v WD, WM (**1.08, 0.82**) **Small:** WM v CD, A (**0.73, 0.54**), WD v CD, A (**0.51, 0.34**), WM v WD (**0.24**) **Trivial:** A v CD (**0.08**)
Running (m)	215 (87)	1367 (193)	1743 (293)	2029 (310)	1865 (324)	1714 (338)	1744 (373)	**Very Large:** CM, CD, WD, WM, A v GK (**7.96, 7.68, 7.06, 6.95, 6.08**), CM v CD (**2.56**) **Large:** WM, WD, A v CD (**1.86, 1.51, 1.26**) **Moderate:** CM v A, WD (**0.97, 0.95**) **Small:** CM v WM (**0.52**), WM v A, WD (**0.46, 0.39**) **Trivial:** WD v A (**0.09**)
HSR (m)	50 (31)	423 (79)	634 (168)	683 (170)	700 (167)	651 (135)	608 (181)	**Very Large:** CD, A, WM, CM, WD v GK (**6.20, 6.12, 5.41, 5.19, 4.83**), WM, A v CD (**2.12, 2.06**) **Large:** CM, WD v CD (**1.96, 1.60**) **Small:** WM v WD (**0.39**), A v WM (**0.32**), CM v WD, A (**0.29, 0.21**) **Trivial:** A v WD (**0.11**), WM v CM (**0.10**)
Sprinting (m)	9 (7)	111 (42)	163 (79)	170 (69)	220 (116)	221 (53)	168 (82)	**Very Large:** A, CD, CM, WD, WM v GK (**5.63, 3.35, 3.27, 2.75, 2.57**), A v CD (**2.30**) **Large:** WM v CD (**1.24**) **Moderate:** CM v CD (**1.02**), A v WD, CM (**0.88, 0.84**), WD v CD (**0.81**) **Small:** WM v WD, CM (**0.58, 0.52**) **Trivial:** CM v WD (**0.10**), A v WM (**0.02**)

Table 4.2 High-speed match physical performance data for elite female players per playing position, along with inferential statistics (effect size) for the between playing position differences (mean ± (SD)

	GK	CD	WD	CM	WM	A	All Outfield	Qualitative Inferences for all Contrasts
THSR (m)	274 (116)	1901 (268)	2540 (500)	2882 (500)	2785 (510)	2586 (463)	2520 (580)	**Very Large:** CD, CM, A, WM, WD v GK (**7.89, 7.18, 6.86, 6.79, 6.24**), CM, WM v CD (**2.44, 2.17**) **Large:** A, WD v CD (**1.81, 1.59**) **Moderate:** CM v WD, A (**0.68, 0.61**) **Small:** WM v WD, A (**0.49, 0.41**) **Trivial:** CM v WM (**0.19**), A v WD (**0.10**)
TVHSR (m)	59 (35)	534 (113)	796 (237)	853 (229)	920 (260)	872 (161)	776 (247)	**Very Large:** A, CD, CM, WM, WD v GK (**6.97, 5.70, 4.85, 4.64, 4.35**), A v CD (**2.43**) **Large:** WM, CM, WD v CD (**1.93, 1.77, 1.41**) **Small:** WM, A v WD (**0.50, 0.37**), WM v CM (**0.27**), CM v WD (**0.24**), WM v A (**0.22**) **Trivial:** A v CM (**0.10**)
VHSRP (m)	17 (14)	103 (48)	309 (161)	311 (197)	485 (195)	530 (127)	313 (210)	**Very Large:** A v GK, CD (**5.70, 4.46**), WM v GK, CD (**3.38, 2.69**), WD, CD, CM v GK (**2.55, 2.40, 2.11**) **Large:** WD v CD (**1.73**), A v WD (**1.53**), CM v CD (**1.46**), A v CM (**1.33**) **Moderate:** WM v WD, CM (**0.98, 0.89**) **Small:** A v WM (**0.28**) **Trivial:** CM v WD (**0.01**)
VHSRWP (m)	26 (16)	371 (100)	418 (120)	485 (163)	366 (116)	274 (114)	399 (143)	**Very Large:** CD, WD, WM, CM, A v GK (**4.83, 4.57, 4.11, 3.97, 3.05**) **Large:** CM, WD v A (**1.50, 1.23**) **Moderate:** CD v A (**0.90**), CM v CD, WM (**0.85, 0.84**), WM v A (**0.80**) **Small:** CM v WD (**0.47**), WD v WM (**0.44**), WD v CD (**0.43**) **Trivial:** CD v WM (**0.04**)
Explosive Sprints (%)	58 (41)	53 (10)	48 (9)	54 (10)	50 (14)	48 (8)	51 (10)	**Moderate:** CM v WD, A (**0.63, 0.61**) **Small:** CD v WD, A (**0.53, 0.48**), GK v WD, A (**0.34, 0.33**), CM, GK, CD v WM (**0.33, 0.26, 0.25**) **Trivial:** GK v CD (**0.17**), WM v WD, A (**0.17, 0.16**), GK v CM (**0.13**), CM v CD (**0.10**), A v WD (**0.01**)
Leading Sprints (%)	26 (34)	47 (10)	52 (9)	46 (10)	50 (14)	52 (8)	49 (10)	**Moderate:** A, WD, WM, CD, CM v GK (**1.05, 1.05, 0.92, 0.84, 0.80**), A, WD v CM (**0.66, 0.63**) **Small:** A, WD v CD (**0.55, 0.53**), WM v CM, CD (**0.33, 0.25**) **Trivial:** A, WD v WM (**0.18, 0.17**), CD v CM (**0.10**), WD v A (**0.00**)

Central midfielders completed a greater percentage of explosive sprints compared to WD and A, with moderate differences observed. All other between playing position differences for the percentage of explosive sprints were small and trivial. Goalkeepers completed a smaller percentage of leading sprints compared to all outfield positions, with moderate differences observed. Attackers and WD completed a greater percentage of leading sprints compared to CM with moderate differences observed. All other between playing position differences for the percentage of leading sprints were small and trivial. When comparing explosive and leading sprints within playing positions, it was observed that CM and GK completed a greater proportion of explosive than leading sprints, with moderate differences observed (ES 0.80-0.85).

The total number of sprints and frequency of different sprint distances per playing position, along with between playing position differences are shown in Figure 4.1. In general, as the sprint distance increased, the magnitude of between playing position differences reduced. Central defenders completed less sprints than all outfield positions with very large differences relative to A, large differences relative to midfielders (WM and CM) and moderate differences relative to WD. Moderate differences for the total number of sprints were also observed between A and WD, CM and WM and CM and WD. All other between outfield playing position differences for the total number of sprints were small and trivial.

Central defenders completed less very short sprints (<5 m) with very large differences observed compared to A, large differences compared to midfielders (WM and CM) and moderate differences compared to WD. Attackers also completed more <5 m sprints compared to WD with moderate differences observed. All other between outfield playing position differences for <5 m sprints were small and trivial. Attackers completed more 5-10 m sprints with large differences observed relative to CD and moderate differences observed relative to CM and WD. The magnitude of between playing position differences for 5-10 m also highlighted large differences between WM and CD and moderate differences between WD and CD. All other between outfield playing position differences for 5-10 m sprints were small and trivial. Attackers also completed more 10-15 m sprints with moderate differences relative to both CD and CM. All other between outfield playing position differences for 10-15 m sprints were small and trivial. The magnitude of between playing position differences for 15-20 m only highlighted small and trivial differences. Wide midfielders completed more >20 m sprints with moderate differences relative to WD, CM and CD. All other between outfield playing position differences for >20 m sprints were small and trivial.

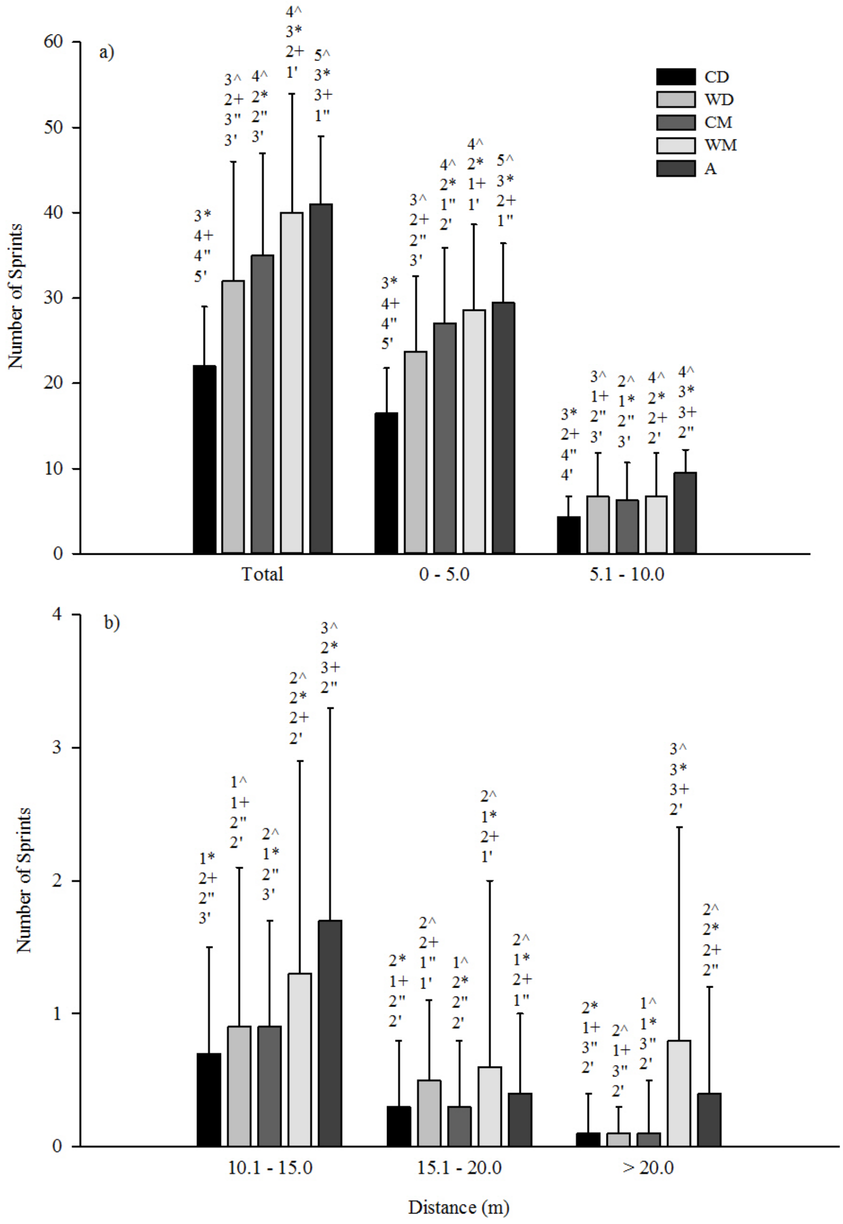

Figure 4.1 Total number of sprints and the number of sprints completed over different distances for elite female players per playing position, along with inferential statistics (effect size) for the between playing position differences (mean ± SD)

*^different from CD, *different from WD, +different from CM, "different from WW, 'different from A. Numbers denote magnitude of between playing position ES: 1=trivial (ES<0.20), 2=small (ES>0.20-0.60), 3=moderate ES (>0.60-1.20), 4=large ES (>1.20–2.00) and 5=very large ES (>2.00).*

4.3.2 Between Half Match Performance: Influence of Playing Position

Differences between first half and second half performance for TD, THSR, TVHSR and sprinting per playing position, along with between playing position differences are shown in Figure 4.2. When considering the sample as a whole, there were moderate reductions in TD (ES 0.80) and small reductions in THSR (ES 0.46), TVHSR (ES 0.35) and sprinting (ES 0.22) distances in the second half compared to the first. Large differences in TD were observed between halves for WM (ES 1.31) with moderate differences observed for all other outfield playing positions (ES: WD 1.08, CM 0.98, CD 0.94, A 0.75). Moderate differences in THSR (ES 0.64), TVHSR (ES 0.74) and sprinting (ES 0.78) distance between halves were observed in A, with moderate differences also observed for THSR in both WM (ES 0.73) and WD (ES 0.60). All other between half differences for THSR, TVHSR and sprinting were small and trivial.

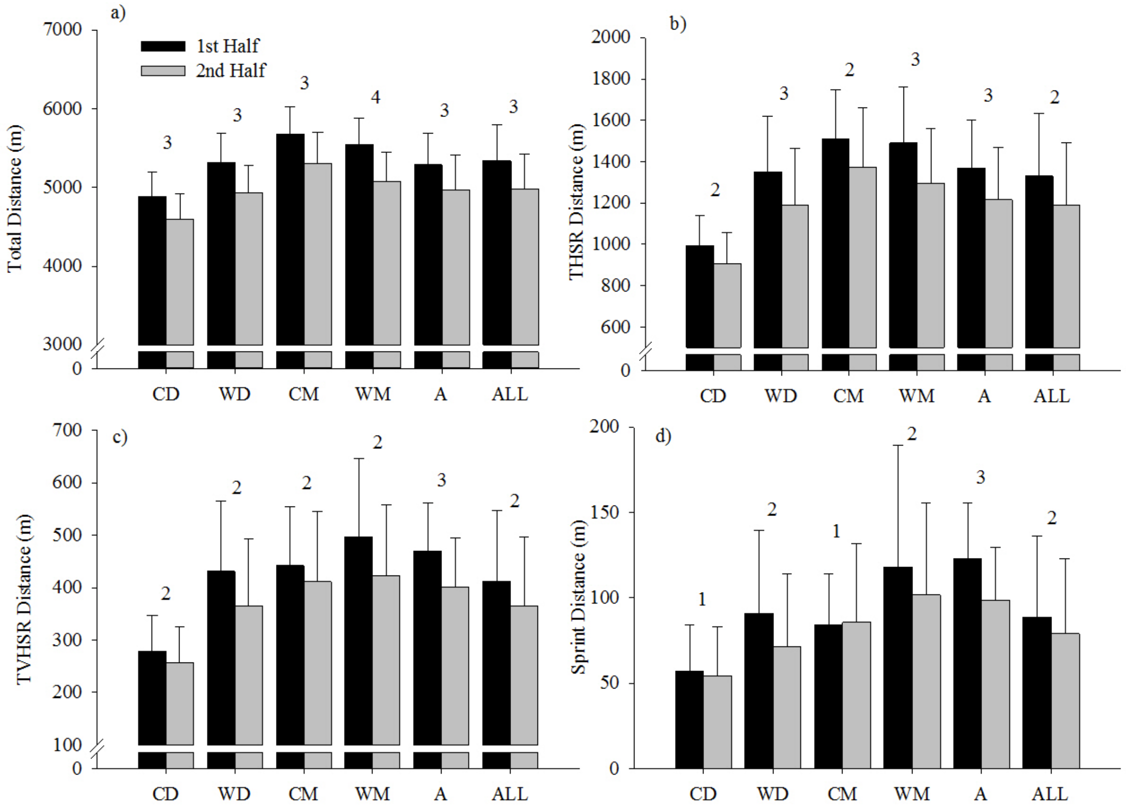

Figure 4.2 Between half differences in (a) TD, (b) THSR, (c) TVHSR and (d) sprinting distances for elite female players per playing position, along with inferential statistics (effect size) for the between half differences (mean ± SD)

Numbers denote magnitude of between half ES: 1=trivial (ES<0.20), 2=small (ES>0.20-0.60), 3=moderate ES (>0.60-1.20), 4=large ES (>1.20–2.00) and 5=very large ES (>2.00).

4.3.3 Within Half Match Performance (15-min intervals)

Differences between 15-min intervals for THSR, along with between 15-min interval differences are shown in Figure 4.3. Total high-speed running distance during the final 15-min period of the match was lower (12-35 %) compared to all other 15-min intervals, with moderate differences (ES 0.72-1.08) observed relative to all time points in the first half and small differences (ES 0.41-0.52) to all other time points in the second half. In both halves, THSR was lower in the final 15 minutes compared to the first and second 15-minute interval (1st half, ES 0.23-0.55; 2nd half, ES 0.41-0.72).

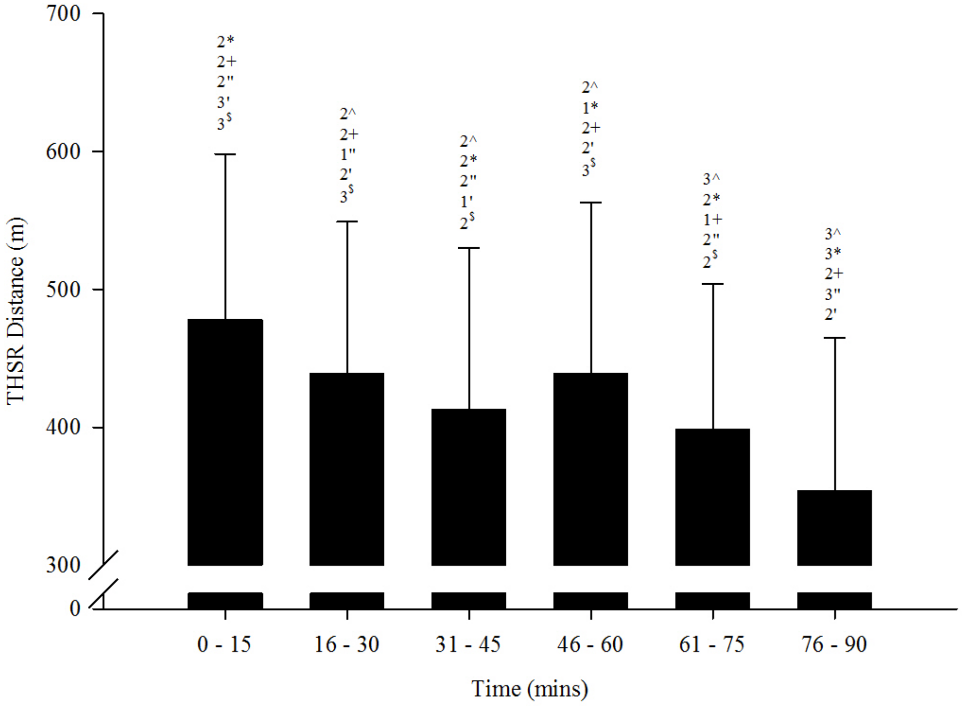

Figure 4.3 Within half differences in THSR for elite female players, along with inferential statistics (effect size) for within half differences (mean ± SD)

*^different from 0-15 mins, *different from 15-30 mins, +different from 30-45 mins, "different from 45-60 mins, 'different from 60-75 mins, $^{\$}$different from 75-90 mins. Numbers denote magnitude of within half ES: 1=trivial (ES<0.20), 2=small (ES>0.20-0.60), 3=moderate ES (>0.60-1.20), 4=large ES (>1.20–2.00) and 5=very large ES (>2.00).*

4.3.4 Within Half Match Performance (5-min intervals)

The peak THSR distance in a 5-min period was 223 ± 47 m. In the following 5-min period, the amount of THSR was 39 % lower (135 ± 47 m) with large differences observed (ES 1.87) but was not different to the mean distance covered during all 5-min intervals not including the peak distance (135 ± 32 m) (ES 0.00).

4.4 DISCUSSION

The present study represents the largest single analysis, based on sample size, of elite female match-play data to date and provides novel insights into the physical demands of different playing positions during competitive international match-play using contemporary techniques. The TD covered during competitive international match-play (10321 ± 859 m) is greater than previously observed in friendly internationals (9292 ± 175 m) (Hewitt, Norton and Lyons, 2014). The present data also highlights large differences in the physical demands of match-play between playing positions. Total distance and THSR were influenced by outfield playing position, with central midfielders completing the highest (10985 ± 706 m and 2882 ± 500 m) and central defenders (9489 ± 562 m and 1901 ± 268 m) the lowest distances, respectively. The number of high-speed efforts is lower (12-35 %) in the final 15-min period of the match compared to all other 15-min time periods. Collectively the current data provides physical coaches with new insights into the position-specific physical demands of competitive international match-play that will inform the design and implementation of training drills for elite female players.

