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Identifying Determinants of Match Performance in Division I Women's Collegiate Soccer Players

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Identifying Determinants of Match Performance in Division I Women's Collegiate Soccer Players

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Doctor of Philosophy in Sport Physiology and Performance

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by

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ABSTRACT

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The purpose of this dissertation was to better understand position specific physical qualities and how they relate to high speed running performance throughout the course of a competitive collegiate soccer season. The amount of literature devoted to female soccer players is scarce when compared to the vast amount of literature associated with male soccer players. The objectives of this dissertation were: 1) to determine if playing position has an influence on physical qualities such as speed, change of direction ability, countermovement jump performance, relative strength, rate of force development, and intermittent endurance capacity, 2) investigate the differences between high and lower caliber players as defined by minutes played per match when considering the physical qualities mentioned previously, 3) and finally to assess the influence of physical qualities and playing position on high speed running performance throughout the course of a competitive season. Data from 57 Division I Women's Collegiate soccer players from a single institution were used. The influence of playing position and caliber of play on physical qualities were assessed using both laboratory and field based testing assessments. It appears that attacking based players (forward, wide midfielder, and attacking midfielder) were faster compared to defensive based players (central defensive midfielder, central defender, and goalkeeper) when assessed during 20 m sprint assessments and change of direction ability assessments. The only variable to differentiate between caliber of play was the

Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT1), indicating that higher caliber players possess greater intermittent endurance capacity compared to lower caliber players. Playing position was the major contributor when assessing high speed running performance during competition, explaining almost 70% of the variance. These findings highlight the impact of tactical factors on physical performance during competition and the need for position based assessments to better identify relevant physical qualities with respect to playing position in Division I Women's Collegiate Soccer players. Further research is needed with a wider range of players from various levels to determine if these findings exist across all levels or are unique to the institution used during these investigations.

DEDICATION

I would like to dedicate this dissertation to my family. Without your help and guidance along the way, I would not be where I am today.

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CHAPTER 1

INTRODUCTION

With advancements in technology over the past 15 to 20 years related to Global Positioning Systems (GPS), accelerometers, and digital camera systems, the ability to measure and quantify the amount of physical work an individual does during a given training session and match has given coaches and sport scientists insight into the demands placed on the athlete like never before. The sport of soccer can be characterized as a high-intensity sport that involves random bouts of anaerobic and aerobic activities such as jogging, sprinting, rapid accelerations and decelerations, sliding, tackling, and jumping (Al-Hazzaa et al., 2001; Bloomfield, Polman, & O'Donoghue, 2007; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004). The early analysis related to the quantification of match demands were mainly done only at the high professional levels due to lack of funding and resources at lower levels of play. Research related to the women's game is even more scarce compared to that of the men's game. More and more investigations specifically in the female population have been completed in recent years looking at both professional (Andersson, Randers, Heiner-Moller, Krustrup, & Mohr, 2010; Mohr, Krustrup, Andersson, Kirkendall, & Bangsbo, 2008) and the youth level (Vescovi, 2014). To the researcher's knowledge, only a few studies have investigated the demands of the women's collegiate soccer game (Alexander, 2014; McCormack et al., 2015; Vescovi & Favero, 2014). These studies looked at the demands of the women's game over the course of a single season (Alexander, 2014; McCormack et al., 2015) or just a single match with various teams (Vescovi & Favero, 2014). The researchers concluded that there are differences amongst playing positions in total distance, high speed running, and sprinting distances. However, these studies observed different subgroups of playing positions making it difficult to make comparisons between the studies themselves. Vescovi and Favero (2014) used more “classic” positional subgroups of defender, midfielder, and forward whereas Alexander (2014) used positional subgroups of central defender, fullback, central defensive midfielder, wide midfielder, central attacking midfielder and forward. With only one of the positional subgroups being similar (forward), comparisons amongst the other positional subgroups cannot be made. Also, differences amongst classifications of velocity bands make it difficult to make comparisons across studies even though the samples being observed were of similar ages.

Current research has shown that in the women’s game, there is a difference in the amount of total distance, high speed distance, and sprinting efforts completed during a 90-minute match based on playing position (Alexander, 2014; Vescovi & Favero, 2014). Studies looking at differences amongst playing position have demonstrated that there were no differences amongst positions (goalkeeper, forward, midfielder, and defender) in speed, agility, and aerobic fitness (Vescovi, Brown, & Murray, 2006). However, this investigation noted that the subjects used were from various universities of various levels of play, which may be a reason for the lack of differences observed. Further research is needed to conclusively determine whether there are differences in physical qualities between playing positions. Other research looking at predictors of high speed running capacity in women’s collegiate soccer identified the main determinant of high speed running capacity using a stepwise regression as aerobic power (VO2max) (McCormack et al., 2014).

One of the discriminant factors between playing positions is the amount of distance covered at high velocities (Alexander, 2014; Bradley et al., 2009; V. Di Salvo et al., 2007; V. Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009). Rampinini, Coutts, Castagna, Sassi, and Impellizzeri (2007) showed that midfielders and fullbacks covered more distance at high velocities (> 19.8 $km \cdot h^{-1}$) compared to central defenders. Alexander (2014) demonstrated that throughout a Division I Women's Collegiate soccer season, fullbacks covered more distance at high velocities (>15 $km \cdot h^{-1}$) compared to central defenders and central midfielders. The athlete's ability to cover distance at high velocities has been shown to be different amongst different standards of play (Andersson et al., 2010; P. S. Bradley et al., 2013; Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mohr, Krustrup, & Bangsbo, 2003). Previous research has shown that athletes who play at a higher level cover more distance at high velocities (>15 $km \cdot h^{-1}$) compared to their lower level counterparts in the female population (Andersson et al., 2010; Mohr et al., 2008). However, P. S. Bradley et al. (2013) showed that the lowest level of play observed in English professional soccer covered the greatest total distance and distance at high velocities (>19.8 $km \cdot h^{-1}$) compared to the highest level of play in the male population, which were attributed to increases in technical proficiency and thus more efficient game play (e.g. fewer technical errors) at the top level of play. When assessing technical ability (pass completion %) in the female population, Alexander (2014) found a significant positive relationship with pass completion % and distance covered at high velocities, indicating that those individuals with greater technical proficiency cover greater distances at high velocities, which is contrary to the findings of P. S. Bradley et al. (2013).

In summary, currently the literature does not appear clear on relationships of physical qualities to player's positions, caliber, and match performance in collegiate women's soccer players. Specifically, the following need further investigation. 1) The relationship of physical qualities with playing positions and player's caliber needs to be further investigated as the previous study's results may have been confounded by the heterogeneous sample (Vescovi et al., 2006). Understanding the relationship can aid in talent identification and what does or does not contribute to key game performance measures such as high speed running distance. 2) The relationship of physical qualities to high speed running capabilities has never been investigated throughout the course of a competition season in Collegiate Women's soccer. Previous research has investigated the relationship between physical qualities and high speed running during a single match (McCormack et al., 2014). Previous research has shown that there can be up to 30% variation of high speed running from match to match (Alexander, 2014; Gregson, Drust, Atkinson, & Salvo, 2010). Thus, investigating a single match may not provide accurate insight into the high speed running capabilities of an individual throughout a competitive season. Thus, this dissertation utilizes data collected from a single team over the course of a season.

Dissