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Physical and Technical Demands of Women's Collegiate Soccer

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Physical and Technical Demands of Women's Collegiate Soccer

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ABSTRACT

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The purpose of this dissertation was to explore the physical and technical demands of the women's college soccer game through a case study approach. With advancements in technology, motion analysis has become commonplace in most professional environments. However, the literature on amateur soccer is quite scarce and warrants more attention. The aims of this dissertation were: 1) to describe the physical demands of each position for a women's college soccer player as they relate to total distance covered, efforts, and distance covered in high-speed velocity bands, 2) explore the variation in physical performance during a competitive season, and 3) compare the physical and technical performance of college soccer players to see if there are correlates in performance between variables. Eleven female collegiate soccer players from a single National Collegiate Athletic Association (NCAA) institution were tracked with Global Position System devices during a competitive season. Physical variables and technical variables were analyzed to gain further insight into the specific events that occur during a women's college soccer match. Significant differences exist between positions for total distance covered during a match, with the forward and central defensive midfielder position covering the greatest distance during a match on average. The central defender position covered a significantly less amount of distance during a match than the other five positional subcategories. Outside players (forward, outside midfielder, and fullback) covered the greatest distance at high-speed velocity bands and perform the highest

volume of high-speed efforts. The only significantly different technical variable found was the pass completion percentage of the central defensive midfielder compared with other positions. The current investigation highlights the unique characteristics of female collegiate soccer players when separated and analyzed by the positional subcategories. With uniqueness present in a once thought to be homogenous population the demand for individualized training protocols becomes paramount to increase chance of optimal performance while simultaneously decreasing risk of injury.

DEDICATION

I would like to dedicate this dissertation to my family – Thomas Alexander, Therese Alexander, and Christopher Alexander. Also, to those that have supported me in my professional and personal life in pursuit of this achievement.

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My colleagues at East Tennessee State University, from already graduated and those just starting, you all are the reason why waking up before the sun rises is worth it. Your friendship and commitment to your own concentrations in sports science is motivation to continue the pursuit for elite performance for our athletes. The best of luck to you in everything you do.

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INTRODUCTION

Introduction To Research Studies

With the development of technology the depth to which sports can be explored and analyzed has grown exponentially. Methods to analyze estimated work completed, effects on the physiological system, and exploration into the most efficient means of training have all become popular interests of coaches and sports scientists. Specifically, with respect to soccer, insight into the demands of soccer can be attained by an integration of monitoring and testing (both laboratory and field-based testing) investigations. Greater and more effective understanding of the effects of training and matches on the player's system could lead to more successful training methods that will help players achieve a higher level of playing performance in a more efficient time span.

With a myriad of demands and characteristics that can determine the success of an individual player and team, coaches are constantly searching for a better understanding of the physical demands of soccer. Soccer is characterized as a high-intensity sport that combines intermittent and random bouts of anaerobic and aerobic activities such as jogging, shuffling, short sprints, rapid acceleration and deceleration, turning, jumping, kicking, and tackling (Al Hazza et al., 2006; Bloomfield, 2006; Ekblom, 1996; Kirkendall, 1985; Wisloff, Helgerud, & Hoff 1998). For many decades the degree of stress and the physiological demands of soccer has been evaluated and the capability of the soccer players to meet these demands has been quantified (Strudwick, 2006). The quantification of these demands through the use of match and motion analysis has been restricted to the professional levels for many years because of the lack of funding and resources at the lower levels of soccer. Exploration of the college game is becoming more pertinent because of the increasing injury rates in female soccer players (Agel et al., 2005). Just as important, bridging the gap from previously established values of physical demands presented for the women's professional level (Andersson et al., 2010; Mohr et al., 2008) and the youth level (Vescovi, 2014) would further promote the understanding of the different demands at playing levels. Establishing these standards of physical performance at different playing standards would arm coaches with information to better train their players for the appropriate level at which they compete.

Recently, the use of motion analysis systems has given insight into the perspective of the physical work completed during a soccer match. Time motion analysis is a useful method to quantify the physical demands of individual players during match play (Rienzi et al., 2000). Technology now allows multiple players to be tracked simultaneously during a single match. The average range of distance covered in a given match is between 10 to 13 kilometers for the professional male and female soccer player, and it has been demonstrated that although the majority of the game, 80% - 90%, is spent at a lower intensity; the amount of high-intensity exercise separates top-class players from players of a lower standard (Andersson et al., 2010; Bangsbo, 1994b; Mohr et al., 2003). Many of the pertinent moments in a game are executed when a player is sprinting, jumping, accelerating, or changing direction at high speed. It has been suggested that the ability to accelerate quickly over short distances and change directions are the two main factors that are characteristic of soccer players, distinguishing them from players in other levels of football (Reilly et al., 2000). Bloomfield et al. (2007) was one of the first investigators to explore the detailed aspects of player movements during a match. Time spent completing specific movements within a match is evidence that training demands need to be tailored to specific player's position and playing level.

Over the last 4 decades several methods have been developed to evaluate player performances during soccer match play (Bangsbo, Norregaard, & Thorso, 1991). Unfortunately, it is common that these investigations have restricted analysis to physical performances and have neglected the technical demands of the game (Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009; Taylor, Mellalieu, James, & Shearer, 2008). A direct comparison of both physical and technical performance between equivalent leagues would be useful in determining whether game performance is general to all leagues or if each league has its own specific playing characteristics (Della et al., 2011). With this information training is likely to become more specific to position and playing level, which will increase the likelihood of optimal levels of performance being achieved while concurrently lowering the risk of injury.

The present dissertation is an attempt to investigate a relatively unexplored population of soccer players. The collegiate population is constantly increasing in quantity. Improper training methodology and pedagogy are prescribed on the basis of ill-informed coaches who want to replicate the 'elite' and professional levels. The current investigation is aiming to satisfy two present needs of sport science soccer community: first, filling the gap between reported youth physical demands (Vescovi, 2014) and the professional level (Andersson et al., 2010). With accurate descriptions of the physical and technical demands of the college game coaches are more likely to make accurate training decisions that will decrease the risk of injury and increase the level of performance of their athletes. Additionally, the present dissertation is an attempt to explore the effects of different training loads on match performance, specifically first versus second match of the week physical performance. The final objective was to analyze the potential fatiguing effects of a compact collegiate season on physical and technical characteristics of college soccer players.

Aims and Objectives

In order to gain further understanding on soccer at the collegiate level in the United States, there must be more descriptive analysis in the aforementioned environment. The advancement of sport science monitoring and testing systems has led to further analysis at the professional level, but the same investigations are still in a rather novel state in a female collegiate environment (Vescovi & Favero, 2014). Thus, the overall purpose of this dissertation was to document and examine the physical and technical demands of the collegiate soccer game of female players. As a result the following studies are described within this dissertation:

1. The analysis of high-speed profiles for a mid-level female collegiate soccer program.
2. The analysis of match-to-match variability during a female collegiate soccer season.
3. Analysis of technical proficiency and demands of collegiate female players during the course of a regular season

The hypotheses to be tested are that:

- The physical demands of the women's collegiate soccer game are similar to previously published literature on the international level of women's soccer
- Total distance covered per match is relatively unchanged throughout the course of a season, but the amount of high-intensity activities performed per match

decreases based on previous week's training loads.

- The technical proficiency of the female collegiate soccer game is less than that of previously published professional male soccer levels

Organization of Investigation

This investigation is presented in six main chapters. The review of literature examines the available studies documenting the physical, technical, and physiological performance characteristics of soccer players at all applicable levels. The physical demands and physiological characteristics are discussed along with the methods of assessments used to evaluate the soccer player population. Special reference throughout the review is given to the population most comparable to the collegiate soccer player present in the United States.

The general methods (Chapter 3) detail all the physical performance measures and technical analysis procedures and guidelines that form the basis of analysis in the current investigation. An outline of statistical processes used to find statistical significance in this dissertation is also provided.

The investigation outcomes (Chapter 6) are examined and explained in relation to the current investigation and their relation to previously explored studies in similar populations.

Conclusions and discussions (Chapter 7) extrapolated from the current dissertation are discussed with references to past literature. Comparisons of physical performance characteristics and physiological characteristics are made between collegiate soccer players and other populations of soccer players previously explored. All evidence inferring preferential training modalities and methods are related to the applicable populations.

Operational Definitions

1. Physical Demands: A measurement of the intermittent activity completed during a soccer match. Activity profiles are described differently between various soccer investigations but can generally fall into two main categories: high-speed activity (events occurring at speeds greater than 15.0 km•h^{-1}, Andersson et al., 2010) and low-speed activity (events occurring at speeds less than 15.0 km•h^{-1}, Andersson et al., 2010). Physical demands are usually listed in distance covered, efforts made, or percentage of time or total distance.

2. Match Analysis: Includes both physical and technical analysis used to quantify performance of a player individually or a team collectively. This form of analysis assists in clarifying and specifying the profile and characteristics of a soccer player (Dellal et al., 2010).

3. Time-Motion Analysis: Time-motion analysis is a useful method to quantify the physical demands of individual players during match-play (Rienzi et al., 2000).

4. High-Speed Velocity Bands: In accordance with Andersson et al., 2010,

High-speed running (15.1 – 18.0 km·h^{-1})

Sprinting (18.1 – 24.9 km·h^{-1})

Max sprinting (≥ 25.0 km·h^{-1})

5. Pass: A player in possession of the ball sends the ball to his or her teammate, consciously, using any aspect of his or her body.

6. Completed Pass: The ball is successfully received by a teammate after a pass from someone on his or her team without interruption or deflection of the intended pass

from the opposition and possession is maintained.

7. Ball Interaction: A player comes in contact with the ball by way of conscious effort to tackle an opponent who has the ball, receives the ball, passes the ball, clears the ball, or deflects the ball either voluntarily or involuntarily.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

This review of literature is an examination of the physical and technical demands of soccer and the physiological characteristics of soccer players. Special attention is given to the field-based monitoring tools that have been used to examine soccer players' physical abilities and the methods to which sport scientists can track their performance to better predict future performances. The current review is an examination of all ages and levels presented in the literature to display the differences in physical demands of the game, and then compared to any investigations or research completed on the American college level.

Match Analysis

The game of soccer, as regulated by the governing body of the Federation International of Football Association (FIFA), is played for 90 minutes, consisting of two 45-minutes halves separated by a 15-minute intermission for half-time. Play may be extended 30-minutes out of necessity to determine a finite winner at the professional level. At the college level in the United States the game is governed by the NCAA (National Collegiate Athletic Association) and is played for the same 90 minutes of regular time, and there is the potential for two sudden victory 10-minutes periods to determine a winner. In consideration for the following review, only the two 45-minute halves were considered to interpret the physical and technical demands of soccer at different levels.

When measuring the physical and technical demands of soccer, there are a number of factors that must be considered. Cultural and environmental factors (i.e. altitude and temperature) of match days, pitch dimensions, and tactical demands of the match are going to influence the outcome as well as an individual player's physiological load attained during that match. The instruments used to collect these data make it difficult to make a valid comparison of the physical performance of any two players across studies. Literature that first explored the physical demands of soccer was limited to a large degree by a low sample size. Initial investigations averaged athlete pools of 2 to 15 (Smaros, 1979; Van Gool et al., 1988; Whitehead et al., 1975; Withers et al., 1982).

Match analyses have been of increasing interest though as technology has continued to improve over the years. Match analyses are popular performance indicators that assist coaches in identifying good and bad performances of individuals or teams as well as in identifying the physical and technical demands of soccer and in examining how a particular player compares to the needs of his or her event (Di Salvo et al., 2007). To begin to understand the physical demands of the game, the total distance covered, the longest studied physical measure, is a necessary place to begin.

Distance Covered

Many investigators have analyzed the estimated work imparted on soccer players during a match according to the distance they are able to cover. Stølen et al. (2005) executed the largest comprehensive review on the 'Physiology of Soccer'. From 181 different investigations Stølen summarized the physical nature of the game and laid an in-depth foundation for the understanding of the physical demands of the game.

Table 2.1 displays all of the investigations analyzed within the Stølen (2005) review, and the distances covered as reported by each respective investigation. The early investigations (Agnevik, 1970; Winterbottom, 1952; Zelenka et al., 1967) were limited by small athlete pools they analyzed. Common to investigations analyzing new populations or areas of interest the methodology had not spread enough, nor was it widely enough used in the world to produce larger sample sizes. They also all used basic means of analyses. The methods of measurement for most investigations of this time were either hand notation or video analysis. Video analysis methods often included specially designed software using, usually one, and sometimes multiple, video camera points of view (POV) to determine distances covered during a match (Helgerud et al., 2001). In recent investigations, similar to the early analyses, Rienzi et al. (2000) the investigators would classify activities based upon the estimates of a trained observer using stride frequencies per second. The observer would plot the movements based on estimates of starting position and terminal position on the field where the defined activity was performed. Heavily dependent on a single observer's subjective opinion, there were many improvements that could be made it to increase validity and reliability.

Compared with today's methods of multi-video camera (i.e 8-16 video camera systems that allow for collection of multi-data points per second collection) systems the measurements of work completed in aforementioned papers are crude estimates and cannot be assumed to be nearly as precise as measurements today with the advancements in technology. As with the evolutionary advancements of technology, has the game of soccer evolved to different degrees of physical demands based upon cultural, technical, and tactical abilities of players from across the globe, or, on the other hand, with such a large degree of variation from Winterbottom et al. (1952) to the Stølen et al. (2005) has the game changed, or has the technology advanced to a degree to which we can now accurately report the true demands of the game?

Tables 2.2 displays the investigations of professional soccer players up to and after the review of Stølen et al. (2005).

Table 2.1. Distance Covered in Different Positions in Professional Soccer Players pre-Stolen et al. (2005)

Study	Level/Country	Sex	n	Distance covered (m) according to playing position, no. of players in parentheses				Method of
				Unspecified	Defender	Midfielder	Attacker	Measurement
Agnevik (1970)	Division 1/Sweden	M	10	10,200				Cine film
Bangsbo et al. (1991)	Division 1 and 2/Denmark	M	14		10,100 (4)	11,400 (7)	10,500 (3)	Video
Bangsbo (1994)	Elite/Denmark	F	1	9,500 (1) [a]				Video
Brewer and Davis (1994)	Elite/Sweden	F		> 8,500				
Ekblom (1986)	Division 1 and 4/Sweden	M	44		9,600	10,600	10,100	Hand notation
	Division 2/Germany	M	10	9,800 (10)				
Helgerud et al. (2001)	Elite juniors/Norway	M	10	9,107 (10)				Video
	Training group	M	9	1,035 (9)				
Knowles and Brooke (1974)	Professional/England	M	40	4,834				Hand notation
Mohr et al. (2003)	Division 1/Denmark	M	24	10,033 (24)				Video
	Top team/Italy	M	18	10,086 (18)				Video
	Combining both teams	M	42		9,740 (11) CB	11,000 (13)	10,480 (9)	
					10,980 (9) FB			
Ohashi et al. (1988)	National/Japan	M	2	9,845 (2)				
	League/Japan	M	2	10,824 (2)				
Reilly and Thomas (1976)	Division 1/England	M	32		7,759 (7) CB	9,805 (11)	8,397 (14)	Tape Recorder
			8		8,245 (8) FB			
Rienzi et al. (2000)	EPL/England	M	6	10,104 (6)				Video
	International/SA	M	17	8,638 (17)				
	EPL/SA International	M	23		8,695 (9)	9,960 (10)	7,736 (4)	
Saltin (1973)	Non-elite/Sweden	M	5	12,000				Cine film
Smaros (1980)	Division 2/Finland	M	7	7,100 (7)				TV cameras
Thatcher and Batterham (2004)	EPL first-team/England	M	12	9,741 (12)				
	EPL U-19/England	M	12	10,274 (12				
Van Gool et al. (1988)	University team/Belgium	M	7		9,902 (2)	10,710 (3)	9,820 (2)	Cine film
Vianni (1973)	Level uknown/Russia	M		17,000				
Wade (1962)	Professional/England	M		1,600 - 5,486				
Whitehead (1975)	Division 1/England	M	2		11,472 (1)	13,827 (1)		Hand notation
	Division 2/England	M	2		10,826 (1)	11,184 (1)		
	Top amateur/England	M	2		9,679 (1)	9,084 (1)		
	College/England	M	2		6,609 (1)	8,754 (1)		
Winterbottom (1952)	Professional/England	M		3,361				
Withers et al. (1982)	National league/Australia	M	15		10,169 (5) CB	12,194 (5)	11,766 (5)	Video
			5		11,980 (5) FB			
Zelenka et al. (1967)	Professional/Czech	M	1				11,500	

[a]= 80 minute game

CB = central-back; Czech = Czech Republic; EPL = English Premier League; F = female; FB = full-back; M = male; SA = South America; U = under

Table 2.2. Distance Covered in Different Positions in Professional Soccer Players post-Stolen et al. (2005)

Table 2. Distance covered in different positions in male and female soccer players (adapted from Stolen et al, 2005)