The TD covered in this current investigation (10321 ± 859 m) is similar to values previously observed in European club football (10754 m) (Bradley et al., 2014a) and college soccer (9496-10297 m) (Vescovi and Favero, 2014) but appear greater than the TD reported during a small sample of international friendlies (9292-9631 m) (Hewitt, Norton and Lyons, 2014). This increase in TD covered during competitive international matches relative to international friendlies (Hewitt, Norton and Lyons, 2014) appears consistent across playing positions (defenders: 9864 v 8759 m, midfielders: 10864 v 10150 m, attackers: 10262 v 9442 m). Whilst some caution should be exercised when comparing data between studies which have utilised different data capture methods (Randers et al., 2010; Harley et al., 2011; Buchheit et al., 2014) and small sample sizes, the moderate to large ES suggests a higher overall physical demand of competitive versus friendly international match-play. This to some extent may simply reflect the greater importance associated with competitive matches.

Low-speed activity (walking and jogging) accounts for the majority (~85 %) of TD covered in elite females, during domestic-level matches (Krustrup et al., 2008; Mohr et al., 2008; Andersson et al., 2010a). However, it is high-speed activity that is widely regarded as an important component of match physical performance as these activities are often critical to the outcome of matches by directly impacting goal scoring opportunities (Mohr, Krustrup and Bangsbo, 2003; Di Salvo et al., 2009). Interestingly, in the current study, a distance of ~2520 m was covered at high-speed, accounting for 24 % of the TD. These observations suggest that a greater proportion of high-speed activity may be undertaken during competitive international football relative to domestic-level matches (Krustrup et al., 2008; Mohr et al., 2008; Andersson et al., 2010a). The findings from the current study indicate similar proportions (23 % in males and 24 % in females) of high-speed activity relative to TD when compared to male players (Bradley et al., 2009). As a consequence, a focus on high-intensity soccer-specific conditioning (Hoff et al., 2002; Kelly et al., 2013) should represent an integral component of the training methodology applied to the development of elite female players.

Previous investigations examining sprint activity in women's soccer are largely limited to the analysis of total sprint distance (Gabbett and Mulvey, 2008; Mohr et al., 2008; Hewitt, Norton and Lyons, 2014; Vescovi and Favero, 2014). The sprint distance covered in the current investigation (168 ± 82 m) was less (ES 1.25-4.89) than values previously observed (221-380 m) in elite players during domestic level matches (Mohr et al., 2008; Andersson et al., 2010a). Since greater THSR was observed in the present study relative to domestic level matches (Krustrup et al., 2008; Mohr et al., 2008; Andersson et al., 2010a), it is possible this increase largely reflects an increase in HSR activity rather than any changes in sprint activity. The present study is the first to provide a comprehensive analysis of both the range of sprint distances and types of sprints undertaken by elite female players. Sprint distances between 0-5 m and 0-10 m accounted for 76 % and 95 % of all sprints, respectively. Whilst female sprint data has not previously been presented in this format, average sprint distances of 15.1 ± 9.4 m have been observed in players from a professional league in the United States (Vescovi, 2012a). It is likely that this distance is greater than the average sprint distance in the current sample of players since 95 % of all sprints were shorter than 10 m. Alongside a high proportion of shorter sprints, the present data demonstrates an even distribution of explosive and leading sprints (51 ± 10 % v 49 ± 10 %). Interestingly, these findings suggest that women adopt a greater proportion of explosive sprints compared to males (77 % leading v 23 % explosive) (Di Salvo et al., 2010). This observation could reflect differences in how the game is played with females being more reactive to match-play events relative to males, or that males obtain the sprint threshold at a lower proportion of their maximum sprint velocity, however further work is needed in order to confirm this. Collectively, the present findings indicate that sprint training in elite female players should include a particular focus on sprinting over short distances (<10 m) with a combination of sprinting from a stationary and rolling start.

Understanding the physical demands of specific playing positions represents an integral component of training prescription. Due to the limited sample sizes employed in previous studies, the examination of playing position has largely been restricted to basic positional comparisons (e.g. defenders, midfielders and attackers) with only one study (Bradley et al., 2014a) further differentiating between central and wide positions. The present findings support previous research which has highlighted that midfielders cover greater TD (Andersson et al., 2010a; Hewitt, Norton and Lyons, 2014; Vescovi and Favero, 2014) and THSR (Andersson et al., 2010a; Hewitt, Norton and Lyons, 2014) than defenders. Large differences (ES 1.40) in TD were observed between defenders and midfielders in the present study. These positional differences are similar (ES 1.64) to those previously noted in international match-play (Andersson et al., 2010a) using video-based technology. However, larger differences (ES 2.68) have been noted between defenders and midfielders during domestic match-play (Andersson et al., 2010a), which may be a consequence of reduced tactical and physical demands of domestic relative to international match-play.

To the authors knowledge the current study is the first to examine the physical demands of specific defensive and midfield positions in competitive international female match-play. Numerous differences in the physical activity profiles between CD and WD and also CM and WM were observed. Specifically, CD completed less TD and THSR than all other outfield playing positions. The activity profile of CD is in contrast to WD, as they completed more TD, THSR and TVHSR than their central defensive counterparts. This confirms the need to analyse physical match performance across five playing positions. The findings from the current study, which highlight that CM cover the greatest TD and CD the least, are in accordance with previous data on European club football (Bradley et al., 2014a). The positional differences observed in the current study are similar to those reported in male match-play (Di Salvo et al., 2009; Bradley et al., 2013) and are likely to be a direct consequence of the tactical role of each playing position within the team. The high requirement of midfielders to cover distance to support attacking and defensive movements is accepted and thus their greater values of TD and THSR are to be expected.

It has previously been shown that attackers complete a greater sprint distance during match-play than defenders and midfielders (Gabbett and Mulvey, 2008; Mohr et al., 2008; Vescovi and Favero, 2014). This finding was in part corroborated in the present study with moderate to large ES shown for differences in sprinting distance between CD and other playing positions (CM (ES 1.02), WM (1.24) and A (ES 2.30)). There was a trend for WM and A to complete a greater number of short sprints (<15 m) than other positions with WM undertaking a greater number of longer sprints (>15 m). Differences in the percentage of sprint type were only highlighted in GK and CM who completed a higher proportion of explosive relative to leading sprints. The differences in sprinting profile between playing positions is again likely to be related to positional requirements in match-play. The tendency for a higher percentage of sprints undertaken by CM to be explosive and shorter in nature may reflect the tighter spaces within which they operate and the tactical role of these individuals as they attempt to counteract the movement of the opposition (Di Salvo et al., 2009). Conversely, the fact that attacking players (WM and A) complete more longer sprints may be a function of their need to complete fast movements away from defending players to generate space or to capitalise on goal scoring opportunities (Di Salvo et al., 2009). The majority of differences between positions were related to CD completing less actions and distances than other outfield playing positions across a number of the measured indices, which is most likely due to their predominant involvement being limited to defensive actions.

This finding highlights the importance of analysing positional subsets, i.e. CD versus WD not only for an understanding of match-play but also for the direct impact on training regimes.

A unique element of the current investigation was to differentiate high-speed activity with and without the ball, which enabled the effectiveness of high-speed efforts in relation to crucial match actions to be evaluated (Di Salvo et al., 2009). A small increase in the amount of TVHSR completed when a team was without possession of the ball was observed (399 ± 143 m v 313 ± 210 m, ES 0.48) as previously reported in male match-play (Di Salvo et al., 2009; Bradley et al., 2013). A link between TVHSR when out of possession and team success has been demonstrated in male match-play with less successful teams completing more VHSRWP (Di Salvo et al., 2009), this analysis was beyond the scope of our study but is a recommendation for future work. Despite an overall increase in TVHSR by the team when out of possession, the amount of TVHSR undertaken with or without possession was dependent upon playing position. Attacking positions (A, WM and CM) completed more TVHSR when the team was in possession with defensive players (CD and WD) completing more TVHSR when the team was without possession. These trends are similar to those previously reported in male match-play (Di Salvo et al., 2009; Bradley et al., 2013). The observed differences in high-speed activity when a team is with and without possession, particularly between different playing positions, provides important insights for physical coaches regarding the influence of styles of play and tactical formations on the physical demands of match-play. For example, activity that incorporates the ball has an increased energetic cost, rating of perceived exertion and blood lactate response (Reilly and Ball, 1984). Consequently, for attacking players it may be important from both a technical and physical perspective that these players undertake a greater proportion of their high-intensity training with the ball compared to more defensive players.

Previous research has used changes in physical performance both between halves and within each half as possible indicators of fatigue (Mohr, Krustrup and Bangsbo, 2005). Reductions in physical performance in the second half have frequently been observed with specific reference to TD, THSR (Mohr et al., 2008; Andersson et al., 2010a) and sprint distance (Mohr et al., 2008). In the present study, TD, THSR and sprint distances were reduced during the second half. The moderate reduction in TD (ES 0.80) between halves was greater than those reported in other studies; however, the small reductions in THSR (ES 0.46), TVHSR (ES 0.35) and sprinting (ES 0.22), respectively were similar to previous reports (Mohr et al., 2008; Andersson et al., 2010a; Hewitt, Norton and Lyons, 2014). Within-half decreases in THSR were also currently observed, with less THSR completed during the final 15-min of each half compared to the previous 15-min. There was also a 35 % reduction in THSR in the last 15-min of match-play compared to the first 15-min interval. This finding was similar to the 26 % reduction shown by Hewitt and colleagues (2014) but less than the 57 % reduction demonstrated by Mohr et al. (2008). These findings may suggest that in some instances elite female players may be unable to perform at the required speed for the duration of the match. A second half reduction in physical performance by females has previously been attributed in part to fatigue development and an insufficient training capacity of players (Krustrup et al., 2005; Mohr et al., 2008; Andersson et al., 2010a). However, due to a lack of data on the match outcome, tactics, fitness status of players or biochemical markers of fatigue it is difficult to provide a clear explanation for the transient changes in high-speed activity presently observed. Furthermore, little information is currently available regarding the variability of within-game physical performance measures and it is likely that differences in activity may be mediated to some extent by the inherent variation in a player's match physical performance that is associated with changes in the tactical and technical requirements of the game as opposed to fatigue (Gregson et al., 2010).

The current investigation reported a 39 % reduction in THSR from the most intense 5-min period to the next 5-min, which was in agreement but less substantial than previous studies (48-58 %) (Mohr et al., 2008; Andersson et al., 2010a). In contrast to earlier reports, the current study failed to demonstrate transient fatigue immediately after the most intense period of the match which is in agreement with other more recent findings (Bradley et al., 2014a). In the current study, the reductions in THSR both toward the end of the match and following intense activity were not as pronounced as studies that were conducted over 5 years ago. This smaller decrease in THSR may be a consequence of increased levels of professionalism and training status of female players in recent years; however, the issues of methodological differences and within game variability must also be considered. There were very few differences between positions for the changes in physical performance shown between halves, which is consistent with previous findings in females (Mohr et al., 2008).

4.5 SUMMARY

The present study provides a detailed examination of the physical demands of competitive international female match-play. Specifically, a number of differences were highlighted between wide and central midfield and defensive playing positions, which suggest that individual positional training drills should be adopted in order to aid specificity of training. The data suggests that sprints are generally <10 m in distance and are both explosive and leading in nature, consequently sprint-training drills should reflect these characteristics. The finding that attackers complete more high-speed activity when a team is in possession whilst defenders complete more high-speed activity when a team is out of possession provides important information for physical coaches preparing players. Reductions in physical performance are apparent between and within halves and although these may not be entirely attributed to fatigue it emphasises the importance of appropriate conditioning levels in order to maintain work rate.

CHAPTER 5

REPEATED HIGH-SPEED ACTIVITY OF ELITE FEMALE SOCCER PLAYERS DURING INTERNATIONAL COMPETITION

5.1 INTRODUCTION

High-speed running is often considered a critical component of soccer performance (Bradley et al., 2009; Di Salvo et al., 2009) since it underpins a number of movements required to win the ball and go past defenders (Stølen et al., 2005; Faude, Koch and Meyer, 2012). Total high-speed running has been shown to account for ~24 % of TD in international competitive female match-play (Chapter 4). Indeed, HSR also differentiates between standards of competition in male (Mohr, Krustrup and Bangsbo, 2003) and female players (Andersson et al., 2010a) and is sensitive to changes in both training status (Krustrup et al., 2003, 2005, 2006) and the tactical role of the player (Bradley et al., 2010; Di Mascio and Bradley, 2013; Chapter 4). A comprehensive understanding of high-speed activity is therefore necessary to inform both training prescription and performance assessment (Reilly, 2005).

The ability to produce consecutive high-speed actions interspersed with short recovery intervals, often referred to as repeated sprint activity (RSA), is considered an important performance parameter for high-intensity intermittent sports (Spencer et al., 2004; Gabbett and Mulvey, 2008). Previous work examining the physical demands of elite female match-play (Bradley et al., 2014a; Chapter 4) have demonstrated large differences between playing positions particularly between central and wide defensive and midfield positions. Whilst marked differences in RSA have been highlighted between playing positions in male players (Carling, Le Gall and Dupont, 2012; Schimpchen et al., 2016), small sample sizes (n = 13) used to date in those studies examining RSA in female players have restricted the depth of positional analysis (Gabbett and Mulvey, 2008; Gabbett, Wiig and Spencer, 2013). Such sample sizes largely reflect the fact that female matches are rarely played in stadiums equipped with the semi automated camera systems required to undertake such detailed analyses and/or the high financial costs associated with GPS technology (Datson et al., 2014).

The traditional criteria of RSA was a minimum of three sprints interspersed with a recovery duration of less than 21 s between sprints (Spencer et al., 2004). Recent studies in both males (Buchheit et al., 2010) and females (Gabbett, Wiig and Spencer, 2013) have expanded this traditional definition to include a minimum of two sprints in order to include all RSA (Gabbett, Wiig and Spencer, 2013). The velocity threshold associated with RSA has also been lowered in recent research (Carling, Le Gall and Dupont, 2012; Gabbett, Wiig and Spencer, 2013) to include repeated high-speed activity (RHSA) since HSR forms the majority of TVHSR during match-play (Bradley et al., 2009; Di Salvo et al., 2009, Chapter 4). The large inter-individual variation in sprinting speed (Abt and Lovell, 2009) and the fact that some players do not achieve maximum running velocity during match-play (Rampinini et al., 2007) necessitates the inclusion of RHSA in order to avoid the underestimation of repeated high-speed activity. Therefore, the aim of the current investigation was to provide a detailed analysis of RSA and RHSA profiles across different playing positions in a large sample of female soccer players during competitive international match-play.

5.2 METHODS

5.2.1 Experimental Approach to the Problem

To quantify the RSA and RHSA demands of competitive international female match-play, physical performance data were collected during the 2011-2012 and 2012-2013 seasons. Data were derived from ten matches, featuring thirteen teams playing in different stadiums across Europe.

5.2.2 Participants

A total of 148 individual match observations were undertaken on 107 outfield players (goalkeepers were excluded) with a median of two matches per player (range = 1-4). Data were only included for those players completing entire matches (i.e. 90-min). Data were collected as a condition of employment in which player performance is routinely measured during match-play (Winter and Maughan, 2009). Therefore, usual appropriate ethics committee clearance was not required. Nevertheless, to ensure team and player confidentiality, all physical performance data were anonymised before analysis. Permission to publish this data was granted by Prozone (Prozone Sports Ltd., Leeds, UK). As data were anonymised it was not possible to obtain descriptive information such as height and body mass for each player, nor was it possible to obtain details regarding the player's menstrual cycle and/or use of the OCP, which is an acknowledged limitation.

5.2.3 Procedures

A computerised semi-automated multi-camera image recognition system (Prozone Sports Ltd., Leeds, UK) was used to collect RSA and RHSA. This system provides valid (Di Salvo et al. 2006) and reliable (Di Salvo et al. 2009) estimations of a variety of match performance indices. A detailed description of the Prozone system can be found in the general methodology (Chapter 3). Players were categorised by playing position; CD (n = 35 match observations), WD (n = 34 match observations), CM (n = 40 match observations), WM (n = 20 match observations) and A (n = 19 match observations) to determine the influence of playing position on RSA and RHSA.

Repeated sprint activity was defined as a minimum of two sprints (>25.1 km.h^{-1}) with 20 s or less recovery between sprints and RHSA was defined as a minimum of two high-speed runs or sprints (>19.8 km.h^{-1}) with 20 s or less recovery between efforts (Gabbett, Wiig and Spencer, 2013). Very high-speed activity (VHSA) efforts were defined as those consisting of HSR or sprinting activity (>19.8 km.h^{-1}).

5.2.4 Statistical Analysis

Data are presented as mean ± SD, to two significant digits (Hopkins et al., 2009). Data were analysed using factorial linear mixed modeling with playing position and time as fixed effects and a random intercept to account for the repeated measures nature of our design (Statistical Package for Social Sciences, Version 21). More detail regarding the statistical approach can be found in the general methodology (Chapter 3). Main effects were followed up with Bonferroni-corrected multiple contrasts. Then, using the mean difference, degrees of freedom and standard deviation derived from the linear mixed model, standardised mean differences (effect sizes) were calculated for the effect of playing position and time and subsequently classified as trivial (<0.20), small (>0.20-0.60), moderate (>0.60-1.20), large (>1.20-2.00) and very large (>2.00) (Hopkins et al., 2009).

5.3 RESULTS

5.3.1 Recovery Duration Between VHSA Efforts

Recovery durations between VHSA efforts per playing position, along with between playing position differences are shown in Table 5.1. For the majority of recovery durations, there were very large and large differences between CD and other outfield playing positions.

The magnitude of the between playing position differences highlighted that CD had a longer mean recovery duration than all other outfield positions, with very large differences observed relative to both WM and CM and large differences observed relative to both A and WD. All other between outfield playing position differences for mean recovery duration were small and trivial. Large differences were also observed between CD and all other outfield playing positions for the frequency of recovery durations that were <10 s and 10-19 s. Moderate differences in the frequency of recovery durations 10-19 s were observed between WD and both CM and WM. All other between outfield playing differences for <10 s and 10-19 s were small and trivial.

The magnitude of the between playing position differences highlighted that CD had fewer recovery durations 10-29 s and 30-60 s with large differences observed relative to CM, WM and A, and moderate differences observed relative to WD. Moderate differences were also observed between WD and both CM and A for 20-29 s and between WM and WD for 30-60 s.

Table 5.1 Mean recovery duration and frequency of different recovery durations between VHSA efforts for elite female players per playing position, along with inferential statistics (effect size) for the between playing position differences (mean ± (SD)

	CD	WD	CM	WM	A	All Outfield	Qualitative Inferences for all Contrasts
Mean Duration (s)	54.1 (9.1)	40.1 (9.3)	35.5 (8.8)	35.1 (8.1)	37.6 (8.3)	41.2 (11.5)	**Very Large:** WM, CM v CD (**2.21, 2.08**) **Large:** A, WD v CD (**1.89, 1.52**) **Small:** WM, CM v WD (**0.57, 0.51**) WM v A (**0.30**), A v WD (**0.28**), CM v A (**0.25**) **Trivial:** WM v CM (**0.05**)
<10 s	32 (11)	54 (19)	65 (23)	64 (21)	56 (16)	53 (22)	**Large:** WM, CM, A, WD v CD (**1.91, 1.83, 1.75, 1.42**) **Small:** CM, WM v WD (**0.52, 0.50**), CM, WM v A (**0.45, 0.43**) **Trivial:** A v WD (**0.11**), CM v WM (**0.05**)
10-19 s	8 (3)	13 (6)	17 (6)	17 (6)	15 (6)	14 (7)	**Large:** CM, WM, A, WD v CD (**1.90, 1.90, 1.48, 1.05**) **Moderate:** CM, WM v WD (**0.67, 0.67**) **Small:** A v WD (**0.33**), CM, WM v A (**0.33, 0.33**) **Trivial:** CM v WM (**0.00**)
20-29 s	7 (3)	10 (5)	14 (5)	12 (5)	13 (4)	11 (5)	**Large:** CM, A, WM v CD (**1.70, 1.70, 1.21**) **Moderate:** CM v WD (**0.80**), WD v CD (**0.73**), A v WD (**0.66**) **Small:** WM v WD (**0.40**), CM v WM (**0.40**), CM v A (**0.22**), A v WM (**0.22**)
30-60 s	17 (5)	24 (7)	27 (8)	29 (7)	27 (8)	24 (8)	**Large:** WM, CM, A v CD (**1.97, 1.50, 1.50**) **Moderate:** WD v CD (**1.15**), WM v WD (**0.71**) **Small:** CM, A v WD (**0.40, 0.40**), WM v CM, A (**0.27, 0.27**) **Trivial:** CM v A (**0.00**)

5.3.2 Repeated High-Speed and Repeated Sprint Activity

5.3.2.1 Total Match Performance

The nature of RHSA bouts per playing position, along with between playing position differences are shown in Table 5.2. For the majority of measures, the greatest between playing position differences were between CD and other outfield playing positions.

The magnitude of the between playing position differences highlighted that CD completed fewer RHSA bouts than all other outfield positions, with very large differences observed relative to WM, CM and A and large differences observed relative to WD. Midfielders (WM and CM) completed more RHSA bouts than WD, with moderate differences observed. All other between outfield playing position differences for the number of RHSA bouts were small and trivial. The number of efforts per RHSA bout were lower in both CD and A compared to WD, WM and CM with moderate differences observed. The duration and distance of efforts per bout were generally less in CD relative to all other outfield playing positions with moderate differences observed.

Shorter durations between efforts within a RHSA bout were observed in CD compared to both CM and A, with moderate differences noted. However, longer durations between RHSA bouts were observed in CD compared to all other outfield playing positions, with large differences observed. Moderate differences were also observed for the duration between RHSA bouts between WD and WM.

Table 5.2 RHSA data for elite female players per playing position, along with inferential statistics (effect size) for the between playing position differences (mean ± SD)

	CD	WD	CM	WM	A	All	Qualitative Inferences for all Contrasts
Total number of bouts	22 (5)	33 (8)	38 (8)	40 (9)	37 (9)	33 (10)	**Very Large:** WM, CM, A v CD (**2.47, 2.40, 2.06**) **Large:** WD v CD (**1.65**) **Moderate:** WM, CM v WD (**0.82, 0.63**) **Small:** A v WD (**0.47**), WM v A, CM (**0.33, 0.23**) **Trivial:** CM v A (**0.12**)
Mean number of efforts per bout	2.7 (0.3)	3.0 (0.3)	3.0 (0.3)	3.0 (0.3)	2.8 (0.2)	2.9 (0.3)	**Moderate:** WD, CM, WM v CD (**1.00, 1.00, 1.00**), WD, CM, WM v A (**0.78, 0.78, 0.78**) **Small:** A v CD (**0.39**) **Trivial:** WD v CM, WM (**0.00, 0.00**), CM v WM (**0.00**)
Duration of efforts (s)	1.4 (0.5)	1.9 (0.5)	1.7 (0.4)	1.8 (0.6)	1.8 (0.3)	1.7 (0.5)	**Moderate:** WD, A, WM, CM v CD (**1.00, 0.97, 0.72, 0.66**) **Small:** WD, A v CM (**0.44, 0.28**), WD v A (**0.24**), WM v CM (**0.20**) **Trivial:** WD v WM (**0.18**), WM v A (**0.00**)
Distance per effort (m)	5.9 (1.0)	6.8 (0.9)	6.3 (0.9)	7.0 (1.5)	6.9 (0.7)	6.5 (1.1)	**Moderate:** A, WD, WM v CD (**1.16, 0.95, 0.86**), A v CM (**0.74**) **Small:** WM, WD v CM (**0.57, 0.56**), CM v CD (**0.42**) **Trivial:** WM, A v WD (**0.16, 0.12**), WM v A (**0.09**)
Duration between efforts (s)	5.6 (1.2)	6.1 (1.1)	6.3 (0.9)	6.0 (1.0)	6.3 (0.9)	6.1 (1.1)	**Moderate:** CD v CM, A (**0.66, 0.66**) **Small:** CD v WD, WM (**0.43, 0.36**), WM v CM, A (**0.32, 0.32**), WD v CM, A (**0.20, 0.20**) **Trivial:** WM v WD (**0.10**), CM v A (**0.00**)
Duration between bouts (s)	236 (62)	166 (52)	141 (40)	137 (42)	142 (35)	169 (62)	**Large:** A, WM, CM, WD v CD (**1.87, 1.87, 1.82. 1.22**) **Moderate:** WM v WD (**0.61**) **Small:** CM, A v WD (**0.54, 0.54**) **Trivial:** WM v A, CM (**0.13, 0.10**), CM v A (**0.03**)

The nature of RSA bouts per playing position, along with between playing position differences are shown in Table 5.3. The incidences of RSA were lower than RHSA with very large (ES 4.48) differences observed. Players completed an average of one RSA bout per match, with 37 % of players failing to complete any RSA bouts. The majority of between playing positions differences for RSA bouts were small and trivial with some incidences of moderate differences.

The magnitude of the between playing position differences highlighted that CD completed fewer RSA bouts than all other outfield positions, with moderate differences observed relative to WM, CM and A and small differences observed relative to WD. Wide defenders also completed fewer RSA bouts than CM, with moderate differences observed. All other between outfield playing position differences for the number of RSA bouts were small and trivial.

Table 5.3 RSA data for elite female players per playing position, along with inferential statistics (effect size) for the between playing position differences (mean ± SD)

	CD	WD	CM	WM	A	All Outfield	Qualitative Inferences for all Contrasts
Total number of bouts	0.6 (0.7)	0.9 (0.9)	1.6 (1.2)	1.4 (1.3)	1.4 (1.4)	1.1 (1.1)	**Moderate:** CM, WM, A v CD (**1.02, 0.77, 0.72**), CM v WD (**0.66**) **Small:** WM, A v WD (**0.45, 0.42**), WD v CD (**0.37**) **Trivial:** CM v WM, A (**0.16, 0.15**), WM v A (**0.00**)
Mean number of efforts per bout	2.1 (0.2)	2.1 (0.3)	2.0 (0.1)	2.1 (0.3)	2.1 (0.2)	2.1 (0.2)	**Moderate:** CD, A v CM (**0.63, 0.63**) **Small:** WD, WM v CM (**0.45, 0.45**) **Trivial:** CD, WD, WM v A (**0.00, 0.00, 0.00**), WD v WM, A (**0.00, 0.00**), WM v A (**0.00**)
Duration of efforts (s)	0.7 (0.2)	0.7 (0.2)	0.6 (0.2)	0.7 (0.2)	0.6 (0.1)	0.6 (0.2)	**Moderate:** CD, WD, WM v A (**0.63, 0.63, 0.63**) **Small:** CD, WD, WM v CM (**0.50, 0.50, 0.50**) **Trivial:** CD v WD, WM (**0.00, 0.00**), WD v WM (**0.00**), CM v A (**0.00**)
Distance per effort (m)	5.1 (1.4)	5.0 (1.4)	4.8 (1.4)	5.0 (1.2)	4.3 (0.6)	4.9 (1.3)	**Moderate:** CD, WM, WD v A (**0.74, 0.74, 0.65**) **Small:** CM v A (**0.46**), CD v CM (**0.21**) **Trivial:** WM, WD v CM (**0.15, 0.14**), CD v WM, WD (**0.08, 0.07**), WM v WD (**0.00**)
Duration between efforts (s)	4.0 (4.5)	4.9 (4.5)	4.1 (4.0)	4.1 (2.4)	2.2 (1.6)	4.0 (3.8)	**Moderate:** A v WM, WD (**0.93, 0.80**) **Small:** A v CM, CD (**0.62, 0.53**), WM, CD v WD (**0.22, 0.20**) **Trivial:** CM v WD (**0.19**), CD v WM, CM (**0.03, 0.02**), WM v CM (**0.00**)
Duration between bouts (s)		834 (544)	697 (564)	790 (822)	497 (351)	700 (547)	**Moderate:** A v WD (**0.74**) **Small:** A v WM, CM (**0.46, 0.43**), CM v WD (**0.25**) **Trivial**: CM v WM (**0.13**), WM v WD (**0.06**)

5.3.2.2 Between Half Match Performance: Influence of Playing Position

Differences between first half and second half performance for the characteristics of RHSA bouts per playing position, along with between playing position differences are shown in Figure 5.1. When considering the sample as a whole, there were small reductions in the number of RHSA bouts (ES 0.45) and the duration between RHSA bouts (ES 0.35) and trivial reductions in the number of efforts per RHSA bout (ES 0.01) and the duration between efforts within a RHSA bout (ES 0.18).

Moderate differences in the number of RHSA bouts were observed between halves for WM (ES 0.73), with small differences observed for all other outfield playing positions. Small and trivial differences were observed between halves for all outfield playing positions for both the number of efforts per RHSA bout and the duration between efforts within a RHSA bout. Moderate differences in the duration between RHSA bouts were observed between halves for A (ES 0.66), with small differences observed for all other outfield playing positions.

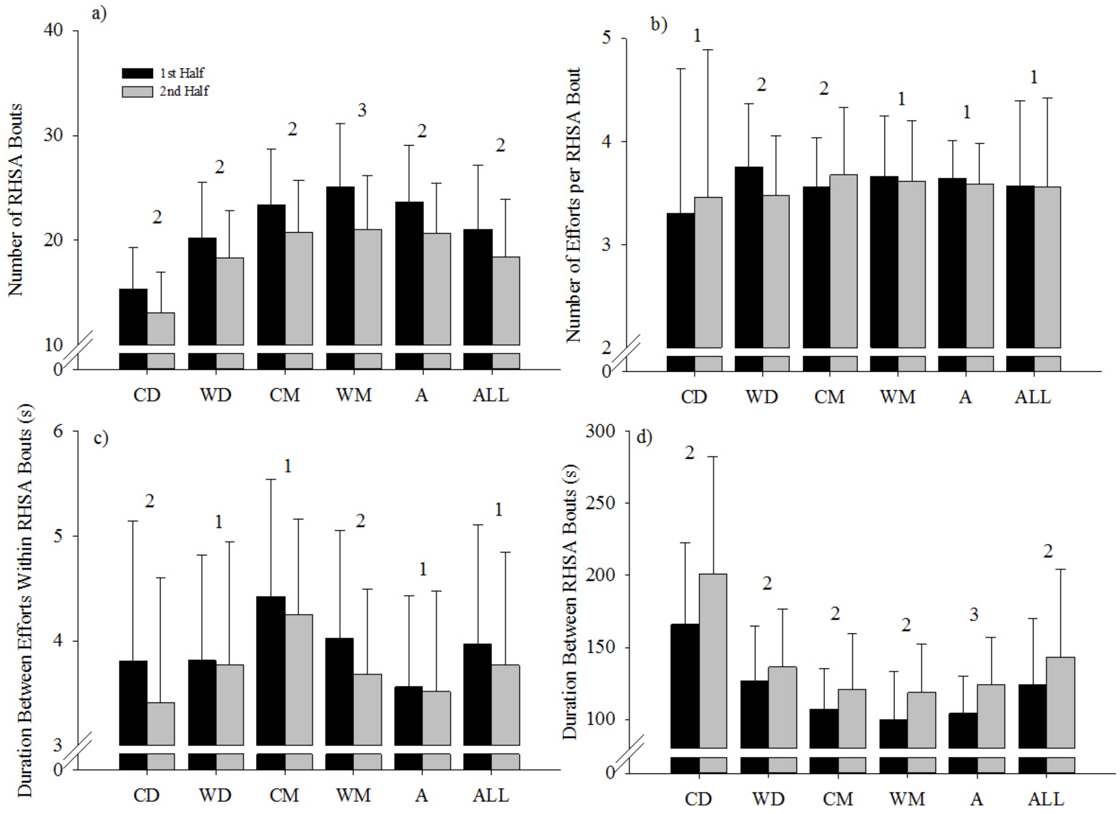

Figure 5.1 Between half differences in (a) number of RHSA bouts, (b) number of efforts per RHSA bout, (c) duration between efforts within RHSA bouts, (d) duration between RHSA bouts for elite female players per playing position, along with inferential statistics (effect size) for the between half differences (mean ± SD)

Numbers denote magnitude of between half ES: 1=trivial (ES<0.20), 2=small (ES>0.20-0.60), 3=moderate ES (>0.60-1.20)

5.3.2.3 Multiple Efforts

The characteristics of RHSA bouts consisting of multiple efforts, along with between RHSA types are shown in Table 5.4. Repeated high-speed activity bouts comprising two efforts were the most common, with very large differences observed compared to RHSA bouts with three or more efforts. Large differences were observed in the number of RHSA bouts comprising three and four efforts. Moderate differences were observed in the number of RHSA bouts comprising four efforts relative to those comprising both five and six bouts. All other differences between types of RHSA bouts were small and trivial.

The characteristics of RSA bouts consisting of multiple efforts, along with between RSA types are shown in Table 5.5. Repeated sprint activity bouts comprising two efforts were the most common, with moderate differences observed compared to RSA bouts with three or more efforts. Duration and distance of efforts remained unchanged as the number of efforts per RSA increased, with trivial differences observed. There was an increase in the duration between efforts as the number of efforts per RSA increased, with moderate differences observed.

Table 5.4 Characteristics of RHSA bouts consisting of 2, 3, 4, 5 or greater than 6 efforts for elite female players, along with inferential statistics (effect size) for the differences between RHSA types (mean ± SD)

	Number of Efforts					
	2	**3**	**4**	**5**	**6**	**Qualitative Inferences for all Contrasts**
Total number of bouts	16.7 (4.5)	8.4 (3.5)	4.1 (2.5)	2.0 (1.7)	1.8 (2.1)	**Very Large:** 2 v 5, 6, 4 (**4.32, 4.24, 3.46**), 3 v 5, 6 (**2.33, 2.29**), 2 v 3 (**2.06**) **Large:** 3 v 4 (**1.41**) **Moderate:** 4 v 6, 5 (**1.00, 0.98**) **Trivial:** 5 v 6 (**0.10**)
Duration of efforts (s)	0.9 (0.9)	1.0 (0.9)	0.9 (0.4)	0.9 (0.3)	0.9 (0.2)	**Small:** 3 v 5, 6, 4, 2 (**0.15, 0.15, 0.14, 0.11**) **Trivial:** 2 v 4, 5, 6 (**0.00, 0.00, 0.00**), 4 v 5, 6 (**0.00, 0.00**), 5 v 6 (**0.00**)
Distance per effort (m)	5.9 (3.5)	5.9 (2.8)	5.8 (2.4)	5.4 (1.9)	5.5 (1.7)	**Small:** 3 v 5 (**0.21**) **Trivial:** 2, 4 v 5 (**0.18, 0.18**), 3, 2, 4 v 6 (**0.17, 0.15, 0.14**), 6 v 5 (**0.06**), 3, 2 v 4 (**0.04, 0.03**), 2 v 3 (**0.00**)
Duration between efforts (s)	5.4 (5.4)	5.2 (3.9)	5.3 (3.2)	5.2 (2.8)	5.7 (2.6)	**Trivial:** 5, 3, 4, 2 v 6 (**0.19, 0.15, 0.14, 0.07**), 5, 3 v 2 (**0.05, 0.04**), 3, 5 v 4 (**0.03, 0.03**), 4 v 2 (**0.02**), 3 v 5 (**0.00**)
Duration between bouts (s)	144 (137)	138 (155)	135 (124)	137 (139)	117 (107)	**Small:** 6 v 2 (**0.22**) **Trivial:** 6 v 3, 4, 5 (**0.16, 0.16, 0.16**), 4, 5, 3 v 2 (**0.07, 0.05, 0.04**), 4 v 3, 5 (**0.02, 0.02**), 5 v 3 (**0.01**)

Table 5.5 Characteristics of RSA bouts consisting of 2, 3, 4, 5 or greater than 6 efforts for elite female players, along with inferential statistics (effect size) for the differences between RSA types (mean ± SD)

	Number of Efforts					
	2	**3**	**4**	**5**	**6**	**Qualitative Inferences for all Contrasts**
Total number of bouts	1.0 (1.1)	0.1 (0.3)				**Moderate:** 2 v 3 (**1.12**)
Duration of efforts (s)	0.7 (0.2)	0.7 (0.1)				**Trivial:** 2 v 3 (**0.00**)
Distance per effort (m)	4.9 (1.4)	4.9 (1.0)				**Trivial:** 2 v 3 (**0.00**)
Duration between efforts (s)	3.8 (3.9)	6.8 (4.5)				**Moderate:** 2 v 3 (**0.71**)
Duration between bouts (s)	702 (559)					

5.4 DISCUSSION

The present study is the first to apply contemporary techniques to provide a detailed analysis of repeated high-speed activity across different playing positions during competitive international female match-play. The present data highlights differences in the repeated high-speed demands between playing positions and the ability to perform these efforts is reduced across the duration of the match. Central defenders generally completed less RHSA bouts comprising shorter distance and duration efforts, relative to other playing positions. Collectively the current data provide physical coaches with new insights into the position specific demands of repeated high-speed activity, which will inform the design and implementation of training drills for elite players.

This study is the first to provide a detailed assessment of the duration between single VHSA efforts in female match-play. Mean duration between VHSA efforts (~41 s) was similar (ES 0.23) to those previously reported in domestic level female players (O'Donoghue, Minnis and Harty, 2004). However, it is challenging to draw comparisons to other studies describing high-speed activity in male players (Buchheit et al., 2010; Carling, Le Gall and Dupont, 2012; Schimpchen et al., 2016) due to methodological variances, notably differences in the minimum duration of VHSA. The mean duration between VHSA efforts in the current study was generally similar between playing positions with the exception of CD. The increased duration between efforts in CD is likely attributed to the reduced TVHSR distance covered in this position (Chapter 4) with subsequently fewer VHSA efforts increasing mean recovery duration between such efforts. In contrast to the present findings, previous studies have highlighted that midfielders demonstrate the longest durations between sprints (Vescovi, 2012a). These differences may be partly explained by the fact that previous studies used more generic position groups (Vescovi, 2012a) by combining CD and WD and CM and WM.

Positional differences were also currently observed across the different durations of recovery between VHSA efforts. Short duration recoveries (<20 s) were more common in CM and WM with longer recoveries (>60 s) more common in CD. These observations are similar to previous reports in male match-play (Carling, Le Gall and Dupont, 2012) and are likely a consequence of differences in the tactical requirements of each position. The role of the midfield player (CM and WM) is to support both attacking and defensive activities and therefore the duration between high-speed involvements is likely to be shorter than other positions, conversely CD's are predominantly only involved in defensive activities and therefore the requirements for high-speed activity may be interspersed with long recovery periods. An understanding of the duration between VHSA efforts is beneficial to physical coaches as this indicates work-to-rest ratios during match-play which can be translated to training prescription (O'Donoghue et al., 2005).

Previous work examining repeated high-speed activities in females have been undertaken using traditional video-based technology (Gabbett, Wiig and Spencer, 2013), which limits the depth of analysis possible. Furthermore, small sample sizes (n = 13) have been adopted and as such limited positional assessments have previously been possible. Large individual variation for RSA was observed in the current study, with some players (37 %) performing no RSA bouts and others up to five bouts per match. The number of RSA bouts for all players was low and was generally similar between positions. The only previous study (Gabbett, Wiig and Spencer, 2013) to analyse RSA in international female match-play reported a much higher (5 ± 5) frequency of RSA (ES 1.08), however, due to the qualitative criteria used during their assessment it is challenging to draw meaningful conclusions to the current study. Minimal differences in the nature of RSA were observed between playing positions, with the number, duration and distance of efforts within bouts remaining similar. The duration within and between efforts also remained fairly consistent between playing positions. It was not possible to calculate the duration between RSA bouts for CD, as no CD recorded multiple RSA bouts during either half of a match, thus highlighting the rarity of this event. The paucity of RSA bouts during female match-play questions the importance of RSA as a crucial component for elite female soccer a supposition recently supported by the work of Schimpchen and colleagues (2016).

Recent match-play studies (Buchheit et al., 2010; Carling, Le Gall and Dupont, 2012; Gabbett, Wiig and Spencer, 2013) have lowered the velocity threshold when analysing repeated activity and included HSR in order to avoid underestimation of repeated high-speed activity. The number of RHSA bouts in the present study was similar (ES 0.12) to those previously reported during international female match-play (Gabbett, Wiig and Spencer, 2013). This closer alignment between the current study and the work of Gabbett and colleagues (2013) for RHSA compared to RSA, may be explained by the difficulties of accurately distinguishing between the movement categories of striding and sprinting when using video-based time motion analysis (Spencer et al., 2005). Consequently, when these movement categories are combined (i.e. RHSA), fewer differences are noted between studies. Attacking-based players (A, WM and CM) completed more RHSA bouts than defensive players (CD and WD), with WM completing 76 % more bouts than CD. In contrast to RSA, the nature of RHSA bouts varied between playing positions; CD produced efforts that were shorter in duration and distance and fewer efforts per RHSA bout compared to other positions. These differences may be attributed to CD workload being largely limited to defensive actions, plus they operate in a relatively small area of the pitch and thus have reduced opportunities to produce high-speed efforts relative to other playing positions.