Study	Year of Analysis and/or Publication	Level/Country	Sex	n	Distance covered (m) according to playing position, no. of players in parentheses: Unspecified	Defender	Midfielder	Attacker	Method of Measurement
Winterbottom	1952	Professional/England	M		3,361				Cine film
Wade	1962	Professional/England	M		1,600 - 5,486				Video
Zelenka et al.	1967	Professional/Czech	M	1				11,500	Video
Agnevik	1970	Division 1/Sweden	M	10	10,200				
Saltin	1973	Non-elite/Sweden	M	5	12,000				Hand notation
Vianni	1973	Level uknown/Russia	M		17,000				
Knowles and Brooke	1974	Professional/England	M	40	4,834				Video
Whitehead	1975	Division 1/England	M	2		11,472 (1)	13,827 (1)		
	1975	Division 2/England	M	2		10,826 (1)	11,184 (1)		Hand notation
	1975	Top amateur/England	M	2		9,679 (1)	9,084 (1)		Video
	1975	College/England	M	2		6,609 (1)	8,754 (1)		Video
Reilly and Thomas	1976	Division 1/England	M	32		7,759 (7) CB	9,805 (11)	8,397 (14)	
	1976			8		8,245 (8) FB			
Smaros	1979	Division 2/Finland	M	7	7,100 (7)				
Withers et al.	1982	National league/Australia	M	15		10,169 (5) CB	12,194 (5)	11,766 (5)	
	1982			5		11,980 (5) FB			Tape Recorder
Ekblom	1986	Division 1 and 4/Sweden	M	44		9,600	10,600	10,100	
	1986	Division 2/Germany	M	10	9,800 (10)				Video
Ohashi et al.	1988	National/Japan	M	2	9,845 (2)				
	1988	League/Japan	M	2	10,824 (2)				
Van Gool et al.	1988	University team/Belgium	M	7		9,902 (2)	10,710 (3)	9,820 (2)	Cine film
Bangsbo et al.	1991	Division 1 and 2/Denmark	M	14		10,100 (4)	11,400 (7)	10,500 (3)	TV cameras
Bangsbo	1994	Elite/Denmark	F	1	9,500 (1) [a]				
Brewer and Davis	1994	Elite/Sweden	F		> 8,500				
Rienzi et al.	2000	EPL/England	M	6	10,104 (6)				Cine film
	2000	International/SA	M	17	8,638 (17)				
	2000	EPL/SA International	M	23		8,695 (9)	9,960 (10)	7,736 (4)	
Hennig and Briehle	2000				10,600				
Helgerud et al .	2001	Elite juniors/Norway	M	10	9,107 (10)				Hand notation
	2001	Training group	M	9	1,035 (9)				
Di Salvo et al.	2002-2004	La Liga/Spain	M	300	11,393 ± 1,016	10,627 ± 893 CB	12,027 ± 625 CM	11,254 ± 894	Amisco
						11,410 ± 708 FB	11,990 ± 776 EM		
Mohr et al.	2003	Division 1/Denmark	M	24	1,033 (24)				
	2003	Top team/Italy	M	18	1,086 (18)				
	2003	Combining both teams	M	42		9,740 (11) CB	11,000 (13)	10,480 (9)	
	2003					10,980 (9) FB			
Thatcher and Batterham	2004	EPL first-team/England	M	12	9,741 (12)				Video
	2004	EPL U-19/England	M	12	10,274 (12				
Vigne et al.	2004-2005	Serie A/Italy	M	293	8,929 ± 3,515	9,698 ± 2,901	8,943 ± 3,992	7,733 ± 3,650	
Krustrup et al.	2005	Elite	F	14	10,300				
Dellal et al	2005-2006	French first league/France	M	3540		10425 ± 808 (1000) CB	11,501 ± 901 (952) CDM	10,942 ± 978 (464)	Amsico
	2005-2006					10,655 ± 860 (756) FB	12,209 ± 977 (202) WM		
	2005-2006						11,726 ± 984 (166) CAM		
Rampinini et al.	2007a	Professional	M		10,864				
Di Salvo et al.	2006	Elite European	M		11,393				
Rey et al.	2006	Spanish League/Spain	M	42	11,052				Amisco
Dellal et al	2006-2007	Premier League/England	M			10,617 ± 857 (1704) CB	11,555 ± 811 (1356) CDM	10,802 ± 992 (724)	Amsico
						10,775 ± 645 (132) FB	11,779 ± 706 (76) CAM		
							11,040 ± 757 (50) EM		
Dellal et al	2006-2007	La Liga/Spain	M			10,496 ± 772 (624) CB	11,247 ± 913 (616) CDM	10,717 ± 901 (262)	Amsico
						10,649 ± 786 (212) FB	11,004 ± 1,164 (82) CAM		
							11,240 ± 761 (100) EM		
Hewitt, Withers, & Lyons	2007	International/Australia	F	6	9,140 ± 1,030				GPS
Scott & Drust	2007	International	F	30	11,979 ± 1,325	11,099 ± 1,399 CB	12,971 ± 537	11,804 ± 1,276	Reilly and Thomas 1976
						12,636 ± 419 FB			
Barros et al	2007	First Division Championship/Brazil	M	112	10,012 ± 1024	9,029 ± 860 CB	10,476 ± 702 CM	9,612 ± 772	Auto Computer Tracking
	2007					10642 ± 663 FB	10,598 ± 890 EM		
Rampinini et al.	2007b	Professional/Italy	M	20	11097 ± 778	9,995 ± 652 (60) CB	11,748 ± 612	10,233 ± 677	ProZone
					10827 ± 760	11,233 ± 664 (70) FB			
Gabbett and Mulvey	2008	Australia	F	13		9,621 ± 1202	10,672 ± 1338	9,609 ± 359	4-camera Video Analysis
Mohr et al.		International/Denmark and Sweden	F	19	10,330 ± 150				
Rampinini et al.	2009	Professional/Italy	M	186	11,647				6-camera Video Analysis
					12,190				
Bradley et al.	2009	Premier League/England	M	370		9885 ± 555 (92) CB	11,450 ± 608 CM	10,314 ± 1,175	ProZone
	2009					10,710 ± 589 FB	11,535 ± 933 EM		
Di Salvo et al	2010	International/Sweden and Denmark	F	17	9,900 ± 1,800 (17)	9,500 ± 900 (9)	10,600 ± 300 (5)	9,800 ± 200 (3)	Computerized Coding Video Analysis
	2010	Domestic top league/Sweden and Denmark	F	17	9,700 ± 1,400 (17)	9,500 ± 100 (9)	10,100 ± 300 (5)	9,500 ± 500 (3)	
	2010	Elite/International/European	M		10,666 ± 566				ProZone
	2010	Domestic European	M		10,859 ± 980				
Andersson et al.	2011	Premier League/England	M	153	10,697 ± 945	10,452 ± 755	11,505 ± 783	9,982 ± 769	ProZone
	2011				10,786 ± 1,041	10,073 ± 852	11,586 ± 494	11,130 ± 999	
Bradley et al.	2011				10,613 ± 1,104	10,123 ± 875	11,606 ± 722	10,012 ± 946	
	2013	UEFA Champions League	M	54	11,142	10,301 CB	12,251 CM	11,319	Amisco
Bradley et al.						10,974 FB	11,394 EM		
	2013	UEFA Champions League	F	59	10,754	10,238 CB	11,160 CM	10,766	
						10,706 FB	10,929 EM		
Bradley et al.	2013	Premier League/England	M	190	10,722 ± 978	9,816 ± 567 CB	11,445 ± 647 CM	10,320 ± 968	ProZone
						10,730 ± 623 FB	11,612 ± 803 WM		
		Championship/England	M	155	11,429 ± 816	10,732 ± 612 CB	11,878 ± 670 CM	11,256 ± 756	
						11,426 ± 560 FB	12,200 ± 666 WM		
Bradley et al.		League 1/England	M	366	11,607 ± 737	10,980 ± 442 CB	12,277 ± 538 CM	11,391 ± 680	
						11,474 ± 512 FB	12,043 ± 662 WM		
	2006-2010	Premier League/England	M	1,241	10,746 ± 964	9,901 ± 619 CB	11,487 ± 727 CM	10,451 ± 944	
						10,639 ± 609 FB	11,496 ± 821 WM		
		Champions League/Europe	M	1,494	11,102 ± 916	10,341 ± 611 CB	11,784 ± 711 CM	10,783 ± 877	
						11,035 ± 663 FB	11,766 ± 775 WM		

[a]= 80 minute game

CB = central-back; Czech = Czech Republic; EPL = English Premier League; F = female; FB = full-back; M = male; SA = South America; U = under

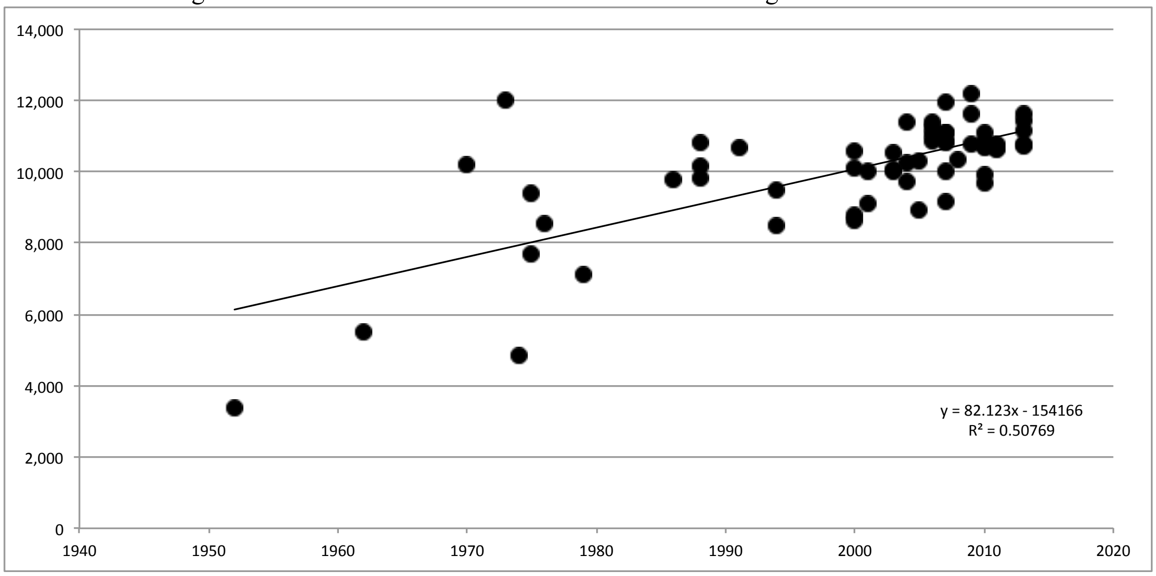
Prior to 2005 literature interpreted a range of 7,100 meters – 17,000 meters as the average distance that a player, independent of position, covered during a match (Table 2.1). Since that review, numerous investigations have shown evidence of distances between 9,700 meters up to 13,007 meters being covered by different positions (Table 2.2). Although still well within the range of the earliest findings, research in more recent years is able to focus on a more specific range, which could possibly lead to more efficient training methods.

An emphasis has always been placed on the importance of aerobic performance and maximal aerobic capacity in soccer players (Stølen et al., 2005). Stølen reviewed multiple papers reporting ranges from 50 – 75 ml/kg/min for maximum oxygen uptake values in male outfield players, and anaerobic thresholds of approximately 76.6% - 90.3% of HR_{max} (Heart rate maximum). With distances covered in a match ranging up to 17,000 meters, or just over 10.5 miles, there would be an increased regard for low-intensity, long-duration work. From this simple measure the sport could easily be perceived as highly aerobic in nature. With a shift in technology the depiction of work completed during a match is more accurate and can potentially shed light on the means by which players are completing work. This topic of motion analysis is discussed at a later point in the review of literature.

Combining to compare the two tables in a time –series analysis (Figure 1) shows a positive trend in the total distance covered in matches starting from the first reported investigation of matches in 1952 to the most recent investigation in the literature. Vianna's (1973) study reporting 17,000 meters as the distance covered for players was thrown out of the current analysis as no other investigation comes close to supporting this distance covered in a league that is considered levels below the top professional leagues in the world. The findings from this time-series analysis can be interpreted in two contrasting perspectives. First, the game appears to grow increasingly more and more physically demanding as time progresses according to the distance that is being covered during matches, independent of playing position. The results do still however show across the literature that the physical demands remain quite varied and could have underlying reasons based on a myriad of other factors (e.g. technical, tactical, cultural, and environmental). Second, the findings across all of the reported investigations vary drastically and are not comparable as a result of the different modalities of data collection used. Both are acceptable interpretations of the graph and should be recognized. For the purpose of this review the author is merely trying to show the variability in measurements and trying to interpret that variability is not so much dependent upon data collection modalities but more a result of the other factors listed previously.

Around 1991 the measurements found in the literature began to get more clustered; one can suspect that the earliest of studies using mainly hand notation and "expert" analysis would not be as accurate as the 25 Hz multi-camera video analysis systems that are widely used in today's match stadiums. With this increase in accuracy of data collection there still appears to be a positive trend that is argument for the ever-increasing physical demands of the game.

Figure 2.1 Total Distance Covered in a Match According to Literature Trend



Comparing the two eras, averages are given in Table 2.3. There was an increase in distance covered by players per position independent of country or league the players were competing in.

Table 2.3. Comparison Before Stolen et al. (2005) and After Stolen et al. (2005)

	Defenders	Midfielders	Forwards
Prior to Stolen et al. (2005)	9,586 ± 1,547	10,752 ± 1508	9,720 ± 1458
Post Stolen et al. (2005)	10,509 ± 679	11,432 ± 700	10,444 ± 866

Distances given in meters

Consistent across all literature, the midfield position is the most physically demanding based on the overall distance covered during a match. Compared with the earliest investigations, the more specific the investigators have gotten in the subcategories of positions of field players. Early investigations had three subcategories for outfield positional players, defender, midfielder, and forward. In the most recent investigations, the positional breakdown is centerback or central defender (CB or CD), fullback or external defender (FB or ED), center-midfielder defensive or attacking (CDM or CAM), external or wide midfielder or outside midfielder (EM or WM or OM), and attacker

(ATT). The more specific the investigations have been the more insight there is to the difference between positional subcategories.

Distance Covered: Level of Play

Recent literature has shown that distance covered during a competitive soccer match is dependent upon playing position (Barros et al., 2007; Dellal et al., 2010), playing level (Bradley et al., 2013a; Bradley et al., 2014), team possession (Bradley et al., 2013b), and tactical formation (Bradley et al., 2011). There is evidence that total work completed can vary significantly. There have also been relationships between the distance covered during a game and the level of competition (Dellal et al., 2011; Reilly et al., 2008). Whitehead (1975) analyzed four different levels of male competitions in England (Table 2.4).

Table 2.4. Distance Covered by Defenders and Midfielders of Different Levels of Competition

	Defender	Midfielder
Division 1/England	11,472	13,827
Divison 2/England	10,826	11,184
Top amateur/England	9,679	9,084
College/England	6,609	8,754

***Measurements given in meters

Unfortunately, the sample size in the study, as stated earlier was small (n=2) in each of the four standards of play. The two top-level players competing in the first division appeared to perform the larger amounts of work when compared to the lower divisions. Although not significantly different from the next lowest division, it is notable that the players performed work in a descending manner from the highest level of competition to the lowest level. Another major limitation, in addition to the sample size, is that there were no attacking players analyzed in this study. Also, being one of the earliest studies to analyze positional differences, the breakdown is not nearly as specific as positional breakdowns in more recent literature. Conclusions from the Whitehead

(1975) investigation appear to support that the highest standard of soccer covers the greatest amount of total distance during a match and was interpreted that the highest level player has the greatest physical demands across all standards. This notion was later challenged by Bradley et al. (2013).

Similar to the Whitehead (1975) study, Bradley et al. (2013) reviewed the top three competitive standards of English professional soccer. As reported by the investigators the main findings from this analysis were: (1) less total and high-intensity running distance was covered in the highest standard of play compared to the lower standards of English soccer, League 1, 10,980 ± 442 meters versus Championship, 10,732 ± 612 meters versus Premier League, 9,816 ± 567 meters; and (2) technical indicators in the highest standard of English soccer were superior to the lower standards. Investigators linked these two findings together by theorizing that the technical demands were reasons to believe the distinct difference between physical performances in different playing standards. More research is needed to further unveil the discrepancies between playing standards.

Distance Covered: Region of World

Other attempts to compare across regions of the world are much more difficult because no study has had access to multiple leagues for a single investigation. Many investigations have explored various regions of the world (Table 2.2), and evidence from a general analysis could lead one to believe that there exist cultural differences in the physical nature of soccer. Considering only the more recent literature that used 25-Hz multi-camera collection methods for the purpose of consistency in analysis, it appears that England consistently has players who cover the greatest distance across numerous investigations (Bradley et al. 2011; Bradley et al. 2013; Dellal et al. 2011). South American, Italian, Scandinavian, and South African league players cover a noticeable less total distance during matches as reported by the literature (Bangsbo 1994; Barros et al. 2007; Mohr et al. 2003; Rienzi et al. 2000).

Specifically one study has analyzed these differences across leagues (Dellal et al., 2011). Dellal and colleagues compared the physical and technical performance in competitive match play between two major European soccer championships (England and Spain). With respect to playing positions the English league central attacking midfielders covered a greater distance than the Spanish league central defensive midfielders (~775 meters more). Reasoning for this, as indicated by the investigators, was linked to playing formations commonly implemented in the English league (Dellal et al., 2011).

Distance Covered: Playing Position

Consistent with the advances in technology, the detail that the game has been studied increased, which lead to the findings of Barros et al. (2007) and the positional differences within a single soccer match (Table 2.5).

Table 2.5. Distances Covered (meters) in Different Ranges of Velocity Bands in Men's Brazilian First Division Soccer. Adapted from Barros et al., 2007

Positions	Total Distance
Central Defenders	9,029 ± 860
External Defenders	10,642 ± 663
Central Midfielders	10,476 ± 702
External Midfielders	10,598 ± 890
Forwards	9,612 ± 772
Total Distance by Match	10,012 ± 1,024

First Division Championship Brazilian soccer players were analyzed across the five positional subcategories (Barros et al., 2007). The First Division Championship is understood to be the highest division in the country. As mentioned earlier, compared to previous literature these distances covered are near the bottom of the average of the typical distance covered by a top class male outfield player during a match. Di Salvo et al. (2006) investigated the highest level of soccer in Europe (The Club European Champions League) and found that the mean distance covered by all players was 11,393 meters. Central defenders covered the least amount of distance (10,627 m ± 893 m) and the central midfielders covered the greatest distance (12,027 m ± 625 m). The external defenders (11,410 m ± 708 m), external midfielders (11,990 m ± 776 m), and forwards (11,254 m ± 894 m) were almost all entirely above the highest distance covered in the Brazilian investigation.

As previously mentioned, the evolution of subcategories for outfield players has now progressed to six (centerback or central defender (CB or CD), fullback or external defender (FB or ED), center-midfielder defensive or attacking (CDM or CAM), external or wide midfielder or outside midfielder (EM or WM or OM), and attacker (ATT). Up to 2011 there was no differentiation between the central midfield positions. Dellal et al. (2011) first differentiated the central midfielder position with the reasoning that the central defensive midfielders hold significantly different tactical roles and responsibilities from those of the central attacking midfielders. The results showed that the physical demand of each position is different as well because central defensive midfielders ran a substantially greater distance than central attacking midfielders (Dellal et al., 2011).

Distance Covered: Women's Soccer

When analyzing the women's game, Bangsbo et al. (1994) reported that the average female soccer player from the elite Danish league covers approximately 9,500 meters in a match. This was 1,000 meters greater than the 8,500 meters reported by Brewer and Davis (1994). It appears that there do exist significant differences between males and females with respect to distance covered during a soccer match. Mohr et al. (2008) analyzed elite (U.S. first division teams) and top-class players from the top divisions in the Danish and Swedish leagues and found mean distance covered during the match was 10.33 ± 0.15 km for the elite players and 10.44 ± 0.15 km for the top-class players. Although not statistically significantly different, the increase in distance covered by the lower class players may have been a result of the lower skill level, therefore, increased amount of turnovers resulting in recovering or defensive runs. Similar to previous men's studies, the elite women covered a greater distance in the first half compared to the second halves (5.28 ± 0.09 km vs. 5.05 ± 0.08 km), whereas the top-class players performed a near identical distance in both the first and second half (5.22 ± 0.09 km vs. 5.21 ± 0.08 km). Unlike previous analysis of the men's match, the women's analysis did not display any statistical difference between total distances covered between different playing positions (Mohr et al., 2008).