The traditional definition of RSA was introduced in field hockey and considered three or more sprints with a short recovery (≤21 s) between sprints (Spencer et al., 2004). This definition has since been applied to male (Carling, Le Gall and Dupont, 2012) and female soccer (Gabbett, 2010). However, use of this definition eliminates the consideration of consecutive efforts which may also be physically demanding (Gabbett, Wiig and Spencer, 2013) and as such some studies have opted to alter the traditional definition to include two or more sprints (Buchheit et al., 2010; Gabbett, Wiig and Spencer, 2013). The present study analysed repeated bouts based on the number of efforts per bout and observed that as the number of efforts per RSA and RHSA bout increased, the number of incidences decreased. This finding was similar to that previously reported by Gabbett and colleagues (2013) but the absolute values varied due to the differences in the methodology of data collection and analysis. No player completed RSA bouts of four or more sprints and very few RHSA bouts were completed with six or more efforts. These findings have direct implications for the employment of suitable training and testing protocols (Reilly, 2005). The results from this and other studies (Buchheit et al., 2010; Schimpchen et al., 2015) questions the validity of repeated speed tests which often employ sprints of 4-6 s which are repeated at least six times (Rhodes and Mosher, 1992; Polman et al., 2004; Impellizzeri et al., 2008; Mujika et al., 2009b; Gabbett, 2010). Interestingly, even as the number of efforts per RSA and RHSA bouts increased there were few differences in the duration between efforts and bouts. This finding was contradictory to previous research (Gabbett, Wiig and Spencer, 2013) which observed greater duration between efforts as the number of efforts per bout increased.

Changes in physical performance between and within halves have previously been used to indicate fatigue (Mohr, Krustrup and Bangsbo, 2005). Reductions in physical performance in the second half have frequently been observed with specific reference to TD, THSR (Mohr et al., 2008, Andersson et al., 2010a; Chapter 4) and sprint distance (Mohr et al., 2008; Chapter 4), however, limited information is available on VHSA and repeated VHSA. In the present study, reductions in the number of VHSA efforts and concomitant increases in the duration between VHSA efforts were observed in the second half. There were also small changes in the nature of RHSA bouts, with fewer instances and greater recovery durations in the second half relative to the first, which support previous results for female match-play data (Gabbett, Wiig and Spencer, 2013). These findings may indicate an inability to perform at the required speed for the duration of the match. A second half reduction in physical performance by females has previously been attributed in part to fatigue development and an insufficient training capacity of players (Krustrup et al., 2005; Mohr et al., 2008; Andersson et al., 2010a). However, due to a lack of data on the match outcome, tactics, fitness status of players or biochemical markers of fatigue it is difficult to provide a clear explanation for the transient changes in high-speed activity presently observed.

5.5 SUMMARY

The present study provides an overview of the position-specific repeated high-speed demands of competitive international female match-play. Repeated sprint activity is rare during match-play in elite female players consequently RHSA should be included to ensure the physical demands of match-play are not underestimated. Attacking-based players (A, WM and CM) complete more RHSA bouts than defensive players (CD and WD) with both RSA and RHSA frequently comprising two efforts per bout, with a maximum of three and six efforts respectively. Reductions in RHSA are apparent between halves and whilst these changes are unlikely to be solely mediated through fatigue, they emphasise the importance of appropriate conditioning levels in order to maintain work rate. Collectively, this information provides physical coaches with useful data for replicating the demands of repeated high-speed activity and an understanding of the positional demands in order to aid the specificity of training.

CHAPTER 6

EVALUATION OF FEMALE-SPECIFIC SPEED ZONES IN ELITE FEMALE SOCCER PLAYERS

6.1 INTRODUCTION

The previous experimental chapters have described in detail the physical demands of international female match-play and specifically RHSA. The findings from these studies have shown that THSR accounts for approximately 25 % of total distance covered and that players complete 33 bouts of RHSA per match. The frequency of TVHSR is lower, with such activity accounting for 8 % of total distance and players completing an average of one RSA bout per match (Chapters 4 and 5). The speed zones and associated activity classifications used in this thesis have previously been employed to quantify the physical demands of male match-play (Bradley et al., 2013; Di Salvo et al., 2013; Bush et al., 2015). These zones are standard settings within the Prozone system (Prozone Sports Ltd., Leeds, UK) and are not routinely changed in either applied research projects or in professional sport science support settings.

The use of standardised speed zones and generic data analysis approaches allow the collation of large datasets, which are commonplace within the male literature (Bradley et al., 2013; Di Salvo et al., 2013; Bradley et al., 2014a; Bush et al., 2015). These large datasets are necessary to minimise the influence of match-to-match variability on study outcomes and to detect real systematic changes in performance (Gregson et al., 2010). To date no match-to-match variability data is available for elite female match-play, however it is reasonable to assume that the activity profiles of this specific sub-group of players would be similar to those observed for males. Therefore, it would also seem essential to establish large datasets for elite female match-play data in an attempt to offset the likely match-to-match variability. As such, the use of player-independent speed zones may be necessary to allow the development of appropriate datasets thus ensuring an adequate sample size.

There are known physiological differences between males and females, with linear sprint times ~10 % lower (Haugen, Tønnessen and Seiler, 2012; Vescovi, 2012b; Haugen, Tønnessen and Seiler, 2013; Ingebrigtsen et al., 2014) and velocity at $VO_{2\ max}$ ~15 % lower (Castagna et al., 2006b; Sirotic and Coutts, 2007; Ingebrigtsen, Dillern and Shalfawi, 2011) in female players compared to males. Recent research has questioned the suitability of using the standard Prozone speed zones and activity classifications for analysing female match-play (Bradley et al., 2014a; Bradley and Vescovi, 2015) with recent attempts made to suggest female-specific speed zones (Bradley and Vescovi, 2015). These zones have however been derived from small sample sizes (n = 5-14) of non-elite players (domestic level) (Krustrup et al., 2005; Dwyer and Gabbett, 2012) and therefore may not be reflective of elite female players. As such it may be that the activity classifications derived from these suggested speed zones in female players (Bradley and Vescovi, 2015) might not be any more valid than the player-independent male zones commonly used. Furthermore, the standard speed zones frequently used in the Prozone system and commonly in research (Bradley et al., 2013; Di Salvo et al., 2013; Bush et al., 2015) do not appear to have been validated against movement speeds and therefore the activity classifications (e.g. walking, jogging, running, HSR and sprinting) may not actually be reflective of the activities that these speeds are supposed to relate for either male or female soccer players.

Determining speed zones is a complex task and currently no consensus exists on the most appropriate methodology (Weston et al., 2012; Carling, 2013; Lovell and Abt, 2013; Hunter et al., 2014). Data from laboratory-based continuous exercise protocols (Abt and Lovell, 2009), field-based fitness tests (Mendez-Villanueva et al., 2013) and maximum running speed (Buchheit et al., 2010) have all been cited as useful determinants for individualising speed zones. However, there are inherent advantages and disadvantages of each methodology

(Weston et al., 2012). Whilst the use of a single fitness characteristic, e.g. maximum running speed to determine speed zones has been criticised (Hunter et al., 2014), this methodology provides strong ecological validity, particularly if maximum running speed is obtained during match-play. In addition, if maximum running speed can be obtained from match-play data then the need for supplementary testing sessions is negated. Utilising percentages of a player's maximum running speed to determine activity classification categories has previously been applied to male players (Buchheit et al., 2010; Schimpchen et al., 2016). Furthermore, the use of maximum running speed to normalise speed zones for a specific population has also previously been employed (Harley et al., 2010). Harley and colleagues (2010) used maximum running speeds of youth players (U12-U16), to scale speed zones relative to those commonly applied to senior players, and as such a similar methodology could be deemed suitable for investigating female-specific speed zones. Therefore, the aim of the current investigation was to attempt to apply a suitable approach for determining speed zones and endeavour to evaluate the application of specific zones to influence data outcome.

6.2 METHODS

6.2.1 Experimental Approach to the Problem

This investigation attempted to determine maximum running speed during a sample of international female matches and field-based linear speed testing. The average maximum running speed in elite female players was then used to scale female-specific speed zones to the current standardised Prozone speed zones using the formula recently used by Harley et al. (2010).

6.2.2 Participants

A total of 230 individual match observations were undertaken on 67 national team senior outfield players (goalkeepers were excluded), with a median of three matches per player (range = 1-10). Data were collected during 19 international matches from 2011-2015. Data were only included for those players completing entire matches (i.e. 90 min). In addition, a total of 249 individual field-based fitness-testing observations were undertaken on 79 national team senior outfield players (goalkeepers were excluded), with a median of three testing occasions per player (range = 1-7). Data were collected during routine fitness testing from 2011-2015. Data were collected as a condition of employment in which player performance is routinely measured during match-play (Winter and Maughan, 2009). Therefore, usual appropriate ethics committee clearance was not required. Nevertheless, to ensure player confidentiality, all data were anonymised before analysis.

6.2.3 Procedures

Match physical performance data, including maximal running speed, were collected via 10Hz GPS units (STATSports, Viper, Ireland). GPS units were positioned between the scapulae in tight-fitting neoprene undergarments to reduce movement artefact. The number of satellites and the horizontal dilution of position, which is a reflection of the geometrical arrangement of satellites and is related to both the accuracy and the quality of the signal, were not collected, which is an acknowledged limitation. Data was processed using the software provided by the manufacturer (STATSports Viper 2.1.3.0) and was then exported in CSV format to custom designed Excel spreadsheets (Microsoft, Redmond, USA).

Maximum match running speed is one of the custom variables measured via the GPS system (STATSports Viper, Ireland) and therefore maximum running speeds were easily identified for each match observation (n = 230) using a custom designed Excel spreadsheet (Microsoft, Redmond, USA). The average maximum running speed for each individual player (n = 67) was then calculated as a mean of each player's maximum match-play running speeds.

Linear speed times of players were evaluated using electronic timing gates (Brower TC Timing System, USA) over distances of 0-30 m. Maximum running speed was defined as the fastest 10 m split time measured during a 30 m sprint. Each player completed an appropriate generic and speed-specific warm-up, prior to the completion of three maximal 30 m sprints. Each sprint was separated by a 3-min recovery period. Players commenced each sprint with either their right or left foot on a line 1 m behind the first timing gate. The fastest 10 m split time to the nearest 0.01 s was identified for each testing observation (n = 249) and then a mean for each player was calculated (n = 79). A detailed explanation of the linear speed protocol, including the specific warm-up activity, can be found in the general methodology (Chapter 3).

Maximum match-play running speed in both males and females is required in order to normalise speed zones between specific sub-groups, as per previous methodologies (Harley et al., 2010). It was beyond the scope of this study to determine male match-play running speed using primary methods and therefore a literature search was undertaken. A search of Pubmed and Google Scholar was performed using a combination of the following terms: "soccer", "football", "match-play", "sprint", "velocity", "match analysis" and "physical performance" to identify articles that reported maximum running speed in elite male match-play and three articles were identified that satisfied the inclusion criteria.

Once maximum match-play running speeds were established, female-specific speed zones were calculated and scaled relative to standard Prozone speed zones. This process ensured that the associated activity classifications were derived relative to a gender-specific maximum running speed. This methodology required a two-step calculation process; firstly, the maximum female match-play running speed was compared to the maximum male match-play running speed and secondly, the female to male maximum speed ratio was multiplied by the standard Prozone speed zone. Thus resulting in a new zone normalised for female maximum running speed. The formula and a worked example are shown overleaf (Harley et al., 2010):

New zone = (maximum female speed/maximum male speed) x standard Prozone zone

For example, if maximum female-match play speed was 27 km.h^{-1} and maximum male match-play speed was 30 km.h^{-1}, then the calculation for HSR, which is normally 19.8 km.h^{-1} would be: 27/30 x 19.8 = 17.8 km.h^{-1}.

6.3 RESULTS

The maximum running speed in elite female match-play, as measured via GPS, was 26.8 ± 1.6 km.h^{-1} (range = 22.9-30.1 km.h^{-1}). The maximum running speed during field-based testing, using the fastest 10 m split time, was 27.8 ± 1.3 km.h^{-1} (range = 24.8-30.2 km.h^{-1}). Thus, players achieved 96 % of their maximum running speed during match-play. It was observed that 87 % of players achieved the Prozone sprinting threshold (>25.1 km.h^{-1}) during match-play, whereas 13 % did not (n = 9 players).

A value for maximum running speed in males was required in order to scale female-specific zones relative to their male counterparts. The literature search yielded three reports of maximum running speed in elite male match-play with an average of 30.6 ± 2.9 km.h^{-1} reported (Bradley et al., 2010; Di Mascio and Bradley, 2013; Schimpchen et al., 2016). This value of maximum running speed in male match-play was used in the calculations of the female-specific zones as per the formula previously described (Harley et al., 2010).

The calculated female specific speed zones computed as per Harley et al. (2010) are shown in Table 6.1. Due to the lower (~3.8 km.h^{-1}) maximum match-play running speed in females compared to males, all the resultant speed zones are lower for females than the standardised Prozone speed zones.

Table 6.1 Standard Prozone zones and calculated female-specific speed zones, derived relative to maximum match-play running speeds (Harley et al., 2010)

	Speed Zones (km.h^{-1})				
	Walking	Jogging	Running	HSR	Sprinting
Standard Prozone Zones	0.7-7.1	7.2-14.3	14.4-19.7	19.8-25.1	>25.1
Calculated Female Zones	0.6-6.2	6.3-12.5	12.6-17.2	17.3-22.0	>22.0

6.4 DISCUSSION

The aims of the current study were to attempt to apply a suitable approach for determining female speed zones and endeavour to evaluate the application of these calculated female-specific zones to influence the data associated with HSR and sprinting in games. A difference of ~3.8 km.h^{-1} was reported between male and female maximum match-play running speed which resulted in a lower velocity for each activity classification in females. The average difference in the lower threshold between male and female speed zones was 12.5 %, which if applied to the data in Chapter 4 would result in small increases in THSR (25 % to 28 %) and TVHSR (8 % to 9 %) relative to TD.

The average maximum female match-play running speed of 26.8 ± 1.6 km.h^{-1} demonstrates that elite female players are generally capable of achieving the standardised Prozone sprinting threshold (>25.1 km.h-^{1}). However, 9 individual players, which represents 13 % of the sample did not achieve the threshold of 25.1 km.h^{-1} in the matches analysed. Interestingly, the failure of these players to achieve the threshold does not appear related to an inability to run at such speeds, as field-based fitness testing data for these individuals, indicated maximum running speeds in excess of 25.1 km.h^{-1}. It would seem that the nature of the activity completed in match-play did not require these individuals to reach maximum speed. The playing positions of these 9 players were; CD (n = 4), CM (n = 3) and A (n = 2) and consequently their failure to achieve the Prozone sprinting threshold during match-play may in part be related to the nature of their tactical role, as these positions are often required to operate in tighter spaces compared to WM and WD (Di Salvo et al., 2009).

Despite the majority of players (87 %) in the present study achieving the Prozone sprinting threshold of 25.1 km.h^{-1} during match-play, it should be noted that such a value represents 94 % of the average maximum female match-play running speed observed in the present study. Consequently, female players would need to be running at a speed close to their maximum for such movement to be classified as sprinting, which may result in some sprinting activity not being classified in this zone. However, application of the calculated female-specific sprinting threshold (22.0 km.h^{-1}) to the match-play data reveals that all players achieved this lower sprinting threshold. Furthermore, the female-specific sprinting threshold represents 82 % of the average maximum female match-play running speed observed in the present study. It seems reasonable to suggest that the standardised Prozone sprinting threshold (>25.1 km.h^{-1}) may not entirely reflect the sprinting speeds of elite female players, due to its proximity to maximum running speed and consequently there may have been an underestimation of sprinting activity in Chapters 4 and 5. Despite this acknowledgement, it is difficult to determine whether either the sprinting threshold proposed in the current study (>22.0 km.h^{-1}) or indeed other recent suggestions (>20.0 km.h^{-1}) (Bradley and Vescovi, 2015) are more closely aligned to the movement speeds associated with sprinting in elite female players. However, as the previously proposed sprinting threshold of >20.0 km.h^{-1} (Bradley and Vescovi, 2015) was based on domestic-level players (Vescovi, 2012b) and small sample sizes (n = 5) (Dwyer and Gabbett, 2012), it might be suggested that the threshold in the current study is more robust and suitable for evaluating physical match-play in elite female players.

One of the primary aims of this thesis is to evaluate between playing position differences for physical match-play characteristics and as a result to provide practitioners with pertinent information to enable the design and delivery of suitable position-specific training drills. Whilst some authors advocate the use of individualised speed zones for evaluating physical match-play (Abt and Lovell, 2009; Lovell and Abt, 2013; Hunter et al., 2014), the use of player-independent speed zones, such as the standardised Prozone zones, are deemed suitable for determining the external load on players and consequently are useful for evaluating differences between playing positions (Hunter et al., 2014). Consequently, even if the standardised Prozone speed zones utilised in Chapters 4 and 5 are not wholly representative of the associated activity classifications they do however permit between playing position and gender comparisons. For example, the data provided in Chapter 4 highlights that CM cover more distance > 14.4 $km.h^{-1}$ and > 19.8 $km.h^{-1}$ than CD, which provides relevant information for physical performance staff. Whilst caution may need to be exercised when assigning activity classifications to speed zones, the between playing position comparisons are still permissible.

No consensus currently exists on the most appropriate methodology for determining speed zones (Weston et al., 2012; Carling, 2013; Lovell and Abt, 2013; Hunter et al., 2014). The methodology of utilising maximal running speed to calculate speed zones has previously been criticised due to questions regarding the obtainment of an accurate maximum running speed (Young et al., 2008) and the classification, description and justification of different zones (Weston et al., 2012). The present study utilised maximum match-play running speed to propose thresholds, as opposed to those derived from field-based fitness testing in an attempt to increase the ecological validity of the dataset. Despite this, the calculated female-specific zones were still scaled relative to standard Prozone zones, and due to a lack of validation against movement speeds, questions pertain as to the suitability of the associated activity classifications. It should also be noted that different data collection methods were used to obtain maximum match-play running speeds in females and males; with GPS used in females (present study) and semi-automated camera systems in males (Bradley et al., 2010; Di Mascio and Bradley, 2013; Schimpchen et al., 2016), which is an acknowledged limitation. It is suggested that if maximum running speed is to be used to help determine speed zones then further work is required to ensure more robust justification of the activity classifications (relative to maximum running speed) and description of such zones. However, it should also be stated that a move towards player-dependent or population-dependent speed zones may reduce the ability to compare and collate data and produce the necessary large datasets to minimise the influence of match-to-match variability.

6.5 SUMMARY

The present study provides an attempt to apply a suitable approach for determining speed zones and to evaluate the application of female-specific zones to influence data outcome. The current investigation determined that maximum match-play running speeds are lower in females than males. As a consequence, when speed zones are scaled relative to maximum running speed, lower thresholds are computed for females compared to males. Whilst the adoption of lower thresholds for female match activity would result in increased distance covered at higher speed zones, it is not possible to suggest from the current dataset whether such female-specific speed zones are any more valid than the current standardised Prozone zones or previous suggestions of female-specific zones (Bradley and Vescovi, 2015).

Consequently, until further validation work is completed, our suggestion is that female match-play data should continue to be analysed using standardised Prozone zones as this permits between playing positions and gender comparisons. However, the activity classifications (e.g. walking, jogging, running, HSR and sprinting) should be removed, as they may not be representative of their associated speed zones, and replaced with the velocity threshold (e.g. 0.7-7.1 km.h^{-1}, 7.2-14.3 km.h^{-1}, 14.4-19.7 km.h^{-1}, 19.8-25.1 km.h^{-1} and >25.1 km.h^{-1}).

CHAPTER 7

RELIABILITY OF ANTHROPOMETRIC AND PERFORMANCE MEASURES IN ELITE FEMALE SOCCER PLAYERS

This study was presented at the World Conference on Science and Soccer

(Portland, USA, June 2014)

7.1 INTRODUCTION

Physiological assessments and performance testing are an established component of an elite soccer player's development programme and are considered important by coaches, fitness professionals and players at national and international level (Hulse et al., 2013; Manson, Brughelli and Harris, 2014). Undertaking such testing protocols enables objective information to be gleaned, which has numerous applications including: talent identification (Hoare and Warr, 2000; Reilly et al., 2000), training monitoring (Buchheit et al., 2012), evaluation of the efficacy of training interventions (Clark, 2010) and identification of individual player's strengths and weaknesses (Svensson and Drust, 2005).

Despite the widespread use of physical testing by researchers and practitioners the critical issues of validity and reliability can often be overlooked (Pyne, Spencer and Mujika, 2014). The reliability of a measurement tool refers to an acceptable level of agreement between repeated tests within a practically relevant timeframe (Atkinson and Nevill, 1998). Factors that influence reliability include any systematic or random changes in the mental or physical state of the individual between trials. The protocol and measurement device used to collect the data may also contribute to the variability of the measurements. A test with poor reliability will be unsuitable for tracking changes in the fitness status of the athlete (Hopkins, 2000)

The use of field based methods to evaluate performance characteristics in soccer are often preferred to laboratory tests as they are thought to enhance the specificity of the evaluation (Svensson and Drust, 2005) and large numbers of players can be tested simultaneously thereby minimising prohibitive costs (Hulse et al., 2013). The reliability of soccer specific field based tests have previously been assessed in males (Impellizzeri et al., 2008; Mirkov et al., 2008; Bradley et al., 2011b; Buchheit and Mendez-Villanueva, 2013; Hulse et al., 2013). To date, limited assessment of the reliability of performance measures in senior female and youth players has been undertaken (Castagna et al., 2010; Gabbett, 2010). Furthermore, these studies have largely focused on specific elements of physical fitness such as maximal aerobic power (Castagna et al., 2010) or repeated sprint ability (Gabbett, 2010) as opposed to a comprehensive field test battery which examines the multitude of physical capacities required within the game (Hulse et al., 2013). Consequently, the aim of the present study was to determine the reliability of a range of anthropometric and field-based performance tests in a group of junior and elite female soccer players. These estimates can then be used to predict sample size requirements in future studies designed to track the fitness status of elite female soccer players and/or to quantify the effects of any intervention.

7.2 METHODS

7.2.1 Experimental Approach to the Problem

To assess the reliability of a range of anthropometric and field-based performance tests in a group of junior and senior elite female soccer players, data were collected from 140 national team players. Anthropometric and performance tests were measured on two separate occasions separated by seven days. Prior to assessment, all players had previously completed each test on at least one previous occasion. All performance tests were performed on third generation turf (indoor arena) and players wore shorts, t-shirt and football boots (except for the jumps when trainers were worn). Players performed a standardised warm-up prior to commencing the physical assessments (Chapter 3). All performance tests were completed at approximately the same time of day to reduce any circadian rhythm effect (Reilly and Brooks, 1986). Tests were completed in a single session and in the same order (anthropometry, jumps, speed, repeated speed and YYIR1) on each test occasion. The test order was designed in an attempt to minimise the influence of previous tests on subsequent performance. Participants were instructed to refrain from strenuous exercise in the 24 hours before the fitness testing session and to consume their normal pre-training diet. To encourage maximal effort, players received verbal encouragement throughout the performance tests.

7.2.2 Participants

A total of 140 international female soccer players participated in the study (Table 7.1). All participants had previously completed the experimental procedures on at least one previous occasion. The associated risks were explained to participants and written informed consent to participate was obtained from either themselves or their parent or guardian. Ethical approval was obtained from the researcher's university ethics committee. Details regarding the player's menstrual cycle and/or use of the OCP were not recorded, which is an acknowledged limitation.

Table 7.1 Age (mean ± SD) of participants and sample sizes for each testing group

Age Group	Participants (n)	Age (years)
Seniors	40	24.7 ± 4.0
U19s	20	18.2 ± 0.9
U17s	20	16.4 ± 0.2
U15s	60	14.1 ± 0.5

7.2.3 Procedures

A detailed explanation of the protocols for all anthropometric and performance measures, including specific warm-up activities, can be found in the general methodology (Chapter 3). The information below provides an overview of the protocols for each anthropometric and performance measure.

7.2.3.1 Anthropometric Measures

The height (m) and body mass (kg) of each player was measured using a stadiometer (Seca 217, Germany) and calibrated digital scales (Seca 876, Germany) respectively. Skinfolds (mm) were taken as an estimate of adiposity and were measured at eight sites: biceps, triceps, subscapular, iliac crest, supraspinale, abdominals, front thigh and medial calf using skinfold calipers (Harpenden, UK). An International Society for the Advancement of Kinanthropometry (ISAK) accredited anthropometrist performed all measurements and ISAK guidelines were followed (Jones et al., 2006).

7.2.3.2 Performance Measures

Countermovement Jump (without arms)

An estimation of a player's lower limb muscular power was assessed via a CMJ on a jump mat (KMS Innervations, Australia). Following a jump-specific warm-up, the player started from an upright position, with feet placed in the middle of the jump mat and hands on hips. The player was instructed to jump as high as possible whilst keeping their hands on their hips. Players were permitted one practice attempt before performing three recorded trials. The highest jump height recorded to the nearest 0.1 cm was used as the criterion measure of performance.

Linear Speed

Linear speed times of players were evaluated using electronic timing gates (Brower TC Timing System, USA) over distances of 0-30 m. Following a speed-specific warm-up, each player completed one practice sprint, prior to the completion of three maximal 30 m sprints. Each sprint was separated by a 3-min recovery period. Players commenced each sprint with either their right or left foot on a line 1 m behind the first timing gate. The fastest time at each distance to the nearest 0.001 s was used as the criterion measure of performance.

Repeated Speed

Repeated speed times of players to complete 30 m sprints was evaluated using electronic timing gates (Brower TC Timing System, USA) during a repeated sprint course. Each player completed 7 x 30 m sprints with a 30 s recovery between sprints. Players commenced each sprint with either their right or left foot on a line 1 m behind the first timing gate. The mean of the seven sprint times to the nearest 0.01 s was used as the criterion measure of performance.

Yo-Yo Intermittent Recovery Test Level 1

To estimate high-intensity endurance capacity each player performed YYIR1 which involved a series of repeated 20 m shuttle runs with progressively increasing running speed (10-19 $km.h^{-1}$), interspersed with 10 s rest intervals (Krustrup et al., 2003). The running speed was determined by an official audio track, which required players to start, stop and turn on each ‘bleep’. When a player failed to make a turn on the ‘bleep’ they were issued with a warning, after two consecutive warnings the player was withdrawn from the test and the level was recorded in metres to the nearest 20 m shuttle.

7.2.4 Statistical Analysis

Altman (1991) advised that approximately 40 participants should be recruited for an agreement-type study like ours in order to ensure appropriate precision of sample agreement statistics (Altman, 1991). Although, our final sample size of 20 participants in two of our age groups (U17 and U19) is smaller than this number, we have reported confidence intervals for the reliability statistics, which are useful for ascertaining if the precision of estimate affects substantially the inferences that are arrived at.

The mean (SD) systematic bias (and associated 95 % confidence interval) between test and retest was first quantified using a paired t-test. Random error between repeated tests was quantified with the within-subjects SD (standard error of measurement (SEM)) and CV.

The test-retest CV was then used as an input in statistical power calculations to estimate whether the random measurement error would be small enough to detect a clinically/practically relevant change in measured outcome with a feasible sample size in a future study (Batterham and Atkinson, 2005). In an attempt to derive an indication of the minimum practically important difference (MPID), a realistic approach (Cook et al., 2014) was taken based upon a scoping review of observed changes in the measured outcome that have been reported in the literature on team sports. The inclusion criteria were interventional studies using female soccer players as the sample. Due to the limited data available, all age groups and competitive levels of female soccer players were included. Both the smallest change and the average of all observed changes in the measured outcome were used for the MPID in the statistical power calculations.

7.3 RESULTS

Tables 7.2-7.4 show the anthropometric and performance measures during the two trials. Height ($p = 0.07$-0.67), body mass ($p = 0.51$-1.00), sum of skinfolds ($p = 0.13$-0.96), 5 m ($p = 0.18$-0.91), 10 m ($p = 0.11$-0.36), 20 m ($p = 0.29$-0.73), 30 m ($p = 0.16$-0.36), CMJ ($p = 0.32$-0.95), repeated speed ($p = 0.07$-0.78) and YYIR1 ($p = 0.22$-1.00) were not significantly different between trials.

The SEM for each anthropometric and performance measure across trials 1 to 2 are shown in Table 7.2. The SEM for sum of skinfolds ranged from 0.78-1.19 mm and when expressed as a CV (percentage of the mean) values of 0.9-1.3 % were observed. The SEM and CV for linear speed and repeated speed tests were 0.02-0.07 s, 0.6-2.4 % and 0.06-0.11 s and 1.2-2.2 %, respectively. The SEM and CV for CMJ were 0.86-1.22 cm and 2.9-4.6 %, respectively. The largest CV (3.8-7.7 %) was found for YYIR1 with a SEM of 65.66-95.65 m.

Table 7.2 Reliability measures (95 % CI) for anthropometric data (mean ± SD) during two separate trials (n = 20-60)

		Trial 1	Trial 2	p value	SEM (95 % CI)	% CV (95 % CI)
Height (m)	**Seniors**	1.673 ± 0.070	1.672 ± 0.070	0.188	0.18 (0.15-0.23)	0.1 (0.08-0.13)
	U19	1.668 ± 0.063	1.668 ± 0.063	0.073	0.16 (0.12-0.23)	0.1 (0.08-0.15)
	U17	1.686 ± 0.038	1.686 ± 0.039	0.671	0.22 (0.17-0.32)	0.1 (0.08-0.15)
	U15	1.617 ± 0.056	1.616 ± 0.056	0.172	0.18 (0.15-0.22)	0.1 (0.09-0.12)
Body Mass (kg)	**Seniors**	62.1 ± 6.2	62.0 ± 6.2	0.766	0.34 (0.28-0.44)	0.5 (0.40-0.60)
	U19	58.2 ± 4.5	58.2 ± 4.6	1.000	0.22 (0.17-0.32)	0.4 (0.30-0.58)
	U17	59.2 ± 4.6	59.2 ± 4.7	0.843	0.24 (0.18-0.35)	0.4 (0.30-0.58)
	U15	52.8 ± 5.9	52.8 ± 5.9	0.511	0.21 (0.18-0.26)	0.4 (0.34-0.49)
Sum of 8 Skinfolds (mm)	**Seniors**	85 ± 18	85 ± 18	0.636	1.03 (0.87-1.27)	1.2 (1.00-1.50)
	U19	83 ± 16	83 ± 16	0.961	0.81 (0.62-1.18)	1.0 (0.76-1.46)
	U17	90 ± 20	90 ± 20	0.603	0.78 (0.59-1.14)	0.9 (0.68-1.32)
	U15	89 ± 23	88 ± 23	0.134	1.19 (1.01-1.45)	1.3 (1.10-1.59)

Table 7.3 Reliability measures (95 % CI) for linear speed data (mean ± SD) during two separate trials (n = 20-60)

		Trial 1	Trial 2	p value	SEM (95 % CI)	% CV (95 % CI)
5 m (s)	**Seniors**	1.052 ± 0.058	1.044 ± 0.064	0.178	0.03 (0.02-0.04)	2.4 (1.97-3.08)
	U19	1.032 ± 0.046	1.030 ± 0.050	0.762	0.02 (0.02-0.03)	2.0 (1.52-2.92)
	U17	1.078 ± 0.038	1.086 ± 0.038	0.266	0.02 (0.02-0.03)	2.0 (1.52-2.92)
	U15	1.063 ± 0.055	1.063 ± 0.061	0.910	0.02 (0.01-0.02)	2.3 (1.86-3.00)
10 m (s)	**Seniors**	1.846 ± 0.080	1.835 ± 0.072	0.179	0.03 (0.02-0.04)	1.9 (1.57-2.44)
	U19	1.836 ± 0.066	1.830 ± 0.069	0.355	0.02 (0.02-0.03)	1.2 (0.91-1.75)
	U17	1.870 ± 0.053	1.880 ± 0.058	0.280	0.03 (0.02-0.04)	1.4 (1.07-2.05)
	U15	1.909 ± 0.098	1.900 ± 0.100	0.106	0.03 (0.03-0.04)	1.6 (1.36-1.95)
20 m (s)	**Seniors**	3.21 ± 0.11	3.22 ± 0.10	0.729	0.04 (0.03-0.05)	1.1 (0.90-1.41)
	U19	3.24 ± 0.11	3.23 ± 0.12	0.292	0.03 (0.02-0.04)	0.8 (0.61-1.17)
	U17	3.31 ± 0.09	3.30 ± 0.10	0.450	0.03 (0.02-0.04)	1.4 (1.07-2.05)
	U15	3.24 ± 0.14	3.24 ± 0.15	0.591	0.04 (0.03-0.05)	1.1 (0.93-1.34)
30 m (s)	**Seniors**	4.54 ± 0.14	4.55 ± 0.15	0.241	0.04 (0.03-0.05)	1.0 (0.82-1.28)
	U19	4.57 ± 0.18	4.58 ± 0.17	0.302	0.03 (0.02-0.04)	0.6 (0.61-1.17)
	U17	4.68 ± 0.12	4.70 ± 0.16	0.356	0.04 (0.03-0.05)	1.4 (1.07-2.05)
	U15	4.79 ± 0.24	4.80 ± 0.25	0.155	0.07 (0.06-0.09)	1.4 (1.19-1.71)

Table 7.4 Reliability measures (95 % CI) for CMJ, repeated speed and YYIR1 data (mean ± SD) during two separate trials (n = 20-60)

		Trial 1	Trial 2	p value	SEM (95 % CI)	% CV (95 % CI)
CMJ (cm)	**Seniors**	32.7 ± 4.2	32.7 ± 3.9	0.953	0.96 (0.79-1.23)	2.9 (2.38-3.72)
	U19	28.9 ± 4.7	29.1 ± 4.4	0.681	1.00 (0.76-1.46)	3.4 (2.59-4.97)
	U17	26.0 ± 3.2	26.3 ± 3.1	0.320	0.86 (0.65-1.26)	3.3 (2.51-4.82)
	U15	26.6 ± 3.7	26.4 ± 3.4	0.427	1.22 (1.03-1.49)	4.6 (3.90-5.61)
Average Repeated Speed (s)	**Seniors**	4.81 ± 0.16	4.78 ± 0.14	0.069	0.06 (0.05-0.08)	1.3 (1.07-1.67)
	U19	4.86 ± 0.17	4.88 ± 0.19	0.358	0.06 (0.05-0.09)	1.2 (0.91-1.75)
	U17	5.01 ± 0.19	5.04 ± 0.18	0.443	0.11 (0.08-0.16)	2.2 (1.67-3.21)
	U15	5.21 ± 0.28	5.22 ± 0.28	0.783	0.11 (0.09-0.13)	2.1 (1.78-2.56)
YYIR1 (m)	**Seniors**	1727 ± 270	1727 ± 269	1.000	65.66 (53.80-84.31)	3.8 (3.11-4.88)
	U19	1460 ± 331	1494 ± 322	0.215	84.59 (64.33-123.55)	5.7 (4.33-8.34)
	U17	1243 ± 339	1278 ± 342	0.257	95.65 (72.74-139.70)	7.5 (5.70-10.95)
	U15	901 ± 289	915 ± 276	0.277	70.54 (59.79-86.03)	7.7 (6.53-9.39)

Table 7.5 provides sample size estimations for future single-sample test-retest tracking studies based upon the smallest and the average MPID derived from a scoping search of existing data. Data were taken from studies on female soccer players for the following variables; sum of skinfolds (Gravina et al., 2008), CMJ (Jensen and Larsson, 1992; Polman et al., 2004; Gravina et al., 2008; Sedano Campo et al., 2009), 5 m (Upton, 2011; Taylor et al., 2012), 20 m (Siegler, Gaskill and Ruby, 2003; Polman et al., 2004; Gravina et al., 2008; Upton, 2011; Taylor et al., 2012), repeated speed (Polman et al., 2004; Taylor et al., 2012) and yo yo intermittent performance (Bradley et al., 2014b). The measurement of sum of skinfolds is estimated to require the largest average sample size (n = 10), while the performance measures require smaller sample sizes (n≤10).

Table 7.5 Sample size estimations for future single sample test-retest tracking studies based upon the smallest and average MPID derived from existing data [selected mean change to detect, 80 % power, two-tailed test, measurement error statistic (SEM or %CV) derived from Tables 7.2-7.4].

	Sum of 8 Skinfolds (% Δ)	**CMJ (cm)**	**5 m (% Δ)**	**20 m (s)**	**Repeated Speed (% Δ)**	**YYIR1 (m)**
Standardised Smallest MPID		0.8		0.53		0.48
Smallest MPID (units or % Δ)	1.6	2.4	2.8	0.08	1.6	203.0
Sample Size	10	6	12	10	20	5
Standardised Average MPID		1.5		1.07		0.53
Average MPID (units or % Δ)	1.6	4.3	5.9	0.16	6.4	224.5
Sample Size	10	4	5	5	4	5

7.4 DISCUSSION

The aim of the current study was to examine the reliability of both anthropometric and performance measures in elite female soccer players. Collectively the data suggest that both junior and senior elite female players are able to adequately reproduce a variety of soccer related performance tests and that reliable measures can be obtained using the present protocols and familiarisation processes. The sample size estimations provide important insights for future studies designed to track the fitness status of elite female soccer players and/or to quantify the effects of any intervention.

In the present investigation overall reliability for anthropometric measures were acceptable with CVs of 0.1 %, 0.4-0.5 % and 0.9-1.3 % observed for height, body mass and sum of 8 skinfolds respectively. Previous evaluations in healthy participants reported similar CVs to the current study with values of 0.0 %, 0.2 % and 3.6-6.4 % observed for height, body mass and sum of 4 skinfolds respectively (Klipstein-Grobusch, Georg and Boeing, 1997). An estimated sample size of 10, based on an average MPID of 1.6 %, is required to track changes in sum of 6 skinfolds in elite female soccer players. It should be noted that due to the lack of female specific data, the MPID calculation is based on sum of 6 and not 8 skinfolds. The percentage change rather than absolute change in the sum of skinfold was therefore used to represent the MPID in the statistical power calculation. Collectively, these observations indicate that the anthropometric assessments undertaken by the qualified federation staff in the current study are suitable for tracking changes in elite female soccer players providing a sample size of ~10 is recruited.

We observed no differences in performance assessments between trial 1 and trial 2 for any age group. This observation suggests that the performance assessments were not systematically influenced by factors such as learning effects or fatigue between trials and that the present protocol and familiarisation processes were sufficient. As such, reproducible measures in these tests can be obtained in future studies by ensuring prospective participants complete the present familiarisation process. In the present study, linear speed and CMJ measures showed acceptable test-retest reliability (0.6-4.6 %). The CV for linear speed measures (0.6-2.4 %) observed in the current study are similar to findings in elite academy male soccer players (1.5-1.9 %) (Hulse et al., 2013) but less than senior male players (3.2 %) (Mirkov et al., 2008). The CV was generally higher in shorter distances (5 and 10 m) as opposed to longer distances (20 and 30 m), thus indicating reduced relative reliability in these measures. Evaluation of CMJ showed generally greater reliability in the current study (2.9-4.6 %) compared to elite male academy players (4.7-6.4 %) (Hulse et al., 2013). These observations indicate that linear speed and CMJ assessments are suitable for tracking changes in physical performance providing a modest sample size is recruited (4-5 players based on an average MPID of 0.16 s, 4.3 cm and 5.9 %, respectively) in elite female soccer players.

The observed CV for YYIR1 in the current study (3.8-7.7 %) was higher than other performance variables, but similar to previous reports (4.9 %) in male players (Krustrup et al., 2003). This increased variability for YYIR1 relative to other performance tests might be attributed to the requirement of players to continue until they reach volitional exhaustion, which may inherently increase the level of variability. At present, there is no available data to allow sample size estimations for YYIR1 and therefore the calculations shown in Table 7.5 are based on the similar YYIE2 test. However, distances covered in the current study (1727 ± 270 m) are similar to those previously reported in the YYIE2 (1774 ± 532 m) (Bradley et al., 2014b). The reported reliability (1.2-2.2 %) for repeated speed assessment in the current study is very good, however, no comparative data is available. Collectively, these observations indicate that linear YYIR1 and repeated speed assessments are suitable for tracking changes in physical performance providing a modest sample size is recruited (4-5 players based on an average MPID of 225 m and 6.4 %) in elite female soccer players.