More recent, Vescovi and Favero (2014), in the only study published on similar population to the current investigations, reviewed the physical demands of the women's collegiate soccer game. In an attempt to fill in the gap between previously reported youth (Vescovi, 2014) measures of 6.5 -9.0 kilometers and the more widely published professional data, Vescovi and Favero found that on average female collegiate soccer players covered between 9.5 and 10.2 kilometers during a competitive match. With professional women reportedly covering over 10 kilometers (Andersson et al., 2010; Mohr et al., 2003) it appears that there is a natural physical progression in the women's game that may be indicative of physical matriculation more so than technical differences.

In summary, it is interpreted that the physical demand of the game differs based on playing position, team tactics, level of competition, and gender. With respect to the collegiate level in the United States, there has been only one study on the female population, to the investigators knowledge, on the total work performed during a soccer match. Therefore, more research should look into the collegiate level to see if the physical demand of 'top-class' players correlates with the collegiate level in the United States.

Motion Analysis Soccer Players

Overall distance travelled was for decades of soccer literature the standard of measure for work completed during a soccer match. Recently with the developments of new technologies there has been an increase in the number of studies analyzing specific movements within a match (e.g. sprinting, jogging, and walking). Motion analysis entails determining work-rate profiles of players within a team and classifying activities in terms of intensity, duration, and frequency (Reilly, 1994). One of the pioneering investigations describing motion analyses was the work of Reilly and Thomas (1976). The investigation counted the number of strides per player for a discrete activity and then estimated distance covered during that activity by multiplying stride repetitions by the average stride length for the movements standing, walking, jogging, and sprinting. Over the past 4 decades technological advances have allowed more frequent and precise motion analyses in soccer (Table 2.6). The premise of motion capture is to objectively account for the frequent alterations of activities, numerous accelerations and decelerations, changes of directions, unorthodox movement patterns, and execution of various technical skills that may not be able to be replicated in a controlled environment (Bangsbo, 1997; Reilly, 1997), thereby, depicting a more accurate external load exerted by a player during a competitive soccer match.

Table 2.6. Percentage of Distance Covered in Different Modes of Movement

Study	Players	Position	Walk	Side/back	Jog	Cruise	Sprint
Reilly and Thomas (1976)	Professional (England)	Full-back	27.8	8.1	35.2	19.2	9.5
		Centreback	22.9	8.4	37.5	20.6	10.7
		Midfield	20.7	5.2	41.2	22.0	10.8
		Forward	27.5	5.9	33.0	20.9	12.7
Withers et al. (1982)	Semi-pro (Australia)	Fullback	23.7	8.9	45.0	14.5	7.9
		Centerback	30.3	15.3	37.9	12.5	3.9
		Midfield	21.9	7.8	49.9	15.1	5.3
		Forward	29.8	10.1	44.4	10.0	5.8
Van Gool et al. (1988)	University (Belgium)	Defense	44.9		49.1	10.0	
		Midfield	39.0		53.2	6.0	
		Forward	47.1		44.1	7.7	
Ohashi et al. (1988)	International (Japan)		31.1		56.1	10.5	2.3
Reilly (2000)			25.0	7.0	37.0	20.0	11.0
Rienzi et al. (2000)	International (South American)	Defenders	31.0	14.0	45.0	8.0	3.0
		Midfielders	25.0	12.0	49.0	11.0	3.0
		Forwards	39.0	9.0	34.0	12.0	7.0
Strudwick and Reilly (2001)	Premier League (England)		36.0	5.0	38.0	10.0	3.0

(Adapted from Hulse, M.A. *Physical Development, and Progression to Professional Soccer, of Elite Child and Adolescent Academy Players*. (2010).

Easily depicted by Table 2.6 is that the majority of a soccer match is spent in low-speed activities. With such a low percentage of the overall work being completed in high-speed activities, it has become extremely important over time to understand these high-speed activities to see if it is these events that separate players of different standards. Before investigating specific events and efforts at various speed intensities it is important to note the inconsistencies in the literature for reporting high-speed activities.

Table 2.7 displays velocity bands that are used across recent investigations in soccer literature. At this time it is important to note that comparisons across different investigations for time spent in different velocity bands is difficult as it evident in the literature that velocity band ranges have not been fully agreed upon. All the publications listed in Table 2.7 are specific to male investigations. Female investigations (Andersson et al., 2010; Krustrup et al., 2005) are more consistent with their classification of velocity bands.

Table 2.7. Velocity Bands Presented in Recent Literature

Study	Velocity 1	Velocity 2	Velocity 3	Velocity 4	Velocity 5	Velocity 6	Velocity 7
Di Salvo et al. (2013)		0.2 - 7.2	7.3 - 14.4	14.5 - 19.8		19.9 - 25.2	> 25.2
Bradley et al. (2013a)		< 7.1	7.2 - 14.3	14.4 - 19.7		19.8 - 25.1	> 25.1
Barros et al. (2007)		0 < V1 < 11		11 ≤ V2 ≤ 14	14 ≤ V3 ≤ 19	19 ≤ V4 < 23	V5 ≥ 23
Bradley et al. (2013b)	0 - 12.0	12.0 - 15.0	15.0 - 18.0	18.0 - 21.0	21.0 - 23.0	23.0 - 25.0	25.0 - 27.0
Bradley et al. (2011)	0.0 - 0.6	0.7 - 7.1	7.2 - 14.3	14.4 - 19.7	19.8 - 25.1	> 25.2	
Mohr, Krustrup, & Bangsbo (2003)	0	0.1 - 6.0	6.1 - 8.0	8.1 - 12.0	12.1 - 15.0	15.1 - 18.0	18.1 - 30.0

All values are written in $km \cdot h^{-1}$

With the implementation of speed and time spent in different speed bands, analyses are no longer limited to total distance covered in a match through estimations based on stride lengths; instead researchers are now able to analyze physical activity (i.e. total distance covered, distances covered at varying intensities, distances covered at high-intensities both with and without possession of the ball) simultaneously with precision (Dellal et al., 2011; Di Salvo et al., 2006).

Time spent and distance covered at these velocity bands are analyzed to explore the differences in the actions performed during a soccer match. It has been previously stated that a player's ability to perform work at these high-intensity velocity bands was what separated players of higher standards from players of lower standards (Bangsbo et al., 2006). Mohr, Krustrup, and Bangsbo (2003) compared time-motion analysis of 24 professional Danish players (age 26.5 ± 1.0 years) and 18 professional players (26.4 ± 0.9

years) from the top Italian division. Although both populations were regarded as 'professional', the Danish population represented the lower level of the two populations. The locomotor categories for analysis were standing (0 km•h^{-1}), walking (6 km•h^{-1}), jogging (8 km•h^{-1}), low-speed running (12 km•h^{-1}), moderate-speed running (15 km•h^{-1}), high-speed running (18 km•h^{-1}), sprinting (30 km•h^{-1}), and backward running (10 km•h^{-1}) in accordance with Bangsbo et al. (1991). Results from the study showed top-class players performed more high-speed running (2.43 vs. 1.90 km) and 58% more sprinting (650 vs. 410 m) than professional players of a lower standard (Mohr, Krustrup, & Bangsbo, 2003). When comparing this study to the Bangsbo et al. (1991) study there was an increase in sprinting during the game by 37%. The authors accounted for this increase in high-intensity running because of the rule change introduced in 1992 by FIFA, stating that the goalkeeper could no longer pick up a back pass from an outfield player (Bangsbo, 1994, Reilly, 1994a).

These findings were consistent across sexes as well. Andersson et al. (2010) analyzed 17 top-class female women soccer players from the national team in Sweden and Denmark in a domestic and international level matches. The results showed that there was a difference found in the number of high-intensity runs, distance covered in high-intensity runs, and total sprint distances, which were all higher in the international competition. Nonetheless, the players being analyzed in the two competitions were identical. Inclusion criteria were that the players had to participate in both levels of matches for the entire match and they had to play the identical position for both teams. Therefore, it is not so much a difference in standards of player, but instead it is a difference in the nature of play. Although this difference may still be relevant to the level of training demanded for the different competitions, the separation does not appear to be in the standard of player at different levels.

Mohr et al. (2008) studied 19 women's national team soccer players currently playing in the professional league in the United States. These 19 players match activities were compared with 15 "elite" players from the Danish and Swedish leagues. Results showed that the top-class players ran longer at high intensities and sprinted more compared to high-level women players competing at a lower standard. However, a concern in the study was that the higher standard of players were observed in either international matches or the U.S top league matches, whereas the lower-standard players were investigated in Danish or Swedish league matches. There does not appear to be designation of which players were observed in league or international matches from the higher standard players that may mislead the results.

Furthermore, Mohr et al. (2003) analyzed the match activities of 18 professional top-class soccer players all of whom were playing for an elite European team, competing in the Italian league and in the European Champions League versus 24 Danish league players. Results of this study showed that top-class players performed 28% and 58% more high-intensity running and sprinting, respectively, during a game ($p < 0.05$, Mohr et al., 2003). Again, as previously mentioned, there are discrepancies in attempting to compare standards of play across regions of the world as the diversity of styles and tactics of play appear drastic and the competitions do not equal.

However, further analysis of these early studies show that there are inconsistencies in this once thought well-supported theory (Bradley et al., 2013).

Bradley and colleagues is the first investigations to the author's knowledge that explores the differences in physical demands between playing levels within the same country. The importance of within the same country allows the investigator to assume similar cultural styles of play, which would negate some of the myriad of variables that may influence the physical demands of the game. This study compared match performance players from the FA Premier League (n=56), Championship (n=61), and League 1 (n=32). The main findings from the Bradley study were, first, that less total and high-intensity running distances were covered in the Premier League compared to lower standards in English soccer, second, that technical indicators in the Premier League were superior to both the Championship and League 1 divisions, and finally, that physical capacity did not differ between players in each standard according to position but correlated with high-intensity running performed in competition. It appears from a review of the literature to date, that high-intensity running does not appear to be a valid measure of different standards of play when considering similar leagues.

Table 2.8 displays all the recent and pertinent literature on the topic of work completed in different velocity bands. It appears there are some consistencies across all standards as well as sex for thresholds of work being completed in the highest speed velocity bands. Attempting to find an absolute value of performance, like total distance covered, is going to be highly impacted by many different physical performance variables.

Table 2.8. Distance Covered in Different Velocity Bands According to Study

Study	Players	Standing	Walking	Jogging	Low-Speed Running	Moderate-Speed Running	High-Speed Running	Sprinting
Andersson et al. (2010)	International (F)					1,530		256
	Domestic (F)					1,330		221
Barros et al. (2007)	Brazilian (M)		5,537		1,615	1,731	691	437
Bradley et al. (2009)	FA Premier League (M)						2,492	
Bradley et al. (2010)	International (M)	22	3,872	4,252		1,609	660	251
	Domestic (M)	27.3	3,803	4,284		1,758	722	265
Bradley et al. (2011)	FA Premier League (M)		3,774		4,290	1,677	956	
			3,832		4,304	1,725	924	
			3,907		4,121	1,684	901	
Bradley et al. (2013)	UEFA Champions League (M)					3,621	1,184	
	UEFA Champions League (F)					3,151	777	
Bradley et al. (2013)	Premier League (M)		3,824	4,259		1,711	681	248
	Championship (M)		3,701	4,630		1,987	803	308
	League 1 (M)		3,602	4,708		2,056	881	360
Dellal et al. (2010)	French First League (M)						230	199
	French First League (M)						274	241
	French First League (M)						302	220
	French First League (M)						335	235
	French First League (M)						334	234
	French First League (M)						300	290
Dellal et al. (2011)	Spanish La Liga (M)						278	229
	FA Premier League (M)						293	253
Di Salvo et al. (2008)	Champions League (M)		7,031		1,654	1,754	605	337
Di Salvo et al. (2009)	FA Premier League (M, CB)					681		167
	FA Premier League (M, FB)					911		238
	FA Premier League (M, CM)					928		217
	FA Premier League (M, WM)					1,049		260
	FA Premier League (M, FW)					968		262
Di Salvo et al. (2010)	UEFA Champions League (M)							205
Di Salvo et al. (2013)	Champions League (M)		3,709	4,468		1,877	750	273
	Premier League (M)		3,794	4,255		1,721	693	258
Gabbett and Mulvey (2008)	Australian (F)		3,213	4,275		1,484	995	
Gregson et al. (2010)	Premier League (M)						680	235
Mohr et al. (2008)	International (F)					1,680		460
	Domestic (F)					1,300		380
Rampini et al. (2007)	UEFA Champions League (M)						902	

* All distances reported with respect to meters

Movement analyses can also be presented as a percentage of overall work completed. Bloomfield et al. (2007) determined that the percentage of time spent completing various activities on the field differed based on the position of the player involved. These investigators developed a movement classification system to motions performed by players of the FA Premier League during competitive matches (Bloomfield et al., 2004). Bloomfield Movement Classification (BMC) system categorized movements either as standing, walking, jogging, running, sprinting, skipping, shuffling, or other. Table 2.9 displays the breakdown of the analysis with player's movements separated by position (Bloomfield et al., 2007). As is evident in Table 2.8, the complexity of the physiological demands of soccer is severe, and even more importantly, the physiological demands at each position are significantly varied. Investigators determined strikers, midfielders, and defenders spent on average 44.1%, 43.2%, and 53.6% standing, walking, or jogging, respectively. Although the percentage of time spent in high-intensity activities was reported to be much less, that does not reduce the level of importance of the high-intensity activities. Previous investigations have stated that the repeated random bouts of high-intensity anaerobic and aerobic activity producing elevations in blood lactate concentrations are mainly responsible for fatigue in match-play (Reilly, 1997).

Recently cited values are in top-class level Danish soccer with observations made in standing 19.5%, walking 41.8%, jogging 16.7%, running 16.8%, sprinting 1.4%, and other 3.7% (Mohr et al., 2003). This brings to light the previously mentioned difference in physical demands of the game based on team tactics. It has been cited through multiple investigations that the difference in time spent in different activities based on the region of the world or league the players participate in (Bloomfield et al., 2007; Dellal et al., 2011; Di Salvo et al., 2007). Unfortunately the motion analysis investigations of soccer in the United States have been limited with no current literature published to the investigator's knowledge.

Table 2.9. Percent Purposeful Movement Time of Motions Performed by Player. Data are means ± SD

Variables	Position			
	Strikers (n=19)	Midfielder (n=18)	Defender (n=18)	All (n=55)
Standing	5.3 ± 3.5	2.1 ± 1.6*	6.3 ± 2.5	4.6 ± 3.2
Walking	14.1 ± 3.8	12.8 ± 4.2	15.8 ± 4.5	14.2 ± 4.3
Jogging	24.7 ± 8.7	28.3 ± 12.0	31.5 ± 6.8	28.1 ± 9.6
Running	11.1 ± 4.5	14.6 ± 9.2	7.6 ± 3.6*	11.1 ± 6.8
Sprinting	5.5 ± 3.3	6.4 ± 3.1	2.5 ± 1.3*	4.8 ± 3.2
Skipping	8.3 ± 2.8	9.1 ± 3.8	12.3 ± 6.2*	9.9 ± 4.7
Shuffling	9.5 ± 1.6	7.9 ± 2.1*	10.5 ± 3.2	9.3 ± 2.6
Other	21.5 ± 7.7	18.8 ± 5.6	13.6 ± 8.0*	18.1 ± (7.8)

* significantly different to both other positions (Adapted from Bloomfield et al, 2007)

The "Other" category of movements consists of analysis of direction, intensity, jump, dive, turn, type, control, pass, shoot, dribble, and touches were also investigated (Bloomfield et al., 2004; Boomfield et al., 2007). Further investigation into the "other" category was the initial development of the BMC (Bloomfield Movement Categories) system, which helps get a more precise understanding of the energy expenditure of players during soccer matches. Although the more traditionally analyzed distance covered at specified intensities does give an estimate for energy expenditure, it is the frequent alterations of activities, numerous accelerations and decelerations, changes of direction, unorthodox movement patterns, and the execution of various technical skills that may more significantly contribute to energy expenditure (Bangsbo, 1997; Reilly, 1997). Investigators found that the attackers may need to be the physically strongest players as they were found to perform the most physical contact at high-intensities. Also, strikers have the highest levels of swerving and slowing more rapidly causing higher shearing forces on the lower limbs (Bloomfield et al., 2007). Another finding in this study was that the number of 90° to 180° turns is relatively evenly distributed with all positions performing approximately 90 and 100, respectively, during match play. This brings to question the ecological validity of many Multi-Stage Fitness Tests commonly used in soccer today.

Even more recent analysis of motion analysis has consisted of multiple camera match analysis systems built into professional stadiums. Di Salvo et al. (2007) analyzed the technical and physical demand of elite level soccer players in two of the highest soccer divisions in the world (i.e. English Premier League and Spanish League First Division). The players were classified into six positions: central defenders, full backs, central defensive midfielders, wide midfielders, central attacking midfielders, and forwards. The match performance variables analyzed included physical activity, total distance covered, distances covered at high-intensities both with and without possession of the ball, technical actions, heading and ground duels, passing, time in possession, and ball touches. Results were consistent with past literature that the midfielder groups covered a greater distance than both the defender and forward groups. More quantitatively, results revealed that players, independent of position, performed 17.3 ± 7.7 (range 3 – 40) bursts of high intensity activity (> 23 $km \cdot h^{-1}$). These bursts of high intensity activity were 19.3 ± 3.2 meters (in distance range: 9.9 – 32.5 m). When comparing the positional roles, external positions (i.e. external defenders and external midfielders) and forwards performed more high intensity bursts compared to the central defenders and central midfielders on average (21 vs. 12) (Di Salvo et al., 2007).

In summary, the demands of soccer are specific to position, and with the improved technology there has been a more qualitative analysis of the game. Further understanding of each movement and the time spent in each movement is going to give a better estimate of the energy expenditure of a match, therefore leading to more precise training, monitoring, and testing methods for the stochastic, acyclical, and intermittent nature of soccer (Nicholas et al., 2000).