7.5 SUMMARY

The results of the current study demonstrate that both junior and senior elite female soccer players are able to reproduce a variety of soccer related performance tests following completion of one familiarisation trial. Utilisation of the MPID allows the estimation of suitable sample sizes required in future studies and suggests that these anthropometric and performance assessments are suitable for the longitudinal tracking of the fitness status of elite female players.

CHAPTER 8

PHYSICAL CHARACTERISTICS OF ELITE FEMALE SOCCER PLAYERS

8.1 INTRODUCTION

As established in the previous chapters, soccer is a multi-directional, high-intensity, intermittent team sport and since players must possess the required levels of fitness to cope with the demands of the game (Reilly, 2005), both anthropometric and performance testing represent an important component of an elite soccer player's development program (Hulse et al., 2013; Manson, Brughelli and Harris, 2014). Data derived from such testing can be used to inform decisions in relation to talent identification, player selection, training monitoring and training periodisation (Hoare and Warr, 2000; Reilly et al., 2000; Svensson and Drust, 2005; Buchheit et al., 2012).

A number of studies have examined the physical characteristics of elite junior (Wong and Wong, 2009; Le Gall et al., 2010; Buchheit and Mendez-Villanueva, 2013; Hulse et al., 2013) and senior (Krustrup et al., 2006; Sporis et al., 2009; Carling and Orhant, 2010; Bradley et al., 2011b; Ingebrigtsen et al., 2012) male soccer players highlighting effects of playing standard (Krustrup et al., 2006; Le Gall et al., 2010; Bradley et al., 2011b; Ingebrigtsen et el., 2012; Hulse et al., 2013), age (Le Gall et al., 2010; Hulse et al., 2013), playing position (Krustrup et al., 2006; Sporis et al., 2009; Carling and Orhant, 2010; Le Gall et al., 2010; Bradley et al., 2011b) and phase of season (Krustrup et al., 2006; Carling and Orhant, 2010; Bradley et al., 2011b) on a range of physical characteristics. In contrast, limited attention to date has focused on female players, particularly elite players, with the majority of research focusing on sub-elite populations (Siegler, Gaskill and Ruby, 2003; Polman et al., 2004; Vescovi and McGuigan, 2008; McCurdy et al., 2010; Sjökvist et al., 2011; Vescovi et al., 2011). Since the absolute physical capacity of males and females differ, detailed examinations of the physical characteristics of elite female players are warranted.

Available data on elite female players suggests some influence of playing position on performance characteristics, with attackers and midfield players demonstrating the fastest and slowest rates of acceleration and speed respectively (Haugen, Tønnessen and Seiler, 2012). Due largely to limitations in sample size, previous investigations into positional differences and performance characteristics have largely focused on generic playing positions (e.g. defenders, midfielders and attackers). However, match physical performance profiles that subdivide players into central and wide positions suggest that differences in performance characteristics are likely to exist between midfield and defensive positions (Bradley et al., 2014a; Chapter 4). To date, only one study (Bradley et al., 2014b) has conducted a detailed analysis of the influence of playing position (e.g. central v wide midfield and defensive positions) on physical performance in elite players, with WM demonstrating greater high-intensity endurance capacity compared to CD and A. Since only one component of physical performance was examined, further in-depth analysis of playing position across a range of physical characteristics in elite players is warranted.

Alongside playing position, the influence of chronological age on the physical characteristics of elite female players has also received little attention to date. High-intensity endurance capacity has been shown to be greater in senior (23 ± 2 years) compared to junior (19 ± 1 years) players (Bradley et al., 2014b). Similarly, single leg lateral and horizontal jump distances were greater in senior compared to U17 New Zealand internationals (Manson, Brughelli and Harris, 2014). However, some contradictory reports exist which show lower limb power to be unaffected by age (15-35 years) (Haugen, Tønnessen and Seiler, 2012) and jump performance to be lower in senior compared to U19 Italian internationals (Castagna and Castellini, 2013). As such, the influence of chronological age on the physical characteristics of elite female players remains unclear and further exploration is required. Normative data for chronological age groups and playing positions will help inform the training process for junior and senior elite players in clubs and national federations. The aim of the current study therefore was to assess the influence of age and playing position on physical performance.

8.2 METHODS

8.2.1 Experimental Approach to the Problem

To assess the physical characteristics of international female players, anthropometric and performance data were collected from 471 national team players from 2011-2015. Prior to assessment, all players had previously completed each test on at least one previous occasion. All performance tests were performed on third generation turf (indoor arena) and players wore shorts, t-shirt and football boots (except for the jumps when trainers were worn). Players performed a standardised warm-up prior to commencing the physical assessments (Chapter 3). All performance tests were completed at approximately the same time of day to reduce any circadian rhythm effect (Reilly and Brooks, 1986). Tests were completed in a single session and in the same order (anthropometry, jumps, speed, repeated speed and YYIR1) on each test occasion. The test order was designed in an attempt to minimise the influence of previous tests on subsequent performance. Participants were instructed to refrain from strenuous exercise in the 24 hours before the fitness testing session and to consume their normal pre-training diet. To encourage maximal effort, players received verbal encouragement throughout the performance tests.

8.2.2 Participants

Anthropometric assessments and performance data were collected from 471 national team female soccer players from 2011–2015. Data were analysed separately by age group (U15s, U17s, U19s or seniors) and also by playing position (GK, CD, WD, CM, WM or A). Age group classification reflected the player's UEFA and FIFA eligibility and the Head Coach of the respective age group categorised the player's into playing positions. Players were tested at multiple time points per season, which resulted in a median of three testing occasions per player (range = 1-12). The number of individual players tested per age group and per playing position, along with the overall number of observations is shown in Table 8.1. Due to the longitudinal nature of the dataset, some player's were tested in multiple age groups (data displayed in Table 8.2) and these repeated measures were accounted for in our statistical model.

Table 8.1 The number of individual participants and the number of observations, per age group and per playing position

For example, there were 84 observations for U15 GKs in the study; however, due to repeated measures these observations were from a sample of 30 individual players.

		U15s	**U17s**	**U19s**	**Seniors**	**All Players**
GK	**Individual players**	30	21	18	15	63
	Observations	(84)	(49)	(45)	(58)	(236)
CD	**Individual players**	47	24	20	16	80
	Observations	(101)	(52)	(41)	(91)	(285)
WD	**Individual players**	25	21	22	22	69
	Observations	(65)	(48)	(56)	(79)	(248)
CM	**Individual players**	61	32	29	21	108
	Observations	(167)	(71)	(72)	(90)	(400)
WM	**Individual players**	40	27	26	18	83
	Observations	(100)	(67)	(56)	(63)	(286)
A	**Individual players**	34	20	20	21	69
	Observations	(84)	(38)	(52)	(86)	(260)
All	**Individual players**	237	145	135	113	472
	Observations	(601)	(325)	(322)	(467)	(1715)

Table 8.2 The total number of participants in each age group, along with the number of participants tested in multiple age groups

For example, of the 135 players that were tested in the U19 age group, 9 had previously been tested in the U15s, 49 had previously been tested in the U17s and 40 were tested again when in the senior age group.

	Total Number of Participants	**U15s**	**U17s**	**U19s**	**Seniors**
U15s	237		67	9	0
U17s	145	67		49	13
U19s	135	9	49		40
Seniors	113	0	13	40	

National federation staff conducted each testing session and the same test protocols were employed on each occasion. Players were aged 12-36 years of age (17.7 ± 4.4 years). All participants had previously completed the experimental procedures on at least one previous occasion. The associated risks were explained to participants and written informed consent to participate was obtained from either themselves or their parent or guardian. Ethical approval was obtained from the researcher's university ethics committee. Details regarding the player's menstrual cycle and/or use of the OCP were not recorded, which is an acknowledged limitation.

It was estimated that 10 participants would enable the detection of a 1.6 % change in the sum of 8 skinfolds, assuming a test-retest CV of 1.1 % (Chapter 7) and a statistical power of 80 %. It was estimated that 4 participants would enable the detection of a 4.3 cm change in CMJ performance, assuming a test-retest CV of 3.6 % (Chapter 7) and a statistical power of 80 %. It was estimated that 5 participants would enable the detection of a 5.9 % and 0.16 s change in 5 and 20 m performance, respectively, assuming a test-retest CV of 1.1-2.2 % (Chapter 7) and a statistical power of 80 %. It was estimated that 4 participants would enable the detection of a 6.4 % change in repeated sprint ability, assuming a test-retest CV of 1.7 % (Chapter 7) and a statistical power of 80 %. It was estimated that 5 participants would enable the detection of a 225 m change in YYIR1 performance, assuming a test-retest CV of 6.2 % (Chapter 7) and a statistical power of 80 %.

8.2.3 Procedures

A detailed explanation of the protocols for all anthropometric and performance measures, including specific warm-up activities, can be found in the general methodology (Chapter 3) and reliability of measures chapters (Chapter 7).

8.2.3.1 Anthropometric Measures

Specific protocols for the measures of height, body mass and sum of skinfolds can be found in Chapter 3 (3.2.1) and Chapter 7 (7.2.3).

8.2.3.2 Performance Measures

Countermovement Jump (without arms)

Specific protocols for CMJ can be found in Chapter 3 (3.2.2.2) and Chapter 7 (7.2.3.2).

Linear Speed

Specific protocols for the 5 m and 30 m linear speed can be found in Chapter 3 (3.2.2.3) and Chapter 7 (7.2.3.2).

Repeated Speed

Specific protocols for repeated speed can be found in Chapter 3 (3.2.2.4) and Chapter 7 (7.2.3.2).

Yo-Yo Intermittent Recovery Test Level 1

Specific protocols for YYIR1 can be found in Chapter 3 (3.2.2.5) and Chapter 7 (7.2.3.2).

8.2.4 Statistical Analysis

Data are presented as mean ± SD, to two significant digits (Hopkins et al., 2009). Data were analysed using linear mixed modeling with age and playing position as fixed effects and a random intercept to account for the repeated measures nature of our design (Statistical Package for Social Sciences, Version 21). Main effects were followed up with Bonferroni-corrected multiple contrasts. Then, using the mean difference, degrees of freedom and standard deviation derived from the linear mixed model, standardised mean differences (effect sizes) were calculated for the effect of age and playing position and subsequently classified as trivial (<0.20), small (>0.20-0.60), moderate (>0.60-1.20), large (>1.20-2.00) and very large (>2.00) (Hopkins et al., 2009). Finally, we used a magnitude-based inference approach to assess the extent of the change in anthropometric and performance measures for each subsequent age group relative to U15s (baseline). Again using the mean difference and degrees of freedom derived from the linear mixed model, inferences here were based on standardised thresholds for small, moderate and large differences of 0.2, 0.6 and 1.2 of the pooled between-subject standard deviations and the chance of the true effect being substantial or trivial was interpreted using the following scale: 25-75 %, possibly; 75-95 %, likely; 95-99.5 %, very likely; >99.5 %, most likely (Hopkins et al., 2009).

8.3 RESULTS

8.3.1 Influence of Age

Anthropometric and physical performance data per age group, along with between age-group differences are shown in Table 8.3. For the majority of anthropometric and performance measures, the between age-group differences were generally small and moderate with a few instances of large differences. Anthropometric and performance measures generally improved with an increase in chronological age.

The magnitude of the between age-group difference in height between U15s and all other age groups were moderate. Small between age-group differences were observed for height between seniors and U17s, whilst all other age-group comparisons were trivial. There were large between age-group differences in body mass between U15s and seniors, with moderate differences between U15s and the other age groups (U17s and U19s). Moderate between age-group differences were observed for body mass between seniors and U17s, whilst all other age-group comparisons were small. There were generally smaller between age-group differences in sum of skinfolds compared to other anthropometric variables, with small differences noted between seniors and all other age groups whilst all other age-group comparisons were trivial.

The magnitude of between age-group differences in speed times was generally greater for 30 m than 5 m. Small differences in 5 m speed times were observed between seniors and U19s when compared to U17s and U15s, with trivial differences between the younger (U15s and U17s) and older (U19s and seniors) age groups. Large and moderate differences for 30 m were observed between seniors compared to U15s and U17s respectively. Moderate differences were also observed between U19 and U17s relative to U15s, whilst all other age-group comparisons were small. The magnitude of the between age-group differences in CMJ between seniors and all other age groups were large (U15s) and moderate (U19s and U17s) respectively. Small differences were observed between U19s compared to U17s and U15s, with trivial differences between U15s and U17s.

Moderate differences were observed between seniors relative to U15s and U17s for repeated speed, with moderate differences also observed between U19s and U15. All other age-group comparisons for repeated speed were trivial. Large and moderate differences for YYIR1 distance were observed between seniors compared to U15s and U17s respectively, with moderate differences also noted between U19s and U15s. All other age-group comparisons for YYIR1 distance were small.

Table 8.3 Anthropometric and physical performance data for elite female players per age group, along with inferential statistics (effect size) for the between age-group differences (mean ± (SD)

	U15	U17	U19	Seniors	Qualitative inferences for all contrasts
Height (cm)	1.620 (0.063)	1.664 (0.051)	1.670 (0.058)	1.679 (0.063)	**Moderate:** Seniors, U19s, U17s vs U15s (**0.92, 0.84, 0.79**) **Small:** Seniors vs U17s (**0.27**) **Trivial:** Seniors vs U19s (**0.14**), U19s vs U17s (**0.11**)
Body mass (kg)	53.9 (7.8)	58.8 (5.5)	61.1 (6.2)	62.5 (5.8)	**Large:** Seniors vs U15 (**1.28**) **Moderate:** U19s, U17s vs U15s (**1.04**, **0.75**), Seniors vs U17s (**0.64**) **Small:** U19s vs U17s (**0.38**), Seniors vs U19s (**0.23**)
Sum of 8 skinfolds (mm)	95 (28)	96 (23)	96 (24)	88 (21)	**Small:** Seniors vs U17s, U19s, U15s (**0.38, 0.35, 0.29**) **Trivial:** U17s, U19s vs U15s (**0.06, 0.04**), U19s v U17s (**0.02**)
5 m (s)	1.078 (0.065)	1.083 (0.052)	1.060 (0.047)	1.056 (0.056)	**Small:** Seniors, U19s vs U17s (**0.51, 0.46**), Seniors, U19s vs U15s (**0.35, 0.31**) **Trivial:** U17s vs U15s (**0.10**), Seniors vs U19s (**0.08**)
30 m (s)	4.78 (0.22)	4.65 (0.20)	4.57 (0.18)	4.52 (0.17)	**Large:** Seniors vs U15s (**1.33**) **Moderate:** U19s vs U15s (**1.05**), Seniors vs U17s (**0.67**), U17s vs U15s (**0.64**) **Small:** U19s vs U17s (**0.38**), Seniors vs U19s (**0.32**)
CMJ (cm)	28.3 (4.0)	29.0 (3.8)	30.1 (4.1)	33.4 (4.0)	**Large:** Seniors vs U15s (**1.27**) **Moderate:** Seniors vs U17s, U19s (**1.12, 0.80**) **Small:** U19s vs U15s, U17s (**0.44, 0.28**) **Trivial:** U17s vs U15s (**0.17**)
Repeated Speed (s)	5.09 (0.24)	4.98 (0.24)	4.91 (0.21)	4.84 (0.21)	**Moderate:** Seniors, U19s vs U15s (**1.12, 0.79**), Seniors vs U17s (**0.63**) **Small:** U17s vs U15s (**0.45**), Seniors vs U19s (**0.37**), U19s vs U17s (**0.30**)
YYIR1 (m)	1101 (369)	1248 (390)	1357 (379)	1583 (416)	**Large:** Seniors vs U15s (**1.22**) **Moderate:** Seniors vs U17s (**0.83**), U19s vs U15s (**0.63**) **Small:** Seniors vs U19s (**0.57**), U17s vs U15s (**0.38**), U19s vs U17s (**0.28**)

Magnitude based inferences for changes in anthropometric and performance measures relative to U15s (baseline) are shown in Table 8.4. There were substantial improvements (e.g., a small effect or greater) in most anthropometric and performance measures with an increase in chronological age-group, with the greatest differences observed between seniors and U15s. The largest between age-group differences were noted for body mass, with most likely (i.e. >99.5 % probability) moderate differences observed between both seniors and U19s compared to U15s. For performance variables, the largest between age-group differences were found between seniors and U15s for 30 m sprint times with very likely (i.e. 95-99.5 % probability) moderate differences noted. Conversely, the smallest between age-group differences were observed in sum of skinfolds with only possibly (i.e. 25-75 % probability) small differences noted between seniors and U15s. Average anthropometric and physical performance data for each age group and playing position are displayed in Tables 8.5-8.8.

Table 8.4 Mean difference with 95 % confidence intervals for anthropometric and physical performance data between each age group and U15s, for elite female players per age group, along with qualitative probabilistic descriptors

	U17s	**U19s**	**Seniors**
Height difference compared to U15s (cm)	0.04	0.05	0.06
95 % confidence interval	(0.02 to 0.06)	(0.03 to 0.07)	(0.04 to 0.08)
Qualitative inference	Very likely small	Most likely small	Possibly moderate
Body Mass difference compared to U15s (kg)	4.3	7.1	8.2
95 % confidence interval	(3.6 to 5.1)	(6.2 to 8.1)	(7.0 to 9.4)
Qualitative inference	Most likely small	Most likely moderate	Most likely moderate
Sum of 8 skinfolds difference compared to U15s (mm)	0.6	0.1	7
95 % confidence interval	(-2.8 to 4.0)	0.2 (-4.7 to 4.8)	(1 to 13)
Qualitative inference	Unclear	0.3 Unclear	Possibly small
5 m (s)	0.004	0.010	0.017
95 % confidence interval	(-0.008 to 0.017)	(-0.004 to 0.024)	(0.003 to 0.031)
Qualitative inference	Unclear	Possibly small	Likely small
30 m (s)	0.14	0.16	0.21
95 % confidence interval	(0.11 to 0.17)	(0.12 to 0.20)	(0.16 to 0.26)
Qualitative inference	Possibly moderate	Likely moderate	Very likely moderate
CMJ (cm)	0.7	2.0	3.8
95 % confidence interval	(0.1 to 1.2)	(1.2 to 2.7)	(2.9 to 4.7)
Qualitative inference	Unclear	Most likely small	Likely moderate
Repeated Speed (s)	0.08	0.10	0.16
95 % confidence interval	(0.05 to 0.12)	(0.05 to 0.15)	(0.10 to 0.21)
Qualitative inference	Very likely small	Most likely small	Possibly moderate
YYIR1 (m)	77	186	283
95 % confidence interval	(23 to 132)	(108 to 163)	(193 to 374)
Qualitative inference	Possibly small	Most likely small	Possibly moderate

Table 8.5 Anthropometric and physical performance data for U15 elite female players, per playing position (mean ± (SD)

	GK	CD	WD	CM	WM	A
Height (cm)	1.672 (0.048)	1.657 (0.051)	1.610 (0.062)	1.597 (0.058)	1.605 (0.054)	1.598 (0.063)
Body mass (kg)	61.1 (9.4)	56.2 (5.0)	51.6 (6.9)	51.6 (6.9)	51.8 (6.4)	52.8 (7.5)
Sum of 8 skinfolds (mm)	114 (38)	98 (23)	83 (21)	95 (26)	89 (25)	89 (25)
5 m (s)	1.107 (0.076)	1.062 (0.063)	1.071 (0.063)	1.086 (0.060)	1.068 (0.068)	1.061 (0.050)
30 m (s)	4.92 (0.25)	4.75 (0.20)	4.72 (0.23)	4.82 (0.19)	4.70 (0.21)	4.73 (0.19)
CMJ (cm)	26.1 (3.5)	27.9 (3.5)	31.0 (4.1)	28.2 (3.9)	28.6 (4.0)	28.9 (3.7)
Repeated Speed (s)	5.31 (0.31)	5.07 (0.21)	5.02 (0.18)	5.11 (0.22)	4.98 (0.20)	5.03 (0.18)
YYIR1 (m)	728 (235)	1101 (298)	1355 (411)	1154 (332)	1133 (319)	1143 (386)

Table 8.6 Anthropometric and physical performance data for U17 elite female players, per playing position (mean ± (SD)

	GK	CD	WD	CM	WM	A
Height (cm)	1.687 (0.048)	1.688 (0.048)	1.657 (0.067)	1.659 (0.049)	1.653 (0.038)	1.639 (0.036)
Body mass (kg)	63.9 (6.3)	60.1 (4.5)	57.6 (5.2)	58.5 (4.6)	57.0 (4.0)	56.1 (5.8)
Sum of 8 skinfolds (mm)	112 (28)	92 (15)	92 (22)	98 (24)	88 (18)	99 (24)
5 m (s)	1.109 (0.064)	1.074 (0.040)	1.097 (0.043)	1.077 (0.054)	1.072 (0.047)	1.074 (0.058)
30 m (s)	4.81 (0.24)	4.60 (0.20)	4.63 (0.15)	4.66 (0.20)	4.55 (0.16)	4.64 (0.17)
CMJ (cm)	27.5 (5.0)	30.2 (2.9)	28.8 (3.9)	28.7 (3.8)	29.8 (3.5)	28.8 (3.2)
Repeated Speed (s)	5.22 (0.25)	4.95 (0.21)	4.95 (0.19)	4.94 (0.22)	4.86 (0.18)	5.02 (0.22)
YYIR1 (m)	911 (383)	1169 (388)	1409 (391)	1413 (357)	1291 (294)	1141 (304)

Table 8.7 Anthropometric and physical performance data for U19 elite female players, per playing position (mean ± SD)

	GK	CD	WD	CM	WM	A
Height (cm)	1.714 (0.041)	1.705 (0.040)	1.645 (0.062)	1.666 (0.061)	1.656 (0.044)	1.654 (0.054)
Body mass (kg)	69.7 (6.9)	63.4 (4.7)	57.7 (4.4)	58.9 (3.9)	59.7 (3.2)	59.8 (6.1)
Sum of 8 skinfolds (mm)	122 (29)	92 (21)	90 (19)	92 (21)	92 (18)	94 (21)
5 m (s)	1.077 (0.052)	1.037 (0.034)	1.081 (0.036)	1.070 (0.042)	1.044 (0.044)	1.050 (0.054)
30 m (s)	4.74 (0.21)	4.49 (0.13)	4.58 (0.15)	4.60 (0.14)	4.52 (0.11)	4.53 (0.22)
CMJ (cm)	28.0 (4.5)	32.5 (3.4)	29.1 (3.7)	29.0 (3.6)	31.5 (3.7)	31.4 (4.3)
Repeated Speed (s)	5.19 (0.22)	4.87 (0.16)	4.90 (0.19)	4.89 (0.12)	4.85 (0.15)	4.81 (0.20)
YYIR1 (m)	914 (323)	1164 (403)	1505 (274)	1463 (346)	1447 (309)	1407 (340)

Table 8.8 Anthropometric and physical performance data for senior elite female players, per playing position (mean ± (SD)

	GK	CD	WD	CM	WM	A
Height (cm)	1.754 (0.044)	1.715 (0.041)	1.658 (0.046)	1.649 (0.076)	1.639 (0.032)	1.669 (0.046)
Body mass (kg)	71.5 (5.7)	63.9 (3.3)	61.8 (4.0)	60.0 (3.9)	57.0 (3.7)	62.3 (5.1)
Sum of 8 skinfolds (mm)	102 (29)	79 (16)	89 (23)	90 (20)	81 (17)	88 (16)
5 m (s)	1.105 (0.063)	1.065 (0.049)	1.053 (0.055)	1.064 (0.041)	1.051 (0.054)	1.019 (0.049)
30 m (s)	4.75 (0.23)	4.52 (0.12)	4.51 (0.12)	4.52 (0.12)	4.48 (0.16)	4.41 (0.15)
CMJ (cm)	32.2 (4.8)	33.6 (3.1)	32.0 (4.0)	33.5 (4.0)	33.9 (3.9)	34.9 (3.8)
Repeated Speed (s)	5.19 (0.26)	4.81 (0.15)	4.80 (0.14)	4.81 (0.16)	4.78 (0.14)	4.75 (0.15)
YYIR1 (m)	1054 (294)	1689 (355)	1689 (354)	1659 (345)	1655 (491)	1566 (382)

8.3.2 Influence of Playing Position

Anthropometric and physical performance data per playing position, along with between playing position differences are shown in Table 8.9. For the majority of anthropometric and performance measures, the between playing position differences were generally small but with some instances of moderate and large differences. Anthropometric and performance measures were generally inferior in GK compared to outfield playing positions.

Goalkeepers and CD were mostly taller than all other positions with large and moderate differences observed. Goalkeepers were heavier than all other positions with large differences relative to CM and WM and moderate differences compared to WD, A and CD. Moderate differences in body mass were also observed in CD relative to CM and WM. Sum of skinfolds were also higher in GK compared to all other playing positions, with moderate differences observed. All other between playing position differences for anthropometric measures were small and trivial.

The magnitude of the between playing position difference highlighted that A were generally faster than all outfield positions over 5 m and faster than CD over 30 m (small differences). There were also small differences observed between CD and WM relative to CM and WD over 5 m. Central midfielders were slower over 30 m and had lower CMJ performances than all outfield positions with small differences noted.

Outfield players had improved repeated sprint scores relative to GKs with large differences noted relative to wide players and attackers, and moderate differences compared to central players. Conversely, WM and A generally had superior repeated sprint scores relative to CM and CD. Outfield players also had improved YYIR1 performance relative to GKs with moderate differences noted relative to CD and large differences compared to all other playing positions. Small differences were also observed between WD and all other outfield playing positions.

Table 8.9 Anthropometric and physical performance data for elite female players per playing position, along with inferential statistics (effect size) for the between playing position differences (mean ± (SD)

	GK	**CD**	**WD**	**CM**	**WM**	**A**	**Qualitative inferences for all contrasts**
Height (cm)	1.702 (0.056)	1.688 (0.052)	1.642 (0.062)	1.632 (0.068)	1.634 (0.049)	1.638 (0.060)	**Large:** GK v WM (**1.31**) **Moderate:** GK v CM, A, WD (**1.13, 1.12, 1.02**), CD v WM, CM, A, WD (**1.07, 0.93, 0.90, 0.80**) **Small:** GK v CD (**0.27**) **Trivial:** WD v CM, WM (**0.16, 0.16**), A v CM (**0.09**), WD v A (**0.08**), A v WM (**0.07**), WM v CM (**0.03**)
Body mass (kg)	65.8 (8.7)	60.4 (5.5)	57.3 (6.5)	56.0 (6.7)	55.7 (5.7)	57.6 (7.5)	**Large:** GK v WM, CM (**1.37, 1.27**) **Moderate:** GK v WD, A (**1.11, 1.01**), CD v WM (**0.83**), GK v CD (**0.75**), CD v CM (**0.72**) **Small:** CD v WD, A (**0.51, 0.41**), A, WD v WM (**0.28, 0.25**), A, WD v CM (**0.23, 0.20**)
Sum of 8 skinfolds (mm)	113 (33)	91 (21)	88 (22)	94 (24)	88 (22)	91 (22)	**Moderate:** GK v WD, WM, A, CD, CM (**0.88, 0.88, 0.77, 0.77, 0.65**) **Small:** CM v WD, WM (**0.25, 0.24**) **Trivial:** CD v WD, WM (**0.16, 0.15**), A v WD, WM (**0.14, 0.14**), CM v A, CD (**0.11, 0.11**), WD v WM (**0.01**), A v CD (**0.01**)
5 m (s)	1.102 (0.067)	1.062 (0.052)	1.074 (0.054)	1.077 (0.053)	1.061 (0.057)	1.047 (0.055)	**Moderate:** A, CD, WM v GK (**0.89, 0.67, 0.66**) **Small:** A v CM, WD (**0.56, 0.49**), WD, CM v GK (**0.46, 0.40**), CD, WM v CM (**0.30, 0.30**), A v CD, WM (**0.27, 0.24**), WM, CD v WD (**0.23, 0.22**) **Trivial:** WD v CM (**0.07**), WM v CD (**0.02**)
30 m (s)	4.84 (0.25)	4.63 (0.20)	4.62 (0.19)	4.70 (0.21)	4.60 (0.20)	4.59 (0.23)	**Moderate:** WM, A, WD, CD v GK (**1.09, 1.05, 1.01, 0.90**) **Small:** CM v GK (**0.58**), WM, A, WD, CD v CM (**0.53, 0.53, 0.44, 0.34**), A v CD (**0.21**) **Trivial:** WM v CD (**0.19**), A, WM v WD (**0.13, 0.11**), WD v CD (**0.09**), A v WM (**0.03**)
CMJ (cm)	28.2 (4.9)	30.8 (4.0)	30.5 (4.1)	29.5 (4.4)	30.5 (4.3)	31.3 (4.6)	**Moderate:** A v GK (**0.65**) **Small:** CD, WM, WD, CM v GK (**0.58, 0.52, 0.51, 0.30**) A, CD, WM, WD v CM (**0.38, 0.29, 0.23, 0.22**) **Trivial:** A v WD, WM, CD (**0.18, 0.16, 0.11**), CD v WD, WM (**0.07, 0.06**), WD v WM (**0.01**)
Repeated Speed (s)	5.25 (0.28)	4.96 (0.22)	4.92 (0.19)	4.99 (0.23)	4.89 (0.19)	4.91 (0.22)	**Large:** WM, A, WD v GK (**1.47, 1.35, 1.35**) **Moderate:** CD, CM v GK (**1.16, 1.10**) **Small:** WM, A, WD v CM (**0.45, 0.36, 0.32**), WM, A v CD (**0.31, 0.23**), **Trivial:** WD v CD (**0.18**), CD v CM (**0.14**), WM v WD, A (**0.14, 0.07**), A v WD (**0.06**)
YYIR1 (m)	850 (316)	1260 (416)	1483 (388)	1336 (393)	1310 (394)	1310 (409)	**Large:** WD, CM, WM, A v GK (**1.79, 1.36, 1.28, 1.28**) **Moderate:** CD v GK (**1.11**) **Small:** WD v CD, WM, A, CM (**0.55, 0.44, 0.43, 0.38**) **Trivial:** CM, WM, A v CD (**0.19, 0.12, 0.12**), CM v WM, A (**0.07, 0.06**), WM v A (**0.00**)

8.4 DISCUSSION

To the authors knowledge the present study provides the largest analysis, based on sample size, of physical performance characteristics in international female soccer players to date. The elite female player's physical profile is influenced by both chronological age and playing position. Generally, anthropometric and performance variables improve with age, though some similarities are observed within the two younger (U15 and U17) and two older (U19 and senior) age groups. Goalkeepers generally exhibited inferior anthropometric and performance capabilities, with faster linear speed over short distances observed in A, greater repeated sprint performance in WM and A and increased intermittent endurance performance in WD. The normative data currently presented for both chronological age and playing position provide important information to professionals involved in player recruitment and talent identification and those responsible for physical development of elite players. Furthermore, the qualitative descriptors based on the magnitude based inferences; provide coaches and other professionals with meaningful information on any between age-group differences.

The anthropometric results indicated that English senior players are typically 1.679 ± 0.063 m in stature and weigh 62.5 ± 5.8 kg which is comparable (ES 0.01-0.53) to previous data on Australian, Scandinavian, Italian and New Zealand international players (Tumilty, 2000; Castagna and Castellini, 2013; Haugen et al., 2014; Manson, Brughelli and Harris, 2014). Less information is currently available on the anthropometric profile of elite youth players, however, available data thus far suggest similar (ES 0.00-0.48) height and body mass values between English youth players (U17 and U19) in the present study and those from Italy and New Zealand (Castagna and Castellini, 2013; Manson, Brughelli and Harris, 2014). Recent data on the body composition of national team players is not available, however, available data on high-level players (Sedano et al., 2009; Krustrup et al., 2010; Gravina et al., 2011) indicates body fat content ranges from 15.5-20.1 %, although the methodology for body fat determination has not always been reported. The current study used a sum of 8 skinfolds as opposed to calculating a percentage body fat due to the unavailability of a suitable equation for this population (Reilly et al., 2009). Suggestions for future work include the development of a female soccer specific equation to estimate body fat percentage from skinfolds. The differences in calculation of body fat content between this and previous studies make it challenging to draw meaningful conclusions. To the author's knowledge this is the first study to report body composition across a range of ages in national team female soccer players.

Senior players in the present investigation exhibited superior anthropometric characteristics relative to the U15 and U17s, with possibly and most likely moderate differences observed for height and body mass respectively, between seniors and U15s. Height and body mass increased with age, with a 6 cm increase in height from U15s to seniors, these observations concur with growth and development literature which indicates females will experience a height gain of approximately 5 cm after menarche (Reilly et al., 2004). The observed increase in height and body mass from U17 to senior players is comparable with previous data for elite female players from New Zealand (Manson, Brughelli and Harris, 2014). Despite the increase in body mass from U15–U19, sum of skinfolds remained similar, thus indicating a likely increase in muscle mass in the older age groups. Sum of skinfolds were lower in senior players compared to all other age groups and this is likely due to the increased training load and professional status of this age group. The average training week for a senior player consists of 4-6 pitch-based training sessions, 2-3 strength and conditioning sessions and a competitive match. Conversely, U15 players are likely to complete 2-3 pitch-based training sessions and one match per week.

In the current study, GK and CD were taller than other playing positions which is in agreement with previous findings for high-level domestic players from England (Todd, Scott and Chisnall, 2002). Other studies using modest sample sizes (n = 29-64) of American and Norwegian domestic level players have also noted trends for defenders and GKs to be taller than players from other positions (Vescovi, Brown and Murray, 2006; Ingebrigtsen, Dillern and Shalfawi, 2011). The differences in physical stature between GK and CD relative to other playing positions likely reflects the demands of the game with increased height being advantageous for players in these positions due to the aerial nature of these roles (Todd, Scott and Chisnall, 2002; Silvestre et al., 2006). Indeed, evidence suggests that some consideration is given to optimal anthropometric characteristics for different playing positions during the talent identification process (Hoare and Warr, 2000). Further differentiation of playing positions in the present study highlights that CD are generally taller than WD which supports previous observations in domestic level Spanish players (Sedano et al., 2009) and university students (Wells and Reilly, 2002). Collectively, these findings demonstrate that a greater understanding of the physical characteristics of playing positions can be achieved by increased categorisation.

The present investigation highlighted GKs to be heavier and with higher skinfolds relative to all other playing positions which may be attributed to their reduced energy expenditure in training and match-play (Datson et al., 2014). This finding is supported by previous research (Todd, Scott and Chisnall, 2002; Ingebrigtsen, Dillern and Shalfawi, 2011), however, some contradictory reports exists which highlight similar body mass and body fat percentages between CD and GK (Sedano et al., 2009). The current study did observe CDs to be heavier than other outfield playing positions but without a concurrent increase in skinfolds, thus suggesting the higher body mass may be attributed to increased height or altered body composition, i.e. increased muscle mass, in these players. Previous reports have found WD to have a lower fat mass than GK and CD (Sedano et al., 2009) this finding was in part substantiated in this investigation, with moderate differences observed between WD and GK, however only trivial differences were noted between WD and CD.

Published reports on the performance profiles of elite international team players are rare which limits the ability to compare the present data to previous research. In the current study, linear sprint times over 5 m (ES 1.73) were quicker than those previously reported for Australian national team players (Tumilty, 2000), however, 30 m sprint times were markedly slower (4.52 s v 4.35 s) than Norwegian national players (Haugen, Tønnessen and Seiler, 2012). It should be noted, however, that methodological differences exist between these studies. In the present investigation a 1m ‘lead-in’ was utilised before the first timing gate, however, no lead-in was used in the previous studies (Tumilty, 2000; Haugen, Tønnessen and Seiler, 2012). Since a lead-in will enable faster linear speed times it would appear that the population of Norwegian national team players were faster over 30 m than the English players presently studied. No comparative data is available for age group linear speed times for national team players. The current study observed similar (ES 0.00-0.46) CMJ values for seniors and U17 English national team players compared to their Italian counterparts (Castagna and Castellini, 2013). The CMJ values achieved by senior players in the current study (33.4 ± 4.0 cm) are in line with the values suggested by Castagna and Castellini (2013) that represent superior vertical jump abilities. Furthermore, the Italian authors also suggested a threshold of 29.8 cm for discriminating between competitive levels, which falls between the CMJ values achieved by U17 (29.0 ± 3.8 cm) and U19 (30.1 ± 4.1 cm) players in the current study. Moderate (ES 0.67) and very large (ES 3.89) differences were observed between the current study and those assessing CMJ ability in Norwegian (Haugen, Tønnessen and Seiler, 2012) and Australian national team players (Tumilty, 2000), with Norwegian players exhibiting lower and Australian players higher jump heights than the current study. A similar methodology appears to have been utilised in all studies and thus the very large ES indicate that Australian players may have increased lower limb power relative to English players, however it is interesting to note that this increased lower limb power did not translate itself into faster 5 m speed times.

Linear sprint performance increased with age in the present investigation, however, similar times were generally observed within the younger (U15 and U17) and older (U19 and senior) age groups. These observations are similar to previous findings which demonstrated age related changes in sprint performance in American high-school and college level players (Vescovi et al., 2011). In the present investigation, between age-group differences increased with sprint distance, with likely small differences for 5m and very likely moderate differences for 30 m, observed between seniors and U15s. Jump height also increased with age, with some similarities between U15 and U17. Likely moderate differences (~3.8 cm) were found in the current study between U15 and senior players for CMJ, which were similar (~4.2 cm) to differences previously reported between junior (17.3 ± 1.6 years) and senior (23.1 ± 2.9 years) domestic level Spanish players (Mujika et al., 2009a). However, less differentiation between age groups has been observed in American high-school and college players (12-21 years) (~2.9 cm) (Vescovi et al., 2011) and Norwegian national team players (13-35 years) (~2.5 cm) (Haugen, Tønnessen and Seiler, 2012). The increased performance of explosive activities that were observed with age in the present study are likely attributed to a combination of factors, including; training responses such as alterations in muscle structure and size (Van Praagh and Doré, 2002; Manson, Brughelli and Harris, 2014) and/or maturity related changes (Malina, Bouchard and Bar-Or, 2004). With reference to the present study, it should be noted that the majority of players would commence formalised strength and conditioning sessions at the age of 18 and this may further explain some of the differentiation between age groups.

The performance data indicated a number of inter-positional differences with the most consistent finding being that GKs exhibited poorer physical characteristics compared to outfield players. Goalkeepers were generally slower and had reduced lower limb power relative to outfield positions. Goalkeepers are required to produce explosive actions throughout training and match-play and therefore these findings might be considered surprising. The reduced jump performance of GKs relative to all other positions has previously been observed in high-level players (Sedano et al., 2009) but not in national team players (Haugen, Tønnessen and Seiler, 2012). These findings suggest that the current methodologies employed for training GKs warrant investigation, to ensure they are optimised for the physical development of these individuals. Attackers were generally faster, particularly over 5m, than other playing positions confirming observations in Norwegian national team players (Haugen, Tønnessen and Seiler, 2012) and high-level domestic English players (Todd, Scott and Chisnall, 2002). Central midfielders were generally slower over the longer sprint distance (30 m) when compared to other outfield positions. This is a unique finding since previous studies have not considered differences in sprint performance between central and wide positions. Interestingly, these findings support match-play observations which report that midfielders obtain lower maximum speeds and complete shorter sprints in terms of duration and distance relative to defenders and attackers

(Vescovi, 2012a). Positional differences were also highlighted in jump performance, with CM generally achieving lower scores relative to other playing positions. This finding differs from previous research in Norwegian national team players (Haugen, Tønnessen and Seiler, 2012) and high-level domestic English players (Todd, Scott and Chisnall, 2002) where no differences in jump performance were demonstrated between outfield positions.

No definitive assessment protocol currently exists for RSA and as such, it is not possible to compare the results of the current investigation with previous studies. As with 30 m linear sprint, there was an increase in repeated sprint performance with age, with possibly moderate differences between seniors and U15s, which is likely due to a combination of training responses and the influence of maturity. The reduced performance by GKs in the repeated 30 m sprint test was not surprising due to the different physical requirements of their position. Attackers and WM produced faster average times for the repeated sprint test compared to CM and CD. This finding may in part be associated with the match physical demands of playing positions as differences were noted between CD and other positions for RHSA (Chapter 5).