Match Analysis: Youth Soccer

Very similar to the women's game, there is a scarcity of information on the technical, physiological, and conditioning aspects of prepubescent and other youth players (Hulse, 2010). It wasn't until 1998 that England started Professional Soccer Academies, which led to many changes that set up the environment for youth soccer that is present today in countries such as England and the United States of America. Match analysis of the prepubescent age became more familiar with the Capranica et al. (2001) investigation of six prepubescent players (age < 11 years old) during an 11-a-side game and a 7-a-side game. No differences in types of activities were reported after analysis of the 11-a-side match compared with the 7-a-side match. The 7-a-side match was played on a pitch with smaller dimensions (60 x 40 m vs. 100 x 65 m). The smaller pitch dimensions were suggested by the investigators to be the cause of the less running frequency found in this study. Also, more passes and fewer tackles were noted during the 7-a-side game, suggesting that the smaller number of team members increases the number of times individual players are in possession of the ball (Capranica et al, 2001). Therefore, small-sided game (i.e. smaller pitch dimensions and less number of players per team on the field) may be more beneficial to younger players where the emphasis is based on improving technical ability.

There was one other study of note investigating time-motion analysis in youth matches. Stroyer et al. (2004) analyzed the actions performed during a match of twenty-six 12 – 14 year old boys in the top academies from Denmark. Unfortunately, for this investigation the authors limited the analysis to the first half of a single match. The groupings of the young boys were divided up subjectively based on the authors rating one club ‘more elite’ than another. From the results of the single 35-minute half of soccer, the time spent in standing activity was significantly higher among the nonelite players than among the elite players. The majority of the time was spent walking during the half, and unlike at the matured male level there were no significant differences between sprints or other high intensity bouts between the levels of competition. It is evident that there is still much more research needed at the youth level before any conclusions can be made on how to best train this population for the physical demands of the game. Vescovi (2014) analyzed 89 female soccer players (14 to 16 years of age). Similar to the professional literature, midfielders covered the greatest distance (7,779 ± 114 meters). On average, all players within this age group covered between 6,500 and 9,000 meters.

Technical Analysis

From a technical standpoint, the literature is quite scarce in the analysis of specific positions having a technical demand different from others. Table 2.10 displays example definitions of technical actions that are commonly used in literature. All of the following studies investigated the physical and technical performances of top-level soccer leagues (Bradley et al., 2013; Dellal et al., 2010; Dellal et al., 2011; Rampinini et al., 2009). Bradley et al. (2013) analyzed different standards of play, all within the country of England. Results showed that the higher standards of play maintained a higher level of pass completion ratings and greater number of completed passes. These results are correlated with less distance and efforts covered in high-speed activities. Higher standards of play also maintained a greater number of touches per interaction when compared to lower standards.

Table 2.10. The Technical Definitions Employed in the Owen et al. (2004) study

Skill	Definition
Pass	Player in possession sends the ball to a team mate (eg using the foot, thigh or chest; using various techniques such as ground, loft, chip, flick or volley; over short or long distances).
Receive	Players gains or attempts to gain control of the ball in order to retain possession
Turn	Player in possession, with ball at feet, changes direction in order to play in other areas of the pitch.
Dribble	Player in possession, with ball at feet, runs with ball, beats or attempts to beat an opponent
Header	Player contacts the ball using their head
Tackle	An action intending to dispossess an opponent who is in possession of the ball.
Block	Ball strikes a player, preventing an opponent's pass from reaching its intended destination.
Interception	Player contacts the ball enabling him to retain possession, preventing an opponent's pass from reaching its intended destination.

Dellal et al. (2011) compared the English Premier League and the Spanish top division of football. Findings showed that central defenders and forwards had the least number of ball interactions; all the remaining outfield positions had a similar number of ball interactions.

Variation In Physical Performance

Previous studies have found that high-speed activity accounts for approximately 8% of the total distance covered during match play (Rampinini et al., 2007). High-speed activity during a soccer match has been found to differentiate between playing position and tactical role of players (Di Savlo et al., 2007; Di Salvo et al., 2009; Krustrup & Bangsbo, 2001) and is related to the overall success of the team (Di Salvo et al., 2009; Rampinini et al., 2007).

Like all measures of sporting performance, high-speed efforts in soccer match play are not stable properties but are subject to variation between successive matches (Gregson et al., 2010). Success within a match has long been understood to be a consequence of the collective technical and tactical skills of a team (Bangsbo, 1994). It has not been until more recent decades that investigators have been able to display the importance of high speed activities during matches. Previous research has demonstrated that high-intensity running was a distinguishing characteristics between players in different playing positions, whereby midfielders covered more distance than central defenders, full backs, and attackers (Rampinini et al., 2008).

Conclusion

The literature shows great variance in both the men and women's professional game for all physical variables. Specifically, the total distance covered in a soccer match has been shown to range from 10 to 13 kilometers for men, but only 10 to 11 kilometers for women. Female youth players cover between 7 to 9 kilometers, and the single investigation on the collegiate female population shows they can cover between 9 - 10.2 kilometers. Distance covered in high-speed velocity bands vary between 1 – 1.7 kilometers.

CHAPTER 3

HIGH-SPEED RUNNING PROFILES OF FEMALE COLLEGIATE SOCCER PLAYERS

Title: High-Speed Running Profiles of Female Collegiate Soccer Players

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Abstract

Interest in the physical demands of the game has continued to grow over the decades. A more accurate understanding of activities the players perform and the amount of work they perform would give coaches insight into how to more effectively and efficiently train their players to improve the likelihood of optimal performance while simultaneously decreasing the risk of overtraining and injury. In the current investigation, six female collegiate soccer players were analyzed during a single competitive season (17 games). Global Position Systems were used to analyze the movement during each match. Results showed that there were differences between positions in the amount of total work that players completed during a match, and the speed at which they completed work. External players (fullback and outside midfielder) covered the greatest distance in the high velocity bands, while the central defender completed the least amount of distance overall. Players covered the majority of the distance during a game at low-intensities and averaged approximately 10% at high-speeds. Unique physical profiles are evidence of the need for coaches to train players of different positions in an appropriate manner. With the evolution of the physical demands of the game, and the emphasis translating to involvements at high-speeds, coaches should focus conditioning protocols on position specific movements in accordance with distances covered in the match at different velocity bands.

Introduction

Interest in scientific investigations of the physical demands of soccer has continued to grow over the past four decades. Since the earliest comprehensive review of the physiology of soccer there have been advances in sport technology that have lead to more detailed analyses of the differences in the physical demands of the game between playing levels and sexes (Bradley et al., 2009; Bradley et al., 2010; Vescovi, 2012; Vigne et al., 2010). The majority of physical demands investigations focus on the male professional population. In the scientific literature, the general measure of physical work completed during a soccer match is widely accepted as falling between 10 and 14 kilometers (Stølen et al., 2005). Dependent upon playing position (Dellal et al., 2010; Barros et al., 2007), playing level (Bradley et al., 2013a; Bradley et al., 2014), team possession (Bradley et al., 2013b), and tactical formation (Bradley et al., 2011) there is evidence that total work completed can vary significantly. The observed high degree of variability is in addition to the previously established sex differences that have also been supported by more recent findings (Stølen et al., 2005; Bradley et al., 2013a).

Although the data on the men's professional game and some amateur standards in the world are well established, the study of the women's game is still in the early stages (Krustrup et al., 2005; Andersson et al., 2010; Vescovi et al., 2012; Vescovi, 2014; Vescovi and Favero, 2014). One of the early investigations on the female population was on a group of fourteen players from the top Danish league. At the time this was considered an elite population. The players were considered as a single group of outfield players for the analysis. Findings showed that players covered approximately 10 kilometers during a match (Krustrup et al., 2005). The majority of the match was spent in low to moderate-speed movements (< 15 $km \cdot h^{-1}$), with the total distance covered at high-speed velocities (> 15.1 $km \cdot h^{-1}$) being measured at 1.31 kilometers. More recently, these findings were supported by Andersson et al. (2010). At the professional standard, players covered 1.33 kilometers in high-speed velocity movements and totaled 9.7 kilometers for the entire match. At the international level, Andersson et al. (2010) found that the physical demands went up to 10 kilometers for total distance covered in a match, and 1.5 kilometers being completed in high-speed velocity bands.

High-speed running distances have previously been thought to differentiate the playing levels of top soccer players (Krustrup et al., 2003; Krustrup et al., 2005; Andersson et al., 2010). Previous research demonstrated that elite players perform 28% more high-speed running than lower standard players (Mohr, Krustrup, & Bangsbo, 2003). However, more recent findings by Bradley et al. (2013a) showed that this notion does not always hold. When the different levels within the same country were analyzed it was the lower level players that covered a greater distance in higher-speed velocity (> 19.8 $km \cdot h^{-1}$) bands, with a possible explanation that lower technical ability leads to greater amounts of turnovers. Physical demands in specific velocity bands are an under analyzed aspect of female soccer players.

In an attempt to get a valid depiction of the development in the women's game from youth to international level competition, Vescovi (2014) collected data on youth players (U-17 players) and showed youth level female soccer players have a lower standard of physical performance in a match (6.5 to 9.0 kilometers) than previously established female professional level players. Less than 1,000 meters of their total work was covered in high-speed velocity bands. Bridging this gap from the women's youth game (Vescovi, 2014) to the women's collegiate game and on to the women's professional and international game (Andersson et al., 2010) is likely to drastically improve understanding of training demands and appropriate training prescriptions.

Until recently, there were no reports on locomotor characteristics of college female soccer players (Vescovi and Favero, 2014). Findings in this study showed that forwards and midfielders cover approximately 10 kilometers in a match and defenders were slightly less at approximately 9.5 kilometers. For this study, 113 female college soccer players from nine National Collegiate Athletic Association (NCAA) Division I universities were monitored during one regular-season match. Averages for work completed for the three subcategories of outfield players (i.e. defender, midfielder, and forward) were established and showed no statistically significant difference between positions. Unfortunately, with such broad categorizations of field player positions differences between positions may have been difficult to detect statistically (Dellal et al., 2010; Barros et al., 2007). A more detailed analysis of positional differences in the college game may elicit a more accurate depiction of the physical demands of the women's college game.

In summary, the current literature shows evidence of a great deal of variation in the physical demands of the game based on a number of different factors in men's soccer, such as playing position (Dellal et al., 2010; Barros et al., 2007), playing level (Bradley et al., 2013a; Bradley et al., 2014), team possession (Bradley et al., 2013b), and tactical formation (Bradley et al., 2011). There is an estimate of the physical demands of the women's game from youth to the international level, but there are few studies and detailed examination of playing position was not present in all investigations. Without an accurate depiction of the physical demands of each standard of women's soccer, and the respective playing positions, it is unlikely that appropriate metabolic conditioning and training can be implemented that can optimize the physical performance of the female players, while simultaneously decreasing the risk of injury. Therefore, the aims of the present study were to (1) determine the activity profiles of a mid-level women's collegiate soccer team through a single competitive season and (2) examine possible differences in high-intensity running during a competitive soccer match between positions using a case study approach.

Methods

Experimental Approach to the Problem

The current investigation was a case study that tracked individual players representing different playing positions over the course of a single competitive soccer season. A Global Position System (GPS) device (miniMax-10 Hz, Catapult Innovations, Melbourne, Australia) was used to evaluate the match performance of collegiate female soccer players. The distance covered, frequency of occurrence, and time spent in different velocity zones were analyzed during the competitive season to identify different physical demands with respect to playing position. These variables were chosen for analysis because previous literature has established these physical variables as important to soccer performance and differentiating the physical demands between position (Stølen et al., 2005: Dellal et al., 2010; Barros et al., 2007; Bradley et al., 2013a; Bradley et al., 2014; Bradley et al., 2013b; Bradley et al., 2011; Krustrup et al., 2003; Krustrup et al., 2005; Andersson et al., 2010).

Subjects and Match Analysis

Seventeen collegiate matches were analyzed. Six outfield collegiate female soccer players (Table 1) were competing for the same institution during the same collegiate competitive season.

Table 1. Characteristics of Soccer Players

Age (years)	Stature (centimeters)	Mass (kilograms)	Percentage of Body Fat (%)	Lean Mass (kg)	Fat Mass (kg)
20.0 ± 1.1	165 ± 6.3	61.6 ± 6.8	17 ± 3.6	51.9 ± 4.3	10.8 ± 3.0

* Values presented as means ± standard deviations

This study examined 6 players representing the following five outfield positions: central defender (CD, n = 1), fullback (FB, n = 1), central defensive midfield player (CDM, n = 1), central attacking midfield player (CAM, n = 1), outside midfielder (OM, n = 1), and forward (F, n = 1). For the purpose of this investigation only one player was analyzed at each position for comparison across positional sub-categories.

The GPS device captured all players' movements during the match by wearing the device in a fitted under garment under their jerseys. The device fit snuggly against the players' back at the nape of the neck. This system has been found reliable and validated for data accuracy with coefficient of variation 3.1 – 11.3% for measurement of instantaneous velocity in various velocity ranges and less than 5.3% and 6% coefficient of variation during acceleration and deceleration phases, respectively. (Jennings et al., 2010: Varley et al., 2011).

To allow for direct comparison between positions, the observations were only used if the player completed the entire match (90 minutes) in the same tactical position from start to finish. This was necessary to discount for playing time in the collegiate environment where the unique "re-entry" substitution rule can alter a players work rate and bias their physical performance. Exclusion of players that did not play 90 minutes also makes the data comparable to previously established standards at the professional and international level. Standardizing analysis by minutes played per match was an effort to depict the physical demands and variation of a 90-minute soccer match at that position.

Matches were all played in the same country, and all pitch dimensions met the NCAA regulations for length and width. Games had 45-minute halves with a "start-and-stop" clock that was stopped for significant injuries, goals scored, or disciplinary actions by the lead official.

Match Activities

Consistent with previous investigations (Krustrup et al., 2005; Andersson et al., 2010) in female soccer motion analysis studies, player activities were categorized in the following speed thresholds: standing (0 - 0.1 $km \cdot h^{-1}$), walking (0.1 – 6.0 $km \cdot h^{-1}$), jogging (6.1 – 8.0 $km \cdot h^{-1}$), low-speed running (8.1 – 12.0 $km \cdot h^{-1}$), moderate-speed running (12.1 – 15.0 $km \cdot h^{-1}$), high-speed running (15.1 – 18.0 $km \cdot h^{-1}$), sprinting (18.1 – 24.9 $km \cdot h^{-1}$), max sprinting ($\geq$ 25.0 $km \cdot h^{-1}$) (Krustrup et al., 2005; Andersson et al., 2010).

High-Speed Distances

Consistent with previous investigations, high-speed running was considered the sum of the distance covered in the high-speed running, sprinting, and max sprinting velocity bands (> 15.0 $km \cdot h^{-1}$) (Krsutrup et al., 2005; Andersson et al., 2010).

Statistical Analysis

The intent of the current investigation is to compare values presented by players of a single team playing in the NCAA Division I classification of women's soccer in the

United States of America. The current investigation is considered a case study. For descriptive purposes the aforementioned six positional subcategories were used. However, the attacker position was excluded from inferential analysis, as it did not meet the minimum requirements of participation in at least three 90 minute matches for analysis.

Non-parametric Tau-U analysis was completed to analyze the difference between players at different positions. Tau-U is a non-parametric method for measuring data non-overlap between two phases (Vannest et al., 2011). To adjust for the five positional sub-categories the p-value was adjusted for significance ($p \leq 0.01$).

Effect sizes, were reported in accordance to each position. Cohen suggested that a large effect = 0.25, medium effect = .09, and a small effect = .01 be applied in accordance to the nature of the Tau-U analysis in the non-parametric nature (Siers et al., 2010).

Results

Activity Profile

Average percentages of distance covered in each velocity band with respect to position are presented in Table 2.

Table 2. Percentage of Overall Distance Covered in Each Velocity Band by Position.

Match Performance Variables	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)	Attacker (games = 2)
Distance Covered (Percent)						
Standing	1.1 ± 0.2 %	0.7 ± 0.1 %	0.5 ± 0.2 %	0.5 ± 0.1 %	0.9 ± 0.2 %	0.9 ± 0.2 %
Walking	40.2 ± 6.6 %	32.6 ± 6.0 %	30.8 ± 5.3 %	43.7 ± 3.9 %	35.9 ± 3.2 %	33.5 ± 1.3 %
Jogging	12.3 ± 1.5 %	10.1 ± 1.4 %	13.4 ± 5.2 %	12.8 ± 1.3 %	10.0 ± 0.7 %	10.1 ± 0.7 %
Low-Speed Running	28.1 ± 3.5 %	28.9 ± 4.3 %	31.3 ± 2.3 %	26.1 ± 2.5 %	27.4 ± 0.6 %	27.9 ± 0.9 %
Moderate Speed Running	10.2 ± 2.1 %	13.1 ± 1.0 %	15.1 ± 4.1 %	8.8 ± 1.1 %	13.2 ± 1.6 %	13.2 ± 0.3 %
High-Speed Running	4.4 ± 0.7 %	8.4 ± 0.7 %	6.0 ± 1.8 %	4.6 ± 1.0 %	7.2 ± 1.3 %	8.2 ± 0.4 %
Sprinting	3.6 ± 0.9 %	6.1 ± 1.1 %	2.7 ± 0.9 %	3.4 ± 1.0 %	5.4 ± 1.3 %	6.2 ± 1.8 %
Max Sprinting	0.0 ± 0.1 %	0.1 ± 0.2 %	0.2 ± 0.3 %	0.1 ± 0.1 %	0.0 ± 0.1 %	0.1 ± 0.1 %

*Values are expressed as mean ± standard deviation.

While no inferential statistic was applied, simple numerical comparisons revealed that during a match, players of all positions stood for approximately 1% of their total distance covered. The central attacking midfield player spent the most time walking with the central defender having the second most distance covered in the walking velocity band. All positions averaged 10 ± 2% in the high-speed running velocity bands.

Low-intensity activity represented approximately 80% of total distance covered in a match. The distance covered at a speed greater than 15.0 $km \cdot h^{-1}$ accounted for approximately 10% of the total distance covered for central players (i.e. central defender, and both central midfield player). Central players covered approximately 8% of their total distance in high-speed velocity bands. Wide players (i.e. fullback and wide midfielder) distance covered in high-speed velocity bands accounted for 12.6% – 14.5% of their total distance covered.

Distance Covered

Mean and standard deviation of total distance covered by all players during a match were 9,058 ± 840 m. The distance covered in each velocity band according to position is presented in Table 3.

Table 3. Distance Covered in Each Velocity Band by Position.

Match Performance Variables	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)	Attacker (games = 2)
Distance Covered (m)						
Standing	80.1 ± 17.5	60.2 ± 12.4	49.7 ± 13.0	47.1 ± 12.0	86.8 ± 18.3	84.5 ± 23.3
Walking	3095.4 ± 610.2	2974.7 ± 653.6	2977.5 ± 596.5	4031.9 ± 317.6	3403.6 ± 190.7	3240.5 ± 10.6
Jogging	940.0 ± 92.7	913.8 ± 77.8	1283.0 ± 431.6	1184.1 ± 148.1	953.6 ± 93.0	978.0 ± 24.0
Low-Speed Running	2148.3 ± 251.3	2611.5 ± 281.1	3016.8 ± 389.3	2412.1 ± 288.6	2608.7 ± 238.3	2698.5 ± 24.8
Moderate Speed Running	782.7 ± 167.9	1190.2 ± 107.7	1453.1 ± 382.8	814.7 ± 121.4	1269.7 ± 246.7	1282.5 ± 85.6
High-Speed Running	334.3 ± 58.9	762.2 ± 93.6	576.8 ± 162.9	423.9 ± 102.8	688.7 ± 170.1	797.0 ± 73.5
Sprinting	276.7 ± 60.8	548.7 ± 100.7	255.6 ± 75.2	315.9 ± 105.4	517.6 ± 154.2	608.0 ± 199.4
Max Sprinting	3.1 ± 5.5	10.7 ± 18.4	15.3 ± 22.2	7.9 ± 10.2	2.0 ± 6.0	6.0 ± 8.5

*Values are expressed as mean ± standard deviations, all values measured in meters.

The central attacking midfield player covered the greatest amount of ground in the walking velocity band. The attacker position and fullback covered the greatest distance in the sprinting velocity band. The majority of work was completed below 15.0 $km \cdot h^{-1}$ for all positions.

Table 4. Tau-U Effect Size Between Positions for Total Distance Covered

Total Distance	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)
Central Defenders		66.6%*	100%*	94.9%*	90.4%*
Full-backs	66.6%*		66.6%*	2.4%	18.5%
Central Defensive Midfielders	100%*	66.6%*		65.7%*	33.3%
Central Attacking Midfielders	94.9%*	2.4%	65.7%*		25.4%
Wide Midfielder	90.4%*	18.5%	33.3%	25.4%	

* $p \leq 0.01$, the attacker was excluded from inferential analysis because of lack of qualifying observations

The central defender covered statistically significant ($p \leq 0.01$) less distance than any other position. The central attacking midfield position covered statistically significant ($p \leq 0.01$) less overall distance than the other central counterpart .

High-Speed Running Profile

Table 5 presents the averages for the high-intensity running profile from the competitive season.

Table 5. High-Speed Profile by Position

Match Performance Variables	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)	Attacker (games = 2)
Distance Covered						
Total (m)	8041.2 ± 371.0	9306.2 ± 367.8	9947.4 ± 577.9	9236.1 ± 491.3	9500.4 ± 847.0	9695.0 ± 401.6
High-intensity running (m)	614.1 ± 98.9	1321.5 ± 173.7	847.7 ± 234.9	747.64 ± 196.5	1208.2 ± 314.1	1411.0 ± 281.4
Sprinting (m)	279.8 ± 66.3	559.3 ± 119.1	270.9 ± 97.4	323.7 ± 115.4	519.6 ± 160.2	614.0 ± 207.9
Other Variables						
Total Efforts	890.9 ± 34.8	929.7 ± 53.4	882.8 ± 42.6	731.6 ± 51.4	1116.9 ± 61.6	1136.0 ± 26.9
High-Intensity Efforts	59.1 ± 6.4	122.0 ± 10.0	76.1 ± 14.6	75.9 ± 16.9	120.4 ± 25.3	138.0 ± 12.7
Sprinting Efforts	18.8 ± 3.5	39.6 ± 5.7	18.7 ± 5.1	23.2 ± 7.1	35.9 ± 9.5	47.0 ± 4.2

*Values are expressed as mean ± standard deviations, all values measured in meters.

Table 6. Tau-U Effect Size Between Positions for Distance Covered in High-Speed Velocity Bands

Distance Covered in High-Speed Velocity Bands	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)
Central Defenders		100%*	65.71%*	42.8%*	100%*
Full-backs	100%*		91.11%*	97.6%*	26%
Central Defensive Midfielders	65.7%*	91.1%*		19%	33.3%*
Central Attacking Midfielders	43%	97.6%*	19%		80.9%*
Wide Midfielder	100%*	26%	65.1%*	80.9%*	

*p ≤ 0.01, Attacker was excluded from inferential analysis because of lack of qualifying observations

The central attacking midfielder covered a statistically greater overall distance than CB ($p = 0.0001$), and a statistically smaller total distance than CDM ($p < 0.003$). Central defensive midfielder covered a statistically significant greater total distance than CAM and CB, ($p < 0.003$). Wide midfielder covered statistically greater total distance than CB ($p = 0.0001$). Fullback covered a statistically greater total distance than CB ($p = 0.0001$). Last, central defender covered a statistically smaller total distance than all field positions ($p < 0.0001$).

The central attacking midfielder covered a statistically greater distance in high-speed velocity bands than WM ($p = 0.001$), and a statistically smaller distance in high-speed velocity bands than FB ($p = 0.0001$). Central defensive midfielder covered a statistically greater distance in high-speed velocity bands than WM, CB, and FB ($p < 0.009$). Wide midfielder covered a statistically greater distance in high-speed velocity bands than CB ($p < 0.0001$). Fullback covered a statistically greater distance in high-speed velocity bands than CB ($p < 0.0001$). Central defender covered a statistically smaller distance in high-speed velocity bands than CDM, WM, and FB ($p < 0.0001$).

Central attacking midfielder covered a statistically smaller amount of distance in sprint velocity bands than WM and FB ($p < 0.005$). Central defensive midfielder covered a statistically smaller amount of distance in sprint velocity bands than WM and FB ($p < 0.0001$). The wide midfielder covered a statistically greater amount of distance in sprint velocity bands than CAM, CDM, and CB ($p <0.005$). The fullback covered a statistically greater amount of distance in sprint velocity bands than CAM, CDM, and CB ($p <0.001$). The central defender covered a statistically smaller total distance in the sprint velocity bands when compared to WM and FB ($p < 0.0001$).

The central attacking midfielder and central defensive midfielder performed a statistically greater number of high-speed efforts than CB ($p < 0.004$), and statistically fewer high-speed efforts than WM and FB ($p < 0.01$). The wide midfielder and fullback performed a statistically greater number of high-speed efforts than CAM, CDM, and CB ($p < 0.01$). The central defender performed statistically fewer efforts in the high-speed velocity bands compared to all other positions ($p < 0.04$).

Similar to high-speed efforts, central attacking midfielder and central defensive midfielders performed statistically fewer sprint efforts than WM and FB ($p < 0.002$). The central defender performed a statistically smaller amount of sprint efforts than OM and FB ($p < 0.0001$).

Table 7. Tau-U Effect Size Between Positions for Total Efforts Made

Total Efforts Made	Central Defenders (games = 14)	Full-backs (games = 6)	Central Defensive Midfielders (games = 15)	Central Attacking Midfielders (games = 14)	Wide Midfielder (games = 9)
Central Defenders		41.7%	8.1%	97.9%*	100%*
Full-backs	41.7%		50.0%	100%*	100%*
Central Defensive Midfielders	8.1%	100%*		96.6%*	100%*
Central Attacking Midfielders	97.9%*	50.0%	96.6%*		100%*
Wide Midfielder	100%*	100%*	100%*	100%*	

* $p < 0.01$, Attackers were excluded from inferential analysis because of lack of qualifying observations

The central attacking midfielder performed statistically fewer total efforts than all analyzed field positions ($p = 0.0001$). The central defensive midfielders performed statistically fewer total efforts than WM ($p = 0.001$). The wide midfielder performed statistically more total efforts than all other positional subcategories ($p < 0.002$).

Discussion

This study aimed to compare the amount of work that a female collegiate soccer player completes during a 90-minute match. It was not until recently that the movement characteristics of Division I female collegiate soccer players were investigated (Vescovi and Favero, 2014). Similar to Vescovi and Favero (2014) the current investigation emphasized the distance and proportion of time spent in different velocity bands. Unfortunately, the Vescovi and Favero (2014) modeled their velocity bands from slightly different sources compared to the current investigation (Dwyer and Gabbet, 2012; Vescovi, 2012) and utilized different GPS systems. With a less collection rate of the GPS device (5 Hz versus 10 Hz in the current investigation) the validity and reliability is less in the aforementioned investigation and makes direct comparisons difficult. The differences in velocity bands resulted in a slightly larger range for moderate speed velocity band (12.1-15.0 $km \cdot h^{-1}$, current investigation vs. 12.1- 15.5 $km \cdot h^{-1}$, Vescovi and Favero, 2014). As well, Vescovi and Favero (2014) had a slightly higher threshold for the sprinting velocity band when compared to the current investigation (>20.1 $km \cdot h^{-1}$, Vescovi and Favero, 2014 vs. 18.1 – 24.9 $km \cdot h^{-1}$, current investigation). The current investigation also included a maximal sprinting velocity band that is not present in the Vescovi and Favero (2014) investigation.

With these differences in velocity bands recognized it is difficult to draw a direct comparison between the two studies when referencing a similar population. Still to note, Vescovi and Favero (2014) analyzed 113 female college soccer players from 9 NCAA

Division I universities for a single match. Six of these universities were ranked in the top 30, and 3 were ranked in the top 10 at the time of match analysis, with eight of the nine teams qualifying for the postseason National Championship tournament. The current investigation analyzed a university whose ranking was not disclosed, but did not qualify for the National Championship tournament during the year of interest.

Unlike previous studies the current investigation implemented a single team, with a single tactical formation. Also different in the Vescovi and Favero (2014) investigation was the classification of outfield positions. Vescovi and Favero (2014) divided the field positions into three subcategories, forward, midfielder, and defender. Findings showed that defender covered significantly less distance than the midfielder (Vescovi and Favero, 2014). Tau-U analysis in the current investigation showed a significant difference comparing the central defender position to all other field positions with respect to average total distance covered in a match. Similar to past literature from the professional men, the central defensive midfielder covered the greatest total distance in a match (Dellal et al., 2011). It wasn't until recently that the division of the central midfield role was recognized in the scientific literature. Dellal et al. (2011) was the first to recognize that the tactical differences between the central attacking and defensive midfielders resulted in a significantly greater overall distance covered during a match, thus stressing the increased fitness demands of this position compared to its attacking counterpart.

When comparing to previous investigations at the international level with similar velocity bands, international players covered greater overall distances when comparing team averages (Andersson et al., 2010). Also, the majority of the match was dominated by movements at lower-speeds, which is in agreement with all previous soccer literature, independent of gender or playing standard (Mohr et al., 2008; Andersson et al., 2010). Similarly, the distance covered at high-intensities, denoted by greater than 15.1 $km \cdot h^{-1}$ in the current investigation, were also lower than the international level competition for all positions except for the attacker's position in the collegiate game (Andersson et al., 2010). Possible explanation for the large amount of high-intensity work completed in the current investigation by the attacker is the formation implemented resulted in only a single player in the highest attacking position. With less teammates in immediate surrounding areas the attacker may have been forced into more high-intensity movements to become involved in the match.

One unique feature that should be addressed in the collegiate game is the substitution rule. The NCAA allows for re-entry for college soccer players during the second half of play (NCAA.org). There appear to be positions on the field that are more likely to be substituted out in the collegiate games (unpublished data). This is a limiting factor that skewed the sample size of some of the positions for the current investigation. However, the overall full match physical demands of the game should be taken into consideration when planning or programming conditioning sessions to prepare these players for a collegiate soccer season.

The current investigation supports previously explored ideas that there is a stepping stone progression of increased physical demands in the female soccer game (Vescovi, 2013; Vescovi and Favero, 2014). In the youth game players commonly cover 7 – 8.5 kilometers in total work during a match and 600 – 650 meters being is covered in high-intensities (Vescovi, 2013). More recently, we have found that the next level, collegiate, women are covering in the range of 9 – 10 kilometers in a match, and 750 –

900 meters of total work is being completed in high intensities (Vescovi and Favero, 2014). Previously established standards at the professional and international level show women cover over 10 kilometers in matches (Mohr et al., 2008; Andersson et al., 2010, Bradley et al., 2013). With established progressions of the physical demands coaches can more appropriately implement conditioning protocols that can improve player's physical performance for their current level without increasing their risk of injury.

Limitations to the current investigation are lead by the small sample size to represent each position. This is the first investigation that has examined at this population for an entire competitive season. The level of soccer player in all of NCAA Division I women's soccer should be assumed to be quite diverse. The demands of the current game as presented in this study are similar to previously and recently published literature (Vescovi and Favero, 2014). However, without further indication of a heterogeneous versus homogenous population in different "tiers" of Division I women's soccer the extrapolation of the current data for use in conditioning protocols should be performed with caution. Like previous findings in the men's game, different playing levels can present different physical demands based on technical and tactical quality of opposition (Bradley et al., 2013a; Bradley et al., 2014). Physical testing and daily monitoring are still highly recommended to best implement an accurate and appropriate conditioning protocol to best prepare female soccer players at any level.

Also, the accuracy and validity of GPS systems vary, and the ability to accurately calculate movements of short distances at high-intensities remains a challenge (Gray et al,. 2010). With such variation in the devices dependent upon manufacturer comparison between investigations utilizing unlike GPS systems is difficult. As well, the comparison across playing levels and different regions of the world is very difficult due to the cultural differences play (Barros et al., 2007; Bradley et al., 2009; Bradley et al., 2014; Dellal et al., 2011).

In conclusion, the current investigation shows evidence that there are physical differences between the six positional subcategories. Past investigations show a growing trend in the amount of high-speed distances covered during a match. With external players (i.e. fullbacks and wide midfielders) covering the greatest amount of distance and efforts made in the high-speed velocity bands there should be a larger emphasis on these velocities in conditioning programs. Consistent with past literature, the majority of the game is spent in low-intensity velocity bands ($< 15.0\ km \cdot h^{-1}$).

Practical Applications

Accurate information regarding the physical activity of female collegiate soccer players is fundamental in the understanding of how to best prepare players for a college season. American colleges are traditionally granted 8 to 10 days of a pre-season camp to work with their players in a fully monitored environment before their first season matches. These restrictions in interactions places a large responsibility on the strength and conditioning coaches and other support staff to provide appropriate programming for these players to make sure they are prepared for the competitive season. The present investigation clearly displays that there is a large emphasis on high-intensity movements and there exists significant differences across positions. This highlights the importance of individualizing programs based on positions as to best focus on the most pertinent physical attributes for players.

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CHAPTER 4

MATCH-TO-MATCH VARIABILITY OF HIGH SPEED ACTIVITIES COMPLETED BY FEMALE COLLEGIATE SOCCER PLAYERS

Title: Match-to-Match Variability of High Speed Activities Completed by Female Collegiate Soccer Players

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Abstract

Like all measures of sporting performance, high-speed efforts in soccer match play are not stable properties but are subject to variation between successive matches (Gregson et al., 2010). A player with the ability to minimize the variation in their performance in a compact, short season is more likely to perform consistently and thus provide their team with a greater chance of positive performances match-to-match. The current investigation analyzed nine female players from a single National Collegiate Athletic Association institution for one competitive season. Global Positioning Systems (GPS) were utilized to capture the physical match performance of the players during the 17 season matches. Analysis compared the first match of the week performances versus the second match of the week performances for the nine players, and the seasonal trends for three of the outfield players (central attacking midfielder, central defensive midfielder, and central defender). Results showed the there was less than a one percent drop in overall distance covered from the first matches of the week to the second matches of the week. However, number of high-speed efforts performed dropped approximately 18% from the first match to the second match on average, and distance covered in high-speed velocity bands dropped by approximately 8%. All three outfield positions showed a positive trend over the course of the season. With the maintenance of overall work, but the drop in high-speed activity, it is inferred that the fatigue carried over from the first match to the second match negatively impacted the player’s ability to recover within the match, and repeatedly perform high-speed efforts. Coaches could place a greater emphasis on the organization and implementation of recovery modalities between matches to improve the physical performance of the second match.

Introduction

Previous studies have found that high-speed activity accounts for approximately 8% of the total distance covered during match play (Rampinini et al., 2007). High-speed activity during a soccer match has been found to differentiate between playing position and tactical role of players (Di Savlo et al., 2007; Di Salvo et al., 2009; Krustrup and Bangsbo, 2001) and is related to the overall success of the team (Di Salvo et al., 2009; Rampinini et al., 2007). Therefore, one would infer that a player's ability to continuously perform high-speed movements and complete more work in high-speed velocity bands match-match would lead to greater success than those

Like all measures of sporting performance, high-speed efforts in soccer match play are not stable properties but are subject to variation between successive matches (Gregson et al., 2010). Success within a match has long been understood to be a consequence of the collective technical and tactical skills of a team (Bangsbo, 1994). It has not been until more recent decades that investigators have been able to display the importance of high-speed activities during matches. Previous research has demonstrated that high-speed running was a distinguishing characteristic between players in different playing positions, whereby midfielders covered more distance than central defenders, full backs, and attackers (Rampinini et al., 2008).

Only one investigation has previously analyzed the movement characteristics of female college soccer players (Vescovi and Favero, 2014). For a single match, Vescovi and Favero (2014) analyzed 113 collegiate players. A single match analysis averaged with multiple people of the same position presented estimations of work completed by a collegiate player in a 90-minute soccer match. To the investigator's knowledge there have been no seasonal variation studies that have analyzed the female collegiate population. The college season presents very unique challenges unlike any other league in the world. Most professional environments present the players with a single match per week over the course of 8 to 9 months. Mixed in are alternative tournaments for a total of 40 to potentially 50 matches in that time period. The collegiate season is 9 to 10 weeks in length with 17 to 20 matches being played. Averaging 2, sometimes more matches per week, every week for that period.

Tracking seasonal performance variation could be indicative of appropriate training loads and habits during the season. In such a dense season there is potential to over-train players and for their physical performance to deteriorate as the season progresses. Not only a negative trend, but also, large variation during the course of the season in physical performance may be indicative of overtraining or accumulation of fatigue throughout a collegiate season. Evidence of small variations and stable performance throughout an entire season could be evidence of proper monitoring and training load modifications. Ultimately, tracking variation is going to be indicative of appropriateness of coach's training prescriptions during a very difficult season where there is a high priority on competing and recovery, with very little emphasis on training.