Limited information on YYIR1 performance is currently available with no published reports for international female soccer players. However, the YYIR1 has been employed to assess high-level players from Spanish (Mujika et al., 2009a) and Danish leagues (Krustrup et al., 2005). As expected, performance was lower in domestic level compared to national team players with large differences (ES 1.04) observed (Mujika et al., 2009a). As with senior players there are no comparative data available for youth national team players for the YYIR1, however junior Spanish domestic league players (17.3 ± 1.6 years) covered less distance (ES 1.42–1.83) than the U17 and U19 national team players presently studied. The ability for players to perform intermittent high-intensity exercise for prolonged periods of time, as measured by the YYIR1 increased with age, with possibly moderate differences between seniors and U15s. The magnitude of increase between U19 and senior players (ES 0.57) was similar to previous reports for national team players for the YYIE2 (Bradley et al., 2014b), however, larger age group differences (ES 1.87) were observed for the YYIR1 in domestic league players (17.3 ± 1.6 years vs. 23.1 ± 2.9 years) (Mujika et al., 2009b). These increases with age for high-intensity performance are likely due to a myriad of factors including elevated glycolytic enzyme activity during and post-puberty (Malina, Bouchard and Bar-Or, 2004) as well as the effects of increased training activity and professionalism of older players. Consequently, more research is required in this area in order to elicit the cause of these age related differences.

High-intensity endurance capacity represents an important aspect of soccer performance with performance in the YYIR1 test closely correlating with match running performance in elite female players (Krustrup et al., 2005). Wide defenders generally completed greater distances during the YYIR1 test relative to other playing positions. No comparative data exists for the YYIR1, however, for the YYIE2 it was found that WM completed the greatest distance (Bradley et al., 2014b). It does not appear that positional differences in YYIR1 are linked to match physical demands, as despite large differences in physical match performance between CD and other outfield playing positions (Chapter 4) there were only trivial differences observed for YYIR1. It should be recognised that although an increased physical capacity would be advantageous for some positions, match physical performance is influenced by the tactical considerations of the role (Krustrup et al., 2005; Gregson et al., 2010).

8.5 SUMMARY

The current study is the first to provide a detailed analysis of the influence of age and playing position on a range of physical characteristics in a large sample of elite female soccer players. Large differences in the physical profiles of GKs were observed compared to outfield players. Attackers and WM demonstrated the fastest linear sprint and repeated sprint times respectively with the greatest intermittent endurance performance observed in WD. There were observed improvements in anthropometric and performance variables with age as demonstrated by the qualitative descriptors based on magnitude based inferences, which highlight the need to ensure the content and delivery of training is age appropriate (Lloyd and Oliver, 2012). The normative physical characteristics presented, provide unique data for professionals involved in player recruitment and talent identification, whilst the positional differences in performance characteristics, coupled with an in-depth understanding of the demands of match-play can be applied to ensure training specificity.

CHAPTER 9

SYNTHESIS OF FINDINGS

The aim of this chapter is to interpret and integrate the findings obtained within this thesis. The possible applications and limitations will be discussed as well as the realisation of the aims of the thesis. Within the general discussion and conclusions that follow, the results of the individual studies will be interpreted with respect to the physical demands of international female soccer match-play and the physical characteristics of elite players.

9.1 REALISATION OF AIMS

The experimental sections of this thesis have fulfilled the aims stated in Chapter 1 and provided an increased understanding of the physical demands of match-play and the physical characteristics of elite female soccer players. The physical requirements of competitive international female soccer match-play were quantified (Aim 1) along with an in-depth understanding of repeated high-speed activity (Aim 2). The findings of these studies showed large differences in the physical demands of match-play between playing positions and the number of high-speed efforts was lowered across the duration of the match. The use of standardised Prozone zones to analyse female match-play were discussed and an attempt was made to provide female-specific zones relative to maximal match-play running speed (Aim 3). Due to the methodological difficulties associated with determining individual or population-specific speed zones, it was suggested that future studies should remove movement classifications (e.g. walk, jog, run, HSR and sprint) and use speeds to define different zones. The reliability of anthropometric and performance measures in elite junior and senior players were determined (Aim 4) and this permitted correct experimental procedures to be formulated in Chapter 7. The anthropometric and performance measures were used to assess the influence of age and playing position on the physical characteristics of elite players (Aim 5). The findings of the study showed large differences in the physical profile of GKs compared to outfield players, with a number of other inter-positional differences also observed between outfield players. Distinct differences were also noted between age groups, with superior physical performances observed with an increased age.

9.2 GENERAL DISCUSSION

Collectively, the current thesis provides the most in-depth analysis of the physical demands and characteristics of elite female players to date. The present findings highlight positional differences between the general physical demands of competitive international female match-play, as well as the specific component of repeated high-speed activity. Furthermore, a reliable battery of anthropometric and performance measures are presented as well as the implications of their use to assess the influence of age and playing position on physical characteristics of elite female players.

The aims of the first two experimental chapters were to provide a large-scale description of the physical demands of competitive international female match-play as well as the specific nature of repeated high-speed activity. The data provided in Chapters 4 and 5 represent the largest analysis, based on sample size, of elite female match-play to date and the first analysis of competitive international match-play using a semi-automated camera system, which offers greater objectivity and volume of information relative to traditional video-based methodologies (Randers et al., 2010). Collectively, the data demonstrates increased physical demands of competitive international match-play relative to friendly internationals (Hewitt, Norton and Lyons, 2014) and domestic level matches (Mohr et al., 2008; Andersson et al., 2010a). Furthermore, the information presented also provides normative data for the physical demands of international match-play across a number of performance metrics. This data can be utilised by those responsible for the physical training and development of elite players to ensure that training activity is specific to the game demands (Reilly, 2005).

It has previously been established that playing position influences match physical performance with midfielders covering greater TD and THSR than defenders (Andersson et al., 2010a; Hewitt, Norton and Lyons, 2014). However, the larger sample size used in the current study has enabled the extension of the positional analysis to include central and wide midfield and defensive playing positions. This further categorisation of position in female players might be important, as previous work in male players has shown greater THSR and sprint distance in wide versus central playing positions (Di Salvo et al., 2009). The data provided in Chapters 4 and 5 demonstrate for the first time in female soccer that there are large positional differences between CD and WD, with WD completing more TD, THSR, TVHSR, RHSA and RSA than their central defensive counterparts. Fewer differences in the physical performance profile were evident between CM and WM; however, WM completed more VHSRP than CM, whereas CM completed more VHSRWP than WM. Wide midfielders also completed more long sprints (>20 m) compared to their CM counterparts. These observed differences between playing positions can inform the training process and enable the development and delivery of position specific training drills that match the physical demands of the game (Reilly, 2005). Despite the current thesis extending previous work and providing greater categorisation of playing positions, evaluating the influence of different playing formations on physical performance could enhance the data further. It has been shown in male soccer that adopting different playing formations can influence the match physical demands of certain positions (Bradley et al., 2011a), however this is yet to be investigated in females. Bradley and colleagues highlighted that A in a 4-3-3 perform

~30 % more distance > 14.4 km.h^{-1} than A in 4-4-2 or 4-5-1 formations. Also, defenders in a 4-4-2 completed more > 19.8 km.h^{-1} than defenders in 4-5-1 or 4-3-3 formations.

The current studies highlighted small yet significant between-half reductions in a number of physical metrics including but not limited to THSR and RHSA. Although these findings may indicate an inability of elite female players to perform at the required speed for the duration of the match, this cannot be substantiated within the present dataset. The lowered physical performance exhibited in the second half might simply be representative of the player managing their physical activity or indeed, a consequence of the high match-to-match variability observed in high-speed activities (Gregson et al., 2010). However to date, the variability of match-to-match physical performance has not yet been evaluated in females and warrants investigation. In order to ascertain the presence of fatigue as a causal contributor to the observed changes in physical performance metrics it would be necessary to undertake a series of performance assessments prior to and following the match (Andersson et al., 2008a).

The use of anonymous datasets such as those presented in Chapters 4 and 5 allow the extensive examination of specific components of performance by providing time efficient approaches to handling large sample sizes. Furthermore, the use of standardised speed zones and generic data analysis approaches allow the collation of large datasets which are necessary to minimise the influence of match-to-match variability and to detect real systematic changes in performance (Gregson et al., 2010). The physical demands of match-play assessed in Chapters 4 and 5 were analysed using arbitrary speed zones which have commonly been applied to male match-play data (Bradley et al., 2013; Di Salvo et al., 2013; Bush et al., 2015). Although this approach has been criticised in recent commentary

(Bradley and Vescovi, 2015), there remains no consensus within the literature as to appropriate recommendations for female-specific speed zones (Weston et al., 2012; Bradley and Vescovi, 2015). An attempt was made in Chapter 6 to apply a suitable approach to determine female-specific speed zones from maximal match-play running speed. It was highlighted that in general, elite female players achieve the standardised sprinting speed (>25.1 km.h^{-1}) during match-play. However, the standardised sprinting threshold represents 94 % of the average maximum female match-play running speed observed and therefore female players would need to be running at a speed close to their maximum for such movement to be classified as sprinting, which may result in some sprinting activity not being classified in this zone. Adoption of the female-specific speed zones presented in Chapter 6, which are on average 12.5 % lower than the standardised male zones, would result in small increases in THSR (25 % to 28 %) and TVHSR (8 % to 9 %) relative to TD. However, it is not possible to ascertain from the current dataset whether these zones, are any more closely aligned, or valid, to the specific movement speeds of elite female players than either male arbitrary zones (Bradley et al., 2013; Di Salvo et al., 2013; Bush et al., 2015) or recently suggested female-specific zones (Bradley and Vescovi, 2015). Future work should focus on deriving appropriate female-specific velocity thresholds from large samples of elite players, ascertained from activity patterns that replicate the movement demands of soccer (Weston et al., 2012). Consideration should also be given to the analysis of match physical performance of junior players to ensure that prescribed training activity is relevant to the game demands for different age groups (Reilly, 2005). To date, no information is available regarding the physical performance of elite youth female players using semi-automated camera systems, however, some initial observations have been highlighted with the use of GPS technology (Vescovi, 2014). Findings have shown an increase in total distance and distance at high speeds (>15.6 km.h^{-1}) with an increase in age (U15-U17) (Vescvoi, 2014).

Trends for positional differences were highlighted in each youth age group and these trends were similar to those previously reported in senior players.

The aim of the final two experimental chapters was to assess the influence of age and playing position on the physical characteristics of elite female soccer players, by using a series of anthropometric and performance measures. The data provided suggests that both junior and senior elite female players are able to adequately reproduce the specific performance tests and that the use of one familiarisation trial for national team players is sufficient. Application of the MPID allowed an estimation of suitable sample sizes required for future single sample test-retest tracking studies. This method of sample size estimation is considered best practice in the clinical literature (Cook et al., 2014) but to date, is less common in performance literature. As there are relatively few intervention studies conducted on female soccer players, there were some difficulties in obtaining literature for the MPID calculations for all performance variables. Therefore, in some instances closely aligned variables, for example sum of 6 skinfolds as opposed to sum of 8 skinfolds were used where data were not available. The findings demonstrated that relatively modest sample sizes (n~10 for anthropometric and n<10 for performance measures) were required to track changes in elite female soccer players. These estimated sample size requirements were used to inform participant recruitment in Chapter 8.

The normative data presented provides the most in-depth analysis of the physical characteristics of international female soccer players to date and provides unique information for professionals involved in player recruitment, talent identification and those responsible for the physical development of players. However, it should be noted that the current data only provides a snapshot of the physical characteristics of players and consequently fails to establish any within or between seasonal changes in performance. Available data on male players has shown within-season changes in anthropometric and performance measures (Krustrup et al., 2006; Magal et al., 2009; Carling and Orhant, 2010); however, few attempts have been made to evaluate such changes in females (Taylor et al., 2012; Bradley et al., 2014b). Assessing the influence of seasonal changes on anthropometric and performance characteristics would allow the effectiveness of phases of training within a periodised programme to be evaluated. Distinct influences of playing position on the elite female player's anthropometric and performance profile were observed. These differences allow normative data for each playing position to be established, which can directly impact upon position-specific training exercises (Reilly, 2005). Whilst, the current dataset is not able to fully explain the differences in physical profile between playing positions, certain aspects can be attributed to the differing match physical demands described in Chapters 4 and 5.

The elite player's anthropometric and performance profile improved with chronological age although some similarities were exhibited between younger (U15 and U17) and older (U19 and senior) age groups. Whilst the observed improvements in anthropometric and performance variables with age allow some level of informed decision making regarding appropriate content and delivery of training prescription (Lloyd and Oliver, 2012) the current study fails to consider the impact of biological maturity. It is recognised that the maturity status of players is an important aspect of the outcome of performance tests (Ford et al., 2011) and therefore the unknown impact of maturity status on the current data, particularly U15s should not be discounted.

The implications arising from this thesis relate to the ergonomics model of the analysis of soccer (Reilly, 2005). The thesis describes in detail the demands of match-play and the physical characteristics of players, including the influence of playing position and age. Collectively, the findings from these studies can be utilised to inform decisions relating to the selection and training of elite players (Figure 1.1). The studies show that the physical demands and physical characteristics of players vary for different playing positions and as such these positional requirements should be considered when designing and implementing soccer-specific training activities. Furthermore, a player's chronological age appears to influence their physical characteristics and the current data provides normative data for both age and playing position. Therefore the present findings provide a significant contribution to the understanding of the physical demands and characteristics of elite female soccer players.

9.3 PRACTICAL IMPLICATIONS

The current thesis provides unique information for professionals responsible for physical development and those involved in the player recruitment and talent identification of female soccer players. The physical match performance data presented in Chapters 4 and 5 can be utilised by practitioners to ensure that training activity is specific to both the game and the positional demands of female players. The normative anthropometric and physical performance data presented in Chapter 8 provides important insights into the influence of age and playing position on a range of fitness characteristics and provides benchmark information for elite level female players.

The physical match performance studies present for the first time, a detailed analysis of the demands of competitive international female match-play for five playing positions. Findings showed that a greater proportion of high-speed activity is undertaken during competitive international match-play (24 % of TD) compared to domestic-level matches (16 % of TD) (Mohr et al., 2008; Andersson et al., 2010a). Such results provide valuable information for those responsible for the physical development of elite level players and support the importance of appropriate conditioning levels in order to maintain the required work-rate for international match-play. Detailed positional comparisons highlighted a number of differences between playing positions. Central defenders completed less TD, THSR, TVHSR and RHSA bouts than all other outfield playing positions. The activity profile of CD was in contrast to WD, as large differences were observed between the two defensive positions for TD, THSR, TVHSR and RHSA bouts. Central midfielders completed the most TD and THSR, whilst WM completed the most TVHSR. Attacking-based players (A, WM and CM) completed more RHSA bouts than defensive players (CD and WD), with WM completing 76 % more bouts than CD. These positional differences are likely to be a direct consequence of the tactical role of each playing position within the team (Di Salvo et al., 2009). Such positional differences suggest that it may be necessary for practitioners to deliver position-specific conditioning programmes to reflect the demands of each playing position. Reductions in match physical performance metrics such as TD, THSR, TVHSR and RHSA were apparent between and within halves and although these may not be entirely attributed to fatigue it emphasises the importance of appropriate conditioning levels in order to maintain work rate.

During match-play the majority of sprints were less than 10 m in distance and an even distribution of explosive and leading sprints were observed. Consequently, soccer-specific sprint drills should predominantly focus on short acceleration based activities from both a stationary and rolling start. However, some sprint training over longer distances (>20 m) may also be required in order to condition players for longer sprint distances that may be necessary during match-play and also to develop maximum sprinting speed. The finding that attacking-based players (CM, WM and A) completed more TVHSR distance when a team was in possession whilst defensive players (CD and WD) completed more TVHSR distance when a team was out of possession provides an important link between tactical and physical decision-making. Specifically, this information may be used by the coach to affect decision-making on substitutions or by the physical trainer to direct post-match training and recovery routines.

It was observed that the occurrence of RSA bouts was rare during competitive international female match-play. Whilst this may in part be attributed to the use of standardised Prozone speed zones for data analysis, it also supports the importance of evaluating RHSA to ensure the physical demands of match-play are not underestimated. No player completed RSA bouts of four or more sprints and very few RHSA bouts were completed with six or more efforts. These findings have direct implications for the employment of suitable training and testing protocols (Reilly, 2005).

Anthropometric and performance testing represent an important component of an elite soccer player's development program (Hulse et al., 2013) and evaluating the reliability of such tests is necessary to assess the suitability for tracking changes over time (Hopkins, 2000). The observed findings demonstrated that both junior and senior elite female soccer players were able to reproduce a variety of soccer related performance tests following completion of one familiarisation trial. However it is recommended that practitioners replicate the methodology used in Chapter 7 with their own population before proceeding with anthropometric and performance assessments.

The anthropometric and performance data in Chapter 8 provides for the first time, a detailed analysis of the influence of age and playing position on a range of physical characteristics in a large sample of elite female soccer players. There were observed improvements in anthropometric and performance variables with chronological age as demonstrated by the qualitative descriptors based on magnitude-based inferences. However, some similarities were exhibited within the two younger (U15 and U17) and two older (U19 and senior) age groups. These between age group observations provide valuable information for those responsible for the physical development of elite level players and highlight the need to ensure the content and delivery of training is age appropriate (Lloyd and Oliver, 2012).

Detailed positional comparisons highlighted a number of differences between playing positions. Goalkeepers generally exhibited inferior anthropometric and performance capabilities compared to outfield playing positions. Goalkeepers are required to produce explosive actions throughout training and match-play and therefore their reduced scores for speed and power might be considered surprising. These findings provide important information for practitioners responsible for the physical development of elite players and suggest that the current methodologies employed for training GKs warrant investigation. Other positional differences were highlighted, with A and WM demonstrating the fastest linear sprint and repeated sprint times respectively and the highest intermittent endurance performance was observed in WD. Some of these positional differences can be linked to the physical match demands observed in Chapters 4 and 5, as A complete the most sprinting distance and WM the highest number of RHSA bouts. Collectively, the normative physical characteristics presented, provide unique data for professionals involved in player recruitment and talent identification, whilst the positional differences in performance characteristics, coupled with an in-depth understanding of the demands of match-play can be applied to ensure training specificity.

CHAPTER 10

RECOMMENDATIONS FOR FUTURE RESEARCH

The studies completed within this thesis provided an in-depth analysis of the physical demands and characteristics of elite players. In achieving this, a number of issues have arisen which have prompted the formulation of recommendations for future research.

Suggestions arising from Chapters 4, 5 and 8:

The data in Chapter 5 highlighted a lack of RSA in elite female match-play; however, a traditional test for RSA was included in the battery of performance assessments. The increased understanding of the match physical performance of elite female players gained from Chapters 4 and 5, will allow the development of a more specific group of performance assessments. Recommendations for future testing protocols would include the removal of the traditional RSA test and the inclusion of a test to determine maximal sprinting speed that could be utilised to determine individual speed zones.

Suggestions arising from Chapters 4 and 5:

The present data provides a comprehensive overview of the physical demands of competitive international female soccer in senior players; however, limited comparative research has been presented to date on the demands of junior match-play and as such this warrants investigation.

Success in soccer is a multi faceted and therefore physical demands of match-play should be contextualised against match-specific information such as playing formations, technical metrics such as ball possession and ultimately the result of the match. Aligning these technical and tactical factors with physical performance data will enable a greater understanding of the overall demands of match-play and is a suggestion for future research.

The current data showed a number of between-half reductions in physical performance; however, it was beyond the scope of the present investigation to identify a cause of such alterations. Therefore, future work to establish match-to-match variability as well as pre and post-match performance measures should be conducted in order to better understand within and between half changes in performance.

Match physical performance in the current studies was analysed using arbitrary speed zones that have commonly been applied to male match-play data (Bradley et al., 2013; Di Salvo et al., 2013; Bush et al., 2015). Whilst the current authors acknowledge the limitations of this approach and an attempt was made to propose female-specific speed zones from maximal match-play running speed (Chapter 6), there remains no consensus within the literature as to appropriate recommendations for female specific thresholds (Bradley and Vescovi, 2015). Consequently, future research should focus on deriving and validating appropriate female-specific speed zones utilising appropriate methodologies (Weston et al., 2012).

Suggestions arising from Chapters 7 and 8:

The current data highlighted that anthropometric and performance characteristics were influenced by chronological age, however, the present study failed to assess the impact of maturation status. The addition of maturation status information determined via skeletal hand-wrist x-rays, to such datasets will provide further relevance to those responsible for the physical development of youth players.

The current anthropometric and performance data does not distinguish between different time-points within a season and as such the presented data merely provides a snapshot of physical characteristics. Additional information relating to the effects of the playing season and intensified periods of training could be gleaned if data were collected at different time-points within a season.

CHAPTER 11

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