Gregson et al. (2010) analyzed match-to-match variation of high-speed activities including total high-speed running distance (THSR) and the total number of sprints undertaken to be between 15.6 - 16.7 %. For high-speed running and total sprint distance the variability increased in the range of 29.9 – 31.7 %. Variability was higher in central players (central midfielders and central defenders), than wide midfielders and attacking players. With respect to seasonal trends, Rampinini et al. (2007) found that total distance, high-intensity running, and very high-intensity running to be greater at the end of the season compared to the beginning of the season. Unfortunately, the season analyzed was not similar to the college season in that it was 8 months in length.

Monitoring seasonal variation in match performance in the college game will indicate potential physical performances for coaches when planning out season training. Specific positions that may show signs of higher levels of variation in physical performance in the college game may need a larger emphasis on recovery between matches, or may need greater levels of decrease in training loads prior to matches.

Therefore, this study was conducted to examine several aspects of female college soccer physical performance that have been neglected in previous literature. The aims of the current investigation were to: (1) determine the between-match variability of total work completed and high-speed running activities completed by female collegiate soccer players during a single competitive season and (2) to determine the influence of playing position on the variability of physical performance. This study also aimed (3) to examine the magnitude of variability between the first match of the week and second match of the week.

Methods

Experimental Approach to the Problem

This was a case study designed to calculate variation in college female soccer players' physical performance during a collegiate competitive season. Study procedures were approved by the respective institution's Institutional Review Board, and the investigation was conducted in accordance with the Declaration of Helsinki. All athletes voluntarily participated and were properly informed of all procedures and risk prior to participation.

Subjects and Match Analysis

A global positioning system (GPS) device (miniMaxX-10 Hz, Catapult Innovations, Melbourne Australia) was used to analyze 17 collegiate matches.

Table 1. Characteristics of Soccer Players

Age (years)	Stature (centimeters)	Mass (kilograms)	Percentage of Body Fat (%)	Lean Mass (kg)	Fat Mass (kg)
20.0 ± 1.1	165 ± 6.3	61.6 ± 6.8	17 ± 3.6	51.9 ± 4.3	10.8 ± 3.0

* Values presented as means ± standard deviations

This study examined nine players from the same institution for a single competitive season. For between first and second match comparison, four players were chosen from different positions that played in five pairs of first and second matches of a week. For the purpose of this investigation only one player was analyzed at each position for comparison across positional sub-categories.

All players' movements were captured by the GPS device during the match by wearing the device in a fitted under garment under their jerseys. The device fit snuggly against the players' back at the nape of the neck. This system has been validated for data accuracy (Varley et al., 2011; Akenhead et al., 2013). The device used in current investigation has a coefficient of variation ranging from 3.1 – 11.3 % for constant velocity, acceleration, and deceleration phases, and a typical error of less than 0.20 $m \cdot s^{-1}$ in all phases (Varley et al., 2011). Consistent with recommendations in literature, devices were not interchanged between players throughout competitive season, or on a match-to-match basis (Varley et al., 2011; Akenhead et al., 2013).

To allow for direct comparison between positions, the observations were only used if the player completed the entire match (90-minutes) in the same tactical position from start to finish. This was necessary to discount for playing time in the collegiate environment where the unique “re-entry” substitution rule can alter a players work rate and ultimately their physical performance. Standardizing analysis by minutes played per match was an effort to depict the physical demands and variation of a 90-minute soccer match at that position. Matches were all played in the same country, and all pitch dimensions met the NCAA regulations for length and width.

Individual players were analyzed between 3 to 17 times throughout the single competitive season. The mean data obtained from all the matches completed by each individual player throughout the study were used for this analysis.

Match Activities

Consistent with previous investigations (Krustrup et al., 2005; Andersson et al., 2010) in female soccer motion analysis studies, player activities were categorized in the following speed thresholds: standing (0 - 0.1 $km \cdot h^{-1}$), walking (0.1 – 6.0 $km \cdot h^{-1}$), jogging (6.1 – 8.0 $km \cdot h^{-1}$), low-speed running (8.1 – 12.0 $km \cdot h^{-1}$), moderate-speed running (12.1 – 15.0 $km \cdot h^{-1}$), high-speed running (15.1 – 18.0 $km \cdot h^{-1}$), sprinting (18.1 – 24.9 $km \cdot h^{-1}$), max sprinting ($\geq$ 25.0 $km \cdot h^{-1}$) (Krustrup et al., 2005; Andersson et al., 2010).

These velocity bands were chosen to make comparisons to higher levels of playing standard. A closer comparison of difference in physical standards between different playing levels could lead to insight of the necessary developmental process of the female soccer player.

High-Speed Distance Thresholds

High-speed running was considered the sum of the distance covered in the high-speed running, sprinting, and max sprinting velocity bands. The term "high-speed" was used to describe the intense activity classifications in the present investigation and to be consistent with terminology of past literature (Gregson et al., 2010).

The following high-speed threshold was used when considering distance covered and percentage of work completed at high-speed velocity bands (> 15.1 $km \cdot h^{-1}$). These variables have been able to separate different playing levels of soccer players as well as individual soccer player's success within a single match. The following high-speed variables were analyzed: (1) total distance completed at high-speed velocity bands, (2) percentage of work completed at high-speed velocity bands, (3) total distance completed at a sprinting velocity bands (> 18.1 $km \cdot h^{-1}$).

Statistical Analysis

Descriptive statistics and the movement analysis data are represented as mean ± standard deviation (SD). Between-match coefficients of variation (CV) were calculated by dividing the standard deviation of repeated performance data by the corresponding mean value for each player and multiplying by 100 to express in a percentage. To determine the magnitude of the variability in high-speed running activities between matches played within the 9-week competitive season match physical performance data from 5 players across 17 matches were evaluated. Matches were also divided into "first match of week" and "second match of week" examine differences in variation in a prepared state versus a match-fatigued state. Four players were selected to study five pairs of games that occurred during the season. These four players each represented one of the six positional sub-categories. Averages were collected between the first matches of the week and second matches of the week. Comparisons were made between coefficient of variations between each set of matches.

Total high-speed distance covered per match was normalized by position:

% of Performance = (Distance Covered in High-Speed Band / Best Physical Performance) * 100

This analysis was selected with the intent to show how often players perform at their best. A high amount of variation performance could indicate approaching matches with too much accumulation of fatigue. Trends over the course of the season were also analyzed to examine if players continued to trend negatively or positively (i.e. progressive decrement or improvement, respectively, in distance covered in high-speed velocity bands).

Data were separated by positional categories, and normalized high-speed distances covered were graphed along an x-y axes with x-axis representing time during the competitive season from beginning to end, and the y-axis representing distance covered in the high-speed velocity bands (> 15.1 $km \cdot h^{-1}$) during a single match in meters. Linear trend lines were set to examine the trend of data points (i.e. positive or negative trend). R^2 values were reported for each position.

Results

Table 2. High-Speed Running by Position

High Speed Activity	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)	Attacker (games = 2)
Total High Speed Running (THSR)	614.1 ± 98.9	1321.5 ± 173.7	847.7 ± 234.9	747.64 ± 196.5	1208.2 ± 314.1	1411.0 ± 281.4
High Speed Running	334.3 ± 58.9	762.2 ± 93.6	576.8 ± 162.9	423.9 ± 102.8	688.7 ± 170.1	797.0 ± 102.8
Total Sprint Distance	279.8 ± 66.3	559.3 ± 119.1	270.9 ± 97.4	323.7 ± 115.4	519.6 ± 160.2	614.0 ± 207.9
High Speed Running Efforts	59.1 ± 6.4	122.0 ± 10.0	76.1 ± 14.6	75.9 ± 16.9	120.4 ± 25.3	138.0 ± 12.7
Sprinting Efforts	18.5 ± 3.0	38.8 ± 5.5	18.3 ± 4.6	22.8 ± 6.4	35.8 ± 9.2	46.5 ± 3.5

*All variables measured in meters

Central defender covered the least amount of distance in the high-speed velocity bands (> 15.1 km·h^{-1}). The attacker, fullback, and wider midfielder position covered the most distance in high-speed velocity bands, as well as, performed the greater number of efforts in the high-speed velocity bands.

Overall between match-variability in high-speed activity

Table 2 shows the high-speed activity profile across the six positions investigated. Values are presented as the seasonal averages in the format of mean ± SD. The associated coefficient of variation (CV) and confidence intervals of means for the high-speed activity profiles, by position are listed in Table 2. Generally speaking, all positions presented high CV ranging from 16.1 % to 33.4 % in high-speed activities throughout the season. Attackers showed the lowest coefficient of variation, but the number of matches available was much fewer than other positions. Both fullbacks and attackers showed the most consistent performance in the number of high-speed efforts during the competitive season relative to their lower coefficient of variation.

Table 3. Coefficient of Variation of High-Speed Activity and Confidence Intervals

High Speed Activity	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)	Attacker (games = 2)
Total High Speed Running Distance (m)	16.1% (515.3 - 713.0)	13.1% (1147.8 - 1495.2)	27.7% (612.9 - 1082.6)	26.3% (551.2 - 944.1)	26.0% (894.2 - 1522.3)	19.9% (1129.6 - 1692.4)
High Speed Running Distance (m)	17.6% (276.4 - 393.2)	12.3% (668.6 - 855.8)	28.2% (413.9 - 739.7)	24.3% (321.1 - 526.8)	24.7% (518.6 - 858.8)	9.2% (723.5 - 870.5)
Total Sprint Distance (m)	22.0% (215.8 - 337.6)	18.4% (448.0 - 649.4)	29.4% (180.5 - 330.8)	33.4% (210.5 - 421.2)	29.8% (363.4 - 671.8)	32.8% (408.6 - 807.4)
High Speed Running Efforts	10.8% (52.8 - 65.5)	8.2% (112.0 - 132.0)	19.2% (61.5 - 90.7)	22.3% (58.9 - 92.8)	21.0% (95.2 - 145.8)	9.2% (125.3 - 150.7)
Sprinting Efforts	16.3% (15.5 - 21.5)	14.2% (33.3 - 43.4)	25.0% (13.7 - 22.8)	28.0% (16.4 - 29.2)	25.6% (26.6 - 45.0)	7.6% (43.0 - 50.0)

* Coefficient of Variation measured as a percentage of standard deviation divided by mean. Confidence intervals presented in parentheses.

First match of the week versus Second match of the week

Table 4. First Match Versus Second Match of the Week

Team Averages	Overall Coefficient of Variation (%)	Overall 95% Confidence Interval	First Match Coefficient of Variation (%)	Second Match Coefficient of Variation (%)	Percentage of Drop from First Match to Second Match in week (%)
Total Distance Covered (m)	9.05%	7530.9 m - 10860.9 m	4.82 ± 1.48	4.63 ± 2.73	0.79 ± 6.99
Work Decrease	209.52%	-11.0 % - 17.8 %	78.09 ± 33.98	6729.30 ± 12051.06	7.61 ± 9.08
Work Rate (m/min)	9.55%	78.2 m/min - 114.9 m/min	5.44 ± 1.88	6.78 ± 2.63	1.58 ± 8.40
Total Efforts	14.14%	644.5 - 1153.0	7.94 ± 3.17	4.88 ± 1.54	2.71 ± 7.83
High-Speed Efforts	24.52%	41.1 - 120.1	14.08 ± 11.98	16.40 ± 7.30	18.81 ±16.84
Sprinting Efforts	28.25%	10.2 - 36.6	21.32 ± 21.60	16.72 ± 5.37	7.60 ± 29.39
Distance Covered in High-Speed (m)	28.69%	373.2 m - 1378.2 m	17.96 ± 10.22	21.24 ± 8.73	7.58 ± 24.18
Distance Covered in Sprinting (m)	30.59%	132.9 m - 552.0 m	28.09 ± 18.74	21.10 ± 5.36	2.44 ± 36.53

* n = 4, 5 matches analyzed as first match of the week and 7 matches included for second match of the week. Percentage of drop was taken as percentage of absolute values.

Total distance covered dropped by less than 1% from the first match of the week to the second match, on average (Table 3). Distance covered in the sprinting velocity band had the largest CV of, 30.59%. There was a higher variation found in the total distance covered, work decrease, work-rate, total efforts made, high-speed efforts made, sprinting efforts made, and distance covered in both high-speed and sprinting velocity bands in the second match compared to those in the first match of the week.

Normalized Performance during Competitive Season (FIGURES)

The central attacking midfielder, central defensive midfielder, and central defender were the only three positions that all had fourteen matches played to depict the most realistic trend of the distance covered in high-speed velocity bands during the competitive season.

Figure 1. Central Attacking Midfielder (CAM) Percentage of Best Performance for Distance covered in High-Speed Velocity Bands

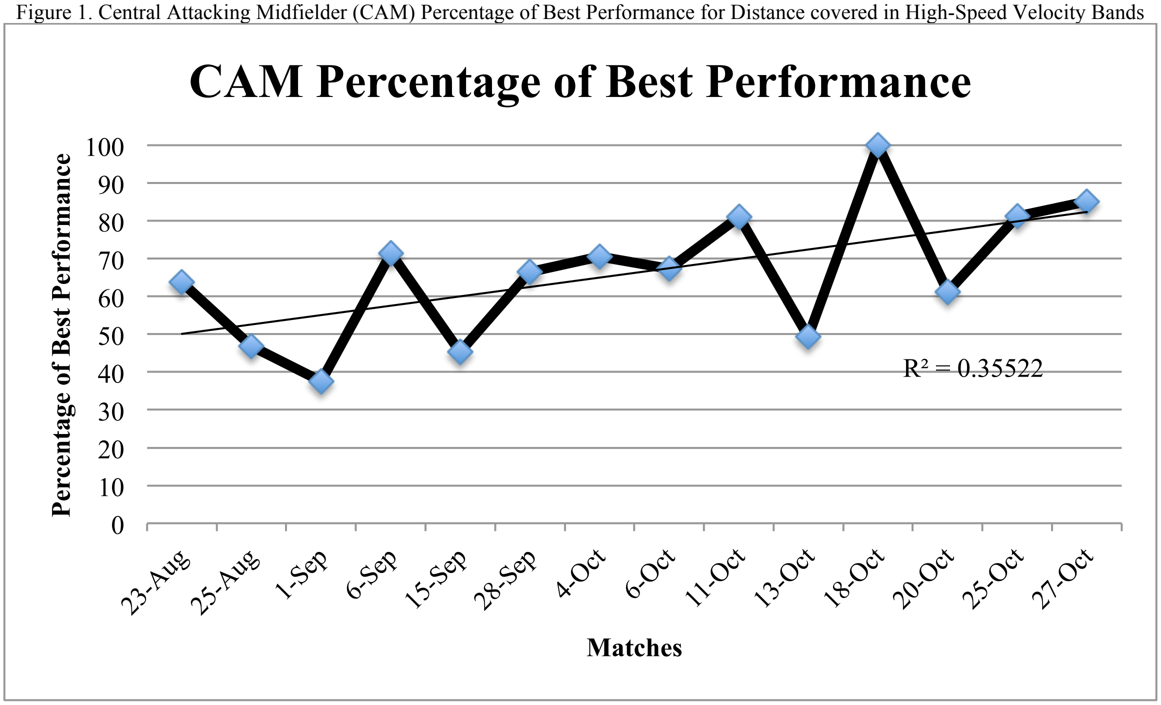

Figure 2. Central Defensive Midfielder (CDM) Percentage of Best Performance for Distance covered in High-Speed Velocity Bands

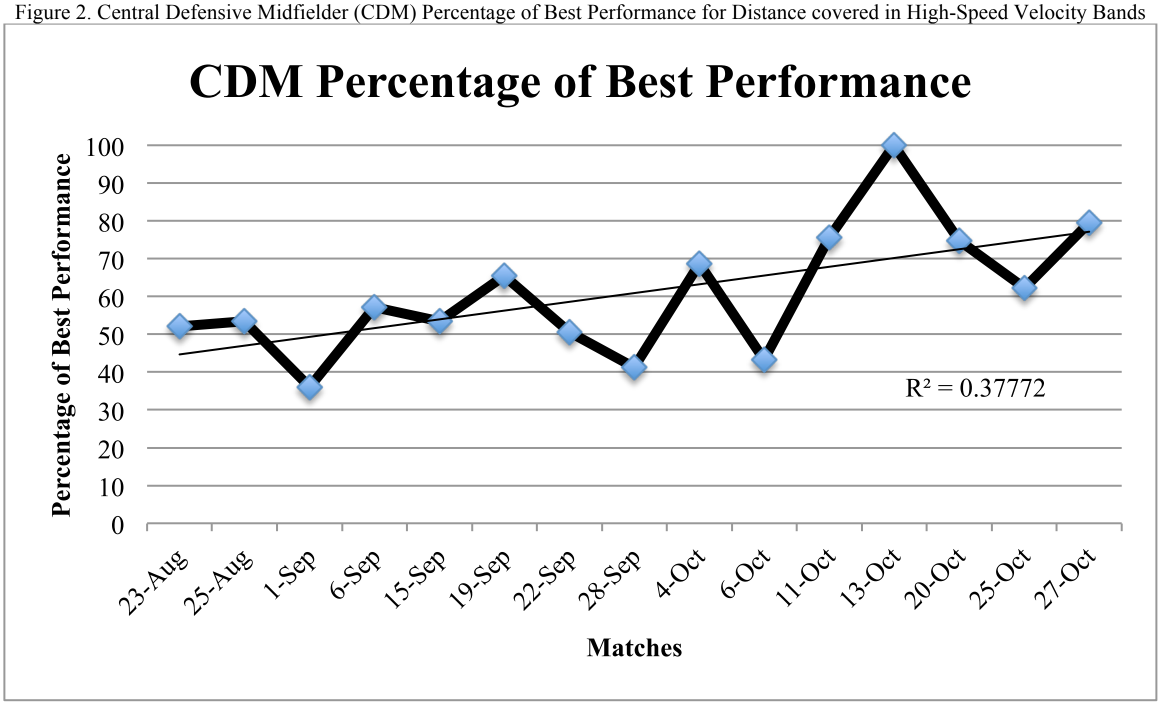

Figure 3. Central Defender (CB) Percentage of Best Performance for Distance covered in High-Speed Velocity Bands

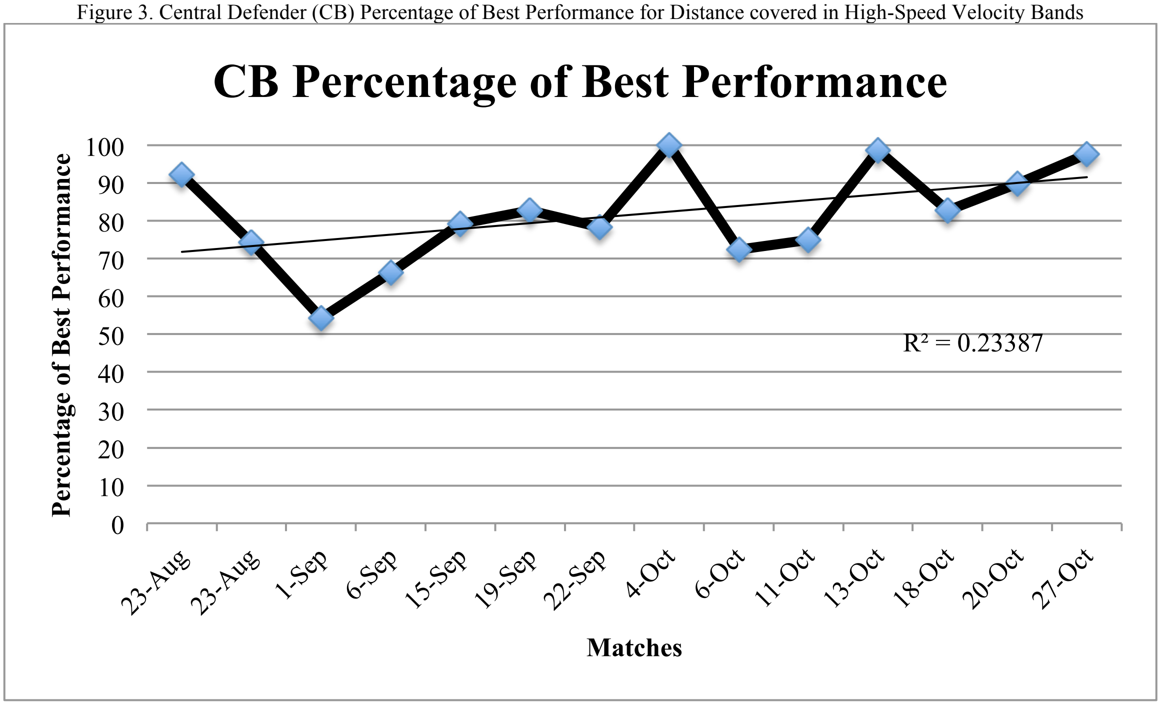

Figure 1 displays the seasonal trend of distance covered in the high-speed velocity bands for the central attacking midfielder. A positive trend throughout the course of the competitive season with an R^2 value = 0.36. Figure 2 displays the seasonal trend of distance covered in the high-speed velocity bands for the central defensive midfielder. A positive trend throughout the course of the competitive season with an R^2 value = 0.38. Figure 3 displays the seasonal trend of distance covered in the high-speed velocity bands for the central defender. A positive trend throughout the course of the competitive season with an R^2 value = 0.23.

Discussion

The aim of the current investigation was to analyze the variability of physical performance of female soccer players during a collegiate season. Specifically the following were investigated: 1) between-match variability of total work completed and high-speed running activities, 2) the influence of playing position on the variability of physical performance, and 3) the magnitude of variability between the first match of the week and second match of the week. As previously stated in literature, caution is necessary in comparing recent data with reported results from past literature, because of the different technologies and categorizations of positions employed in separate investigations (Rey et al., 2010). There are limited data on match-to-match variability of high-speed activities in soccer players (Rampinini et al., 2007; Gregson et al., 2010). There are no data to the investigator's knowledge on match-to-match variability for collegiate female soccer players. The NCAA competitive season is a meager nine to ten weeks in length. With adequate performance over that time span teams are able to qualify for post-season play. However, with large variation within a competitive season a team becomes prone to negative performances that could put their qualification for post-season tournament participation at a great risk.

The current investigation shows evidence of variability (16.1 % – 33.4 %) in sprinting performances from match-to-match. Previous investigations have validated the importance of high-speed and sprinting activities in a soccer match as a means of classifying the level of soccer player (Krustrup et al., 2003; Krustrup et al., 2005; Andersson et al., 2010; Mohr et al., 2008). Although no longer consistent across all literature (Bradley et al., 2013a) there is plenty of evidence that involvement in high-speed activities is pertinent to overall soccer performance (Di Savlo et al., 2007; Di Salvo et al., 2009; Krustrup and Bangsbo, 2001; Rampinini et al., 2007). In the current investigation there was a team average CV of 30% in number of sprinting efforts performed per match. This just falls on the previously found range of 28-30% in professional male soccer players (Gregson et al., 2010). This was the most inconcsistent physical variable in this investigation, only slightly more inconsistent than distance covered in the sprinting velocity band (Table 3). This might be explained by previous findings in that sprinting is the most sensitive physical variable to impacts of fatigue (Gregson et al., 2010).

When separated into their respective positions, the wide midfielder had the highest coefficient of variation compared to the other positions in three of the five physical variables (total sprint distance, high-speed running efforts, and sprinting efforts) (Table 2). The central defensive midfield position had the largest coefficient of variation in total high-speed running distance and high-speed running distance (Table 2). Gregson et al. (2010) found that the central midfielder or central defender had the highest coefficient of variation in all high-speed activity variables except when measuring high-speed running while their team was in possession. Analysis of work while team is in or out of possession was outside the scope of the current investigation. Reason for the possible trend in variation largely impacting central players more so than wide players is unknown. This is a possible area of further investigation to explore tactical implications for this within individual teams.

Unique to the collegiate environment is that each institution has a very high percentage of participating in at minimum 2 matches per week. The NCAA regular season is on average 9 to 10 weeks in duration. Teams have to squeeze 16 to 20 matches in a 10 week period resulting in multiple matches per week usually only separated by 24, 36, or in best case scenarios 48 hours. The increased variability across the team may be indicative of this dense scheduling, but also a result of the different physical demands of the game.

As described by Vescovi and Favero (2014) there are an unlimited number of substitutions allowed in college matches; a player can return in the second half after being substituted out during the first half, and a player can be substituted out and then back into the match during the second half. With freedom to enter and leave the game multiple times in a single match, coaches often utilize this tactic to attenuate fatigue. As a result it is difficult to accurately calculate variation and physical demands of the college game at specific positions, because unlike the international level, the majority of college players (5-7) starting a game in a field player position may only play 60-75 minutes of the entire match.

In the current investigation, work decrease calculations were made across a number of different physical variables. Total distance covered in a match only decreased by 0.79%, but the distance covered in high-speed velocity bands decreased by an average of 7.58% from the first match of the week to the second match. With a near maintenance in overall work completed in the first match to the second match, and the decrease in high-speed distance covered, a higher percentage of low-intensity activity is expected to be completed during the second match of the week. This is evidence that just viewing the overall work completed during a game (i.e. distance covered) is not an accurate depiction of the decrements in performance due to fatigue throughout a week. All of the physical variables explored in this investigation increased in variation when comparing the first match of the week to the second match of the week (Table 3). Consistent decreases in performance at high-speed velocity bands are indicative of possible accumulation of fatigue from the first to second match.

When analyzing the between position differences, the midfielders had the most inconsistent high-speed physical performances when compared with the other positions. Although all CVs, by position, were within the range previously found there are distinct differences between the positional sub-categories (Gregson et al., 2010). A possible explanation for the variability is the dependence on opposition's tactics for some positions. Tactically a team can defend or attack in a given formation, and players will be given roles and responsibilities consistent throughout the season with only minor modifications based on opposition, score line in the match, match objectives based on time in the season. Midfielders, possibly, are more prone to changes in physical performance based on the fact that their role is one that can change the most in an offensive or defensive manner from match-to-match. With this in mind, it is possible that different standards of inconsistencies should be set by position to qualify whether or not fatigue is impacting performance.

The trend analysis of the three players in the current study showed positive effects of the in-season training. Traditionally it may be perceived that the collegiate season has a negative impact on the physical performance of the player. However, through monitoring, and proper training load modifications, positive trends in physical performance and thus management of fatigue, during the competitive season are possible. While it is outside the scope of this study, it could be helpful to implement measures of both subjective and objective performance to best measure their player's performance in areas of physical, technical, and psychological aspects to best prepare them on a match-to-match basis.

Conclusion

The current investigation provides evidence that, similar to the men's professional game in Europe, women's collegiate soccer is variable within a single competitive season. With differences in physical performance and demands of the game between positions (unpublished data) there are inconsistencies in physical performance across the majority of positions during a competitive season. With variation being higher in the midfield player compared with the attacker and the defender, tactical considerations need to be made for physical standards during a college season. Strength and conditioning coaches with the appropriate sport technology can monitor trends in variation from match-to-match for an indication of accumulating fatigue or general negative trends in performance. Through proper preparation and monitoring of female college soccer players it is realistic to assume that variation should decrease and physical performance could positively trend during a competitive season. Future research should focus on upper-class (3rd and 4th year collegiate players) versus lower-class (1st and 2nd year) in determining if variance in physical performance could also be based on experience in the collegiate environment. It should be noted that the current study was a case study and larger sample sizes across the different standards of women's soccer play should be analyzed to see if the findings in the current investigation are present across all standards of female soccer performance.

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CHAPTER 5

PHYSICAL AND TECHNICAL DEMANDS OF WOMEN'S COLLEGIATE SOCCER – SPECIAL REFERENCE TO PLAYING POSITION

Title: Physical and Technical Demands of Women's Collegiate Soccer – Special Reference to Playing Position

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Abstract

The majority of scientific investigations have focused on purely physical performance analysis. By combining the performance of players physically and technically the coach may gain insight to the potential impacts of fatigue on technical performance. Ten collegiate female soccer players were tracked over the course of a single competitive season. Global Positioning Systems (GPS) were used to track the physical performance, and manual scripting of the matches tracked the number of ball interactions, pass completion percentages, and number of turnovers. Results showed a statistically significant relationship between distances covered in high-speed velocity bands and technical performance variables of ball interactions and pass completion percentage. There were no differences in the number of ball interactions between positions, but the central defender had statistically significant less pass completion percentage then the other outfield player positions. The evidence that players that perform more work in high-speeds were the more successful technical players on the team is support for college coaches to emphasis aerobic fitness leading up to the collegiate season. The positional differences in pass completion percentage are evidence that tactical roles and responsibilities of a single team may force players into more vulnerable situations. Notation of the nature of each position could assist coaches in recognizing player deficiencies, either technically or physically, and better adjust training regimens to meet the demands of each player during the competitive season.

Introduction

Over the last couple of decades there has been a large increase in the study of time-motion characteristics of soccer players (Andersson et al., 2010; Andersson, Ekblom, & Krustrup, 2008; Bangsbo, Norregaard, and Thorso, 1991; Bradley et al., 2013; Di Mascio & Bradley, 2013; Di Salvo et al., 2007; Mayhew & Wenger, 1985; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007; van Gool, van Gercen, & Boutmans, 1988; Withers, Maricic, Wasilewski, & Kelly, 1982). Time-motion analysis is a valuable data collection technique used to quantify the match running performance of soccer players (Carling, Bloomfield, Nelsen, & Reilly, 2008). For a long time research fully supported the notion that players at a higher standard of play perform more high-speed running than players of a lower standard (Andersson, Randers, Heiner-Moller, Krustrup, & Mohr, 2010; Bangsbo et al., 1991; Ekblom, 1986; Mohr et al., 2008).

More recent investigations with full-time elite leagues and sub-elite leagues have shown evidence that lower standard players cover more total distance at high-speed velocities (Bradley et al., 2013; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009, 2013; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009). Contrasting results may be indicative of the various forms of data collection in the leagues and the lack of standardization across studies. However, these findings could also be associated with technical characteristics inherent to lower standards that require players to perform greater amounts of physical work (Bradley et al., 2013a). That is why it is important that analysis of match performances are not divided separately into technical, tactical, and physical, but instead the game is viewed from a holistic perspective in which variation in one variable may be associated with success or failure from another. Technical performance is referring to the player's efficiency and skill with the ball to complete dribbles, passes, and shots. The tactical success of a team pertains to the possession and retention of the ball in certain areas or aspects of the field. While the physical success of a team, the more widely analyzed aspect of soccer (Stølen et al., 2005) consists of one's ability to complete and sustain levels of work during a match.

Dellal et al., (2011) was one of the first research groups to link the technical and physical performance of elite level soccer players. Male soccer players from the English Premier League (England's top club league) and La Liga (Spain's top club league) had their physical and technical performances correlated across the two leagues to find similarities and differences. This was also one of the first investigations to divide the central midfield position into both an attacking and defensive role for analysis. Differences in the physical efforts made by the central defensive and central attacking midfield position were found to be statistically significant in total distance covered, total sprint distance in possession, and total high intensity run distance. Those differences suggest that the central defensive midfielder has a greater overall exertion demand per match, and may need higher fitness standards to sustain physical performance throughout the course of a season. General findings presented evidence that both technically and physically there are unique characteristics about each of the positional sub-categories that when recognized can provide necessary information that would improve training regimens to improve overall performance.

More recently, Bradley et al. (2013) found that less total and high-speed running distances were covered in the Premier League compared to lower standards in English soccer. Also, players covered more high-speed running when moving down levels of league play. Technically, the Premier League was the most superior league with the highest number of passes completed at every position, the highest pass completion percentage at every position, and the highest volume of ball receptions when compared to the two lower divisions (Bradley et al., 2013).

Dellal et al. (2010) performed another investigation, on the French First League. Findings showed that distances covered ranged from 10425 meters to 12029 meters. Pass completion percentages for central defensive midfielders, and central attacking midfielders ranged from 75% to 78% with forwards and central defenders averaging only 71% and 63%, respectively. This drastically differs from the values found in the English Premier League where the central defenders had the second highest pass completion percentage with 80% (Bradley et al., 2013). The analyses in combination (physical and technical) must allow for adjustments to be made in the training of elite players based on their playing positions.

Unfortunately, to the author's knowledge, the inclusion of technical proficiency has not been included in analyses of the female population of soccer players. To the author's knowledge current research on the women's game has been limited to motion analysis (Andersson et al., 2010; Vescovi, 2012; Vescovi & Favero, 2014). Therefore, the aim of the current investigation was to examine both the physical and technical activities of a single collegiate women's team competing in a single National Collegiate Athletic Association Division I competitive season, with special reference to their playing position.

Methods

Experimental Approach to the Problem

A Global Position System (GPS) device (miniMaxx-10 Hz, Catapult Innovations, Melbourne, Australia) was used to evaluate the match performance of collegiate female soccer players. The distance covered, frequency of occurrence, and time spent in different velocity zones were analyzed during the competitive season (17 matches) to identify different physical demands with respect to playing position. Technical actions were manually scripted with post-match video analysis.

Subjects and Match Analysis

With consent and institutional ethics approval, a global positioning system was used to analyze 17 collegiate matches. The ten mid-major collegiate female soccer players representing the same institution during the same collegiate competitive season were analyzed. All players' movements were captured by the GPS device during the match by wearing the device in a fitted under garment under their jerseys. The device fit snuggly against the players' back at the nape of the neck. This system has been validated for data accuracy (Varley et al., 2011; Akenhead et al., 2013). The device used in the current investigation was reported to have a coefficient of variation ranging from 3.1 – 11.3 % for constant velocity, acceleration, and deceleration phases, and a typical error of less than 0.20 $m \cdot s^{-1}$ in all phases (Varley et al., 2011). Consistent with recommendations in literature, devices were not interchanged between players throughout competitive season, or on a match-to-match basis (Varley et al., 2011; Akenhead et al., 2013).

To allow for direct comparison between players, data were only used if the player completed the entire match (90-minutes) in the same tactical position from start to finish. Matches were all played in the same country, and all pitch dimensions met the NCAA regulations for length and width.

Match Activities

Consistent with previous investigations (Krustrup et al., 2005; Andersson et al., 2010) in female soccer motion analysis studies, player activities were categorized in the following speed thresholds: standing (0 - 0.1 $km \cdot h^{-1}$), walking (0.1 – 6.0 $km \cdot h^{-1}$), jogging (6.1 – 8.0 $km \cdot h^{-1}$), low-speed running (8.1 – 12.0 $km \cdot h^{-1}$), moderate-speed running (12.1 – 15.0 $km \cdot h^{-1}$), high-speed running (15.1 – 18.0 $km \cdot h^{-1}$), sprinting (18.1 – 24.9 $km \cdot h^{-1}$), max sprinting ($\geq$ 25.0 $km \cdot h^{-1}$) (Krustrup et al., 2005; Andersson et al., 2010).

Technical Events

Match analysis also included pass completion percentage, number of ball interactions, and total number of turnovers. The aforementioned events were marked utilizing post-match visual analysis. When each event occurred the viewer marked the respective player and event through subjective analysis. The same viewer was utilized for all post-match technical analysis. The following definitions were utilized to attempt to standardize the events:

1. Ball Interactions: Number of situations where the player is in contact with the ball; if the player touched the ball more than once before releasing or losing it then this was recorded as one ball interaction (Rampinini et al., 2009).
2. Pass Completion Percentage: Number of successful passes divided by number of unsuccessful pass, then translated into a percentage. Successful passes were

defined as pass performed by a player and successfully received by another player of the same team. An unsuccessful pass was a pass attempt that was not successfully received by a player on the same team, but either intercepted by the other team, or ran out of bounds.

3. Turnover: A loss of possession by an individual either through means of an unsuccessful pass, dribbling the ball out of bounds, or the opposition tackling the ball away from the player.

Statistical Analysis

All data analyses were conducted using statistical software (SPSS Inc., Chicago, USA). All values were expressed as mean values ± standard deviation (mean ± SD). Relationships between technical events and running profiles were analyzed using non-parametric Tau-U statistic to examine between each of the six playing positions (central defender, fullback, central attacking midfielder, central defensive midfielder, outside midfielder, and attacker/forward) in the distance run at the two high-speed velocity bands (> 15.1 $km \cdot h^{-1}$, high-speed running and > 18.1 $km \cdot h^{-1}$, sprinting). To adjust for the five positional sub-categories the p-value was adjusted for significance ($p \leq 0.01$). Pearson correlation was run to distinguish any relationship between high-speed running distances completed in a game and technical performance.

Results

Table 1. Characteristics of Soccer Players

Age (years)	Stature (centimeters)	Mass (kilograms)	Percentage of Body Fat (%)	Lean Mass (kg)	Fat Mass (kg)
20.0 ± 1.1	165 ± 6.3	61.6 ± 6.8	17 ± 3.6	51.9 ± 4.3	10.8 ± 3.0

* Values presented as means ± standard deviations

Physical Performance by Position

Table 2. Distance Covered in Each Velocity Band by Position (Alexander et al., First Paper)

Match Performance Variables	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)	Attacker (games = 2)
Distance Covered (m)						
Standing	80.1 ± 17.5	60.2 ± 12.4	49.7 ± 13.0	47.1 ± 12.0	86.8 ± 18.3	84.5 ± 23.3
Walking	3095.4 ± 610.2	2974.7 ± 653.6	2977.5 ± 596.5	4031.9 ± 317.6	3403.6 ± 190.7	3240.5 ± 10.6
Jogging	940.0 ± 92.7	913.8 ± 77.8	1283.0 ± 431.6	1184.1 ± 148.1	953.6 ± 93.0	978.0 ± 24.0
Low-Speed Running	2148.3 ± 251.3	2611.5 ± 281.1	3016.8 ± 389.3	2412.1 ± 288.6	2608.7 ± 238.3	2698.5 ± 24.8
Moderate Speed Running	782.7 ± 167.9	1190.2 ± 107.7	1453.1 ± 382.8	814.7 ± 121.4	1269.7 ± 246.7	1282.5 ± 85.6
High-Speed Running	334.3 ± 58.9	762.2 ± 93.6	576.8 ± 162.9	423.9 ± 102.8	688.7 ± 170.1	797.0 ± 73.5
Sprinting	276.7 ± 60.8	548.7 ± 100.7	255.6 ± 75.2	315.9 ± 105.4	517.6 ± 154.2	608.0 ± 199.4
Max Sprinting	3.1 ± 5.5	10.7 ± 18.4	15.3 ± 22.2	7.9 ± 10.2	2.0 ± 6.0	6.0 ± 8.5

*Values are expressed as mean ± standard deviations, all values measured in meters.

The central attacking midfield player covered the greatest amount of ground in the walking velocity band. The attacker position and fullback covered the greatest distance in the sprinting velocity band. The majority of work was completed below 15.0 $km \cdot h^{-1}$ for all positions (Alexander et al., First Paper).

Table 3. High-Speed Profile by Position (Alexander et al., First Paper)

Match Performance Variables	Central Defenders (games = 14)	Full-backs (games = 6)	Central Defensive Midfielders (games = 15)	Central Attacking Midfielders (games = 14)	Wide Midfielder (games = 9)	Attackers (games = 2)
Distance Covered						
Total (m)	8041 ± 371	9306 ± 377	9947 ± 578	9236 ± 491	9500 ± 847	9695 ± 401
High-intensity running (m)	614 ± 174	1321 ± 174	848 ± 235	1092 ± 295	1208 ± 314	1411 ± 281
Sprinting (m)	277 ± 61	467 ± 147	256 ± 75	316 ± 105	518 ± 154	608 ± 199
Other Variables						
Total Efforts	891 ± 35	929 ± 53	883 ± 43	732 ± 51	1117 ± 62	1136 ± 26
High-Intensity Efforts	59 ± 6	122 ± 10	76 ± 15	76 ± 17	120 ± 25	138 ± 13
Sprinting Efforts	19 ± 3	39 ± 6	18 ± 5	23 ± 6	36 ± 9	47 ± 4

*Values are expressed as mean ± standard deviations, all values measured in meters.

The central defender covers less total distance that the rest of the field players, but performs equal amount of efforts as the central defensive midfielder and a greater number of efforts than the central attacking midfielder. The wide midfielder, fullback, and attacker perform the most over efforts, as well as, the greatest amount of efforts in high-speed and sprinting velocity bands.

Technical Events

Table 4. Technical Performance by Position.

Technical Activity	Central Defenders	Full-backs	Central Defensive Midfielders	Central Attacking Midfielders	Wide Midfielder	Attackers
Pass Completion Percentage (%)	67.96 ± 9.24	73.69 ± 9.21	82.80 ± 7.62	74.87 ± 5.54	73.47 ± 8.46	75.00 ± 5.54
	(64.31 - 71.62)	(68.78 - 78.60)	(78.58 - 87.02)	(71.80 - 77.93)	(69.40 - 77.55)	(27.09 - 100.00)
Ball Interactions	55.85 ± 13.22	54.87 ± 16.11	66.20 ± 15.39	58.9 ± 13.07	58.84 ± 13.55	59.33 ± 11.37
	(50.62 - 61.08)	(46.29 - 63.46)	(57.67 - 74.72)	(51.69 - 66.17)	(52.31 - 65.37)	(31.08 - 87.58)
Total Turnovers	11.44 ± 4.38	10.00 ± 4.03	8.00 ± 3.80	12.13 ± 3.23	11.95 ± 3.80	13.67 ± 5.51
	(9.71 - 13.18)	(7.85 - 12.14)	(5.90 - 10.10)	(10.35 - 13.92)	(10.12 - 13.78)	(0 - 27.35)

* Values presented as a mean ± standard deviations, pass completion percentage listed as percentage, ball interactions and total turnovers listed as number of occurrences

Table 5. Tau-U Effect Size Between Positions for Pass Completion Percentage

Pass Completion Percentage	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)
Central Defenders		61.9%*	95.2%*	42.86%*	93.6%*
Full-backs	61.9%*		51.1%	14.3%	25.9%
Central Defensive Midfielders	95.2%*	51.1%		60%*	42.2%
Central Attacking Midfielders	89.8%*	14.3%	60%*		30.2%
Wide Midfielder	93.6%*	13.0%	42.2%	30.2%	

*$p \leq 0.01$, Attacker was excluded from inferential analysis because of lack of qualifying observations

The central attacking midfielder (CAM) had a statistically significant less pass completion percentage than the central defensive midfielder (CDM) ($p = 0.006$), and a statistically significant greater pass completion percentage than the central defender (CB) ($p = 0.0001$). The central defensive midfielder had a statistically significant greater pass completion percentage than CAM and CB ($p < 0.0001$). The central defender had a statistically significant less pass completion percentage compared with CAM, CDM, and the wide midfielder (OM) ($p < 0.0002$).

Table 6. Tau-U Effect Size Between Positions for Ball Interactions

Ball Interactions	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)
Central Defenders		20.2%	32.9%	10.2%	21.4%
Full-backs	20.2%		50.0%	27.4%	51.9%
Central Defensive Midfielders	32.9%	50.0%		25.2%	35.6%
Central Attacking Midfielders	10.2%	27.4%	25.2%		0.8%
Wide Midfielder	21.4%	51.9%	35.6%	0.8%	

*$p \leq 0.01$, Attacker was excluded from inferential analysis because of lack of qualifying observations

No significant differences present between positions for ball interactions.

Table 7. Tau-U Effect Size Between Positions for Turnovers

Turnovers	Central Defender (games = 14)	Full-back (games = 6)	Central Defensive Midfielder (games = 15)	Central Attacking Midfielder (games = 14)	Wide Midfielder (games = 9)
Central Defenders		79.7%*	70.9%*	14.8%	39.7%
Full-backs	79.8%*		11.1%	64.3%	55.6%
Central Defensive Midfielders	70.9%*	11.1%		61.9%*	20.6%
Central Attacking Midfielders	14.8%	64.2%*	61.9%*		64.3%
Wide Midfielder	39.7%	55.5%	56.3%	20.6%	

*$p \leq 0.01$, Attacker was excluded from inferential analysis because of lack of qualifying observations

The central defender had a statistically significant greater amount of turnovers than the fullback and central defensive midfielder ($p < 0.005$). The fullback and central defensive midfielder had a statistically significant less amount of turnovers than the central defender and central attacking midfielder ($p < 0.004$).

Technical Success and the Relationship to Physical Performance

Table 8. Average and Standard Deviations by Technical Variable (n = 10).

	Distance Covered in High-Speed (meters)	Pass Completion Percentage	Ball Interactions	Turnovers
Average	895.8	72.8%	57.0	10.5
Standard Deviations	183.5	5.1%	7.6	1.3

There was a statistically significant relationship between pass completion percentage and average distance covered in high-speed velocity bands (> 15.1 $km \cdot h^{-1}$, r =

0.69). Also, a statistically significant relationship was present between amount of ball interactions and distance covered in high-speed velocity bands ($r = 0.70$). There was also a statistically significant relationship present between pass completion percentage and number of ball interactions ($p < 0.74$).

Discussion

The physical demands of soccer have become a common area of investigation. With more of an emphasis on multiple variables involved in soccer performance there will be a more accurate view on the components of success. The current investigation was the first to the investigator's knowledge to combine an analysis of commonly explored physical variables with a few technical variables in the women's collegiate game. With the majority of this study being focused on exploratory purposes, it is pertinent that the data on this population continue to increase so that coaches can be better equipped with standards of performance to build their training programs from.

Analysis shows that the central defensive midfielder (CDM) averaged the highest pass completion percentage compared to the rest of the field positions. CDM pass completion percentage was statistically significantly higher than the central defender and central attacking midfielder ($p < 0.006$). Similar to previous findings, the central midfielder was found to have the highest pass completion rating for male elite Premier League and French First division soccer players (Dellal et al., 2010; Bradley et al., 2013). However, Dellal et al. (2011) did not separate defensive from attacking central midfield roles when comparing the top Premier League and La Liga (Spanish Division) players. In the more recent Dellal et al. investigation La Liga central defensive midfielders had the exact same pass completion percentage as their attacking counterparts, but had a slightly lower pass completion percentage than the fullback position (78% CM vs. 79% FB). Fullbacks in the Premier League also recorded the highest pass completion percentage (Dellal et al., 2011).

In the current investigation there were no statistically significant differences in ball possessions or ball interactions between any of the positions. This finding is unlike previous studies that have shown central midfielders, specifically central attacking midfield positions, where investigated, have a significantly higher possessions than other field positions (Dellal et al., 2010; Dellal et al., 2011; Bradley et al., 2013). Similarities in the present investigation may be an indication of playing style in the women's collegiate game. Whether that is an indication for greater or less technical or tactical methodology by players in a match is undetermined.

Unlike other studies, the quantity of turnovers by position was calculated in the current investigation. The intent was to decipher if the number of turnovers by a player would be correlated to the lack of movement or total work being completed. Although the central defensive midfield position did display the lowest average of turnovers during the college season, there were no statistically significant differences resulting from statistical analysis. However, there are some practical differences evident between the more offensive positions (i.e. attackers, central attacking midfielders, and wide midfielders), but this difference is hypothesized to be a result of the average position on the field for these players is in a less advantageous position where they are less likely to have a numerical advantage of teammates versus opposing players around them. The offensive players are likely to take more risk in their passes and dribbling attempts, thus increasing the likelihood of losing the ball to the opposing team.

The analysis by Pearson's correlation of the high-speed physical activity with the technical actions resulted in statistically significant relationships between distance covered in high-speed velocity bands and pass completion percentage as well as the number of ball interactions ($r = 0.69$ and $r = 0.70$, respectively). This is evidence that players that covered a greater distance at high-speed velocity bands had a better pass completion percentage and/or more ball interactions as indication of their ability to delay the onset of fatigue within the match. There was also a statistically significant relationship between pass completion percentage and ball interactions. All of these relationships indicate that a fit player that is able to cover a greater distance in the high-speed velocity bands is going to be more successful within a game. Therefore, this highlights the importance of the understanding of the physical demands of the women's college game to properly prepare them for the work that must be completed during a match.

The current investigation did not expand the technical analysis to tackles, aerial challenges, and/or offensive attempts on goal. These statistical variables may be more pertinent and show a clearer depiction of the relationship between the physical performance of players in offensive positions and overall success in a match. This is considered a limitation of the current investigation and should be considered for future research. In the college environment multi-camera analysis systems are becoming more common and should be utilized to gain the aforementioned insight.

Practical Application

To our knowledge this is the first study to begin to analyze the physical and technical performance of female college soccer players. The data from this study should be used to modify training programs accordingly to emphasize the demands of the game specific to each position. So often players are asked to complete the same conditioning regimen or execute a single technical workout during the off-season in preparation for the competitive season. Understanding there is a large time demand to individualize programs by position, but with attention to the specified physical and technical demands of female college athletes may assist in more efficiently prescribed training loads.

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CHAPTER 6

SUMMARY AND FUTURE INVESTIGATIONS

The physical demands of the college game are a missing link in the investigation of the physical demands of the game. Thousands of young men and women participate in collegiate athletics every year. The college systems serve for most professional sports in the United States as a stepping-stone from amateurism to professional status. With only one additional study outside of the current investigation analyzing the demands of the women's collegiate game, and none on the men's side to the author's knowledge shows a deficiency in the current literature.

The professional game on the men's side is well studied (Bradley et al., 2013; Dellal et al., 2009; Stølen etl., 2005). The women's investigations have recently begun to grow in number as well (Andersson et al., 2010; Vescovi et al., 2012, Vescovi, 2014, Vescovi and Favero, 2014). The current investigation served as a case study, and the fist of its kind to analyze a single collegiate team through a competitive season. Although small in the number of players the authors could analyze, the current investigation served as an attempt to depict the physical demands of a women's collegiate soccer season. The physical demands presented in the current investigation fit in the middle of previously explored standards of the youth (6.5 kilometers – 9.0 kilometers, Vescovi et al., 2012) of the youth women's game, and the professional (> 10 kilometers, Andersson et al., 2010).

Unlike the previous investigation on the women's collegiate population, the current investigation divided the outfield players into six positional subcategories (Vescovi & Favero, 2014). Similar to the findings of Dellal et al. (2011), the separation of the two central midfielders into an attacking and defensive role highlighted potential differences between the two positions. Dellal et al. (2011) found that differences in physical performance across playing positions suggest that specific high-intensity conditioning regimes may be more beneficial for certain individuals within the team formation based on tactical responsibilities. Intermittent exercises, repeated-sprint drills, and small-sided games are commonly used to improve aerobic performance and aid in recovery between sprints (Dellal et al., 2008). However, with enhanced sports technology and the development of the physical aspect of soccer, Global Positions Systems (GPS) technology may be able to assist traditional strength and conditioning coaches in the United States in specifying conditioning protocols that would be appropriate for out of season training when the National Collegiate Athletic Association (NCAA) limits the amount of sport specific training time.

Findings from the current investigation also showed consistency with previous literature on match-to-match variability in physical performance. Previous investigations have shown players physical performance to have an approximate coefficient of variation of (CV) 30% during a single competitive season (Gregson et al., 2010; Rampinini et al., 2009). The current investigation of the women's college soccer team found that high-speed running variables can vary between 25% and 31%. Also pertinent to the current investigation is the ability of a player to maintain performance in two matches in close proximity to each other. Common to the collegiate environment teams will play two matches within 40 to 48 hours of each other on a weekend. Maintenance of player's physical performance could be indicative of overall team performance. Large drops in work from a first match of the week to second match of the week could be evidence of fatigue accumulation and recovery modality implementation. With an percentage of drop from first to second match of the week of approximately 7% in high-speed and sprinting efforts, the players show an ability to nearly repeat performance for two matches in close proximity to each other.

The final findings of the current investigation show that there is a relationship between players' ability to perform work repeatedly and at a high-speed intensity during a match and their technical success. Players who covered a greater distance in high-speed velocity bands were able to complete a higher percentage of their passes and were able to interact with the ball more. A heavy emphasis is on players' fitness in the United States. Soccer researches in some areas of the world believe this is to a fault. However, current findings would support the notion that a fit player is going to be more successful than one who is not able to sprint or cover as great of a distance in high-speed velocity bands. Therefore, by combining the findings of the current investigation and providing appropriate and efficient conditioning protocols for players should increase the amount of time a coach can spend on tactical and technical development, which would, in theory, enhance all aspects of a player's performance.

Future investigators should attempt to increase the size of the sample. Consistent with the current investigation it is important to maintain the six positional subcategories to decipher any positional differences between those that were once thought to be similar in demands. Analysis over the course of a season should focus on players in the upperclassmen (third and fourth year college players) versus underclassmen (first and second year college players) to determine if there are differences between experience levels at the collegiate standard.

Future investigators should also be sure to include teams across different conference or league affiliations. The NCAA governs over 250 female Division I soccer teams. The playing level across all of those teams is not the same; therefore, analyzing the differences between the different conference affiliations can help determine playing standards for coaches. By determining the different playing standards the coaches are able to be more specific and efficient in their training regimens for their players.

Future investigators should also use GPS technology to monitor training loads leading into matches to determine if at the collegiate level there are thresholds of training loads that could increase the likelihood of a positive physical performance versus a training load that may lead to a negative physical performance. Indication of ranges of training loads could lead to better understanding of how to train or taper female college soccer players into matches to promote optimal performance while simultaneously decreasing the risk of injury.

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APPENDIX

East Tennessee State University
Office for the Protection of Human Research Subjects • Box 70565 • Johnson City, Tennessee 37614-1707
Phone: (423) 439-6053 Fax: (423) 439-6060

IRB APPROVAL – Initial Expedited Review

March 21, 2014

Ryan Alexander

Re: The physical and technical activity of female soccer players participating in NCAA Division I athletics - with special reference to playing position
IRB#:c0214.23sw
ORSPA #:

The following items were reviewed and approved by an expedited process:

- xform new protocol submission, CV of PI

On **March 20, 2014**, a final approval was granted for a period not to exceed 12 months and will expire on **March 19, 2015**. The expedited approval of the study will be reported to the convened board on the next agenda.

Study has been granted a Waiver or Alteration of Informed Consent under category: 45 CFR 46.116(d)

The research involves no more than minimal risk to the participants as the study involves retrospective data analysis only. The waiver or alteration will not adversely affect the rights and welfare of the subjects as it is retrospective data analysis only. The research could not practicably be carried out without the waiver or alteration because the data were collected previously and the participants are no longer at ETSU**.** Providing participants additional pertinent information after participation is not appropriate as they have already left ETSU and this is a retrospective data analysis study.

Projects involving Mountain States Health Alliance must also be approved by MSHA following IRB approval prior to initiating the study.

Unanticipated Problems Involving Risks to Subjects or Others must be reported to the IRB (and VA R&D if applicable) within 10 working days.

Accredited Since December 2005

Proposed changes in approved research cannot be initiated without IRB review and approval. The only exception to this rule is that a change can be made prior to IRB approval when necessary to eliminate apparent immediate hazards to the research subjects [21 CFR 56.108 (a)(4)]. In such a case, the IRB must be promptly informed of the change following its implementation (within 10 working days) on Form 109 (www.etsu.edu/irb). The IRB will review the change to determine that it is consistent with ensuring the subject's continued welfare.

Sincerely,
Stacey Williams, Ph.D., Vice-Chair
ETSU Campus IRB

cc: Satoshi Mizuguchi

VITA

RYAN ALEXANDER

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Professional Experience:	Physiologist, United States Soccer Federation, Carson, California, 2013 – Present Sport Scientist, Centre of Excellence, Johnson City, Tennessee 37659, 2010-2014 Doctoral Fellow, East Tennessee State University, Johnson City, Tennessee 37659, 2011 – 2014
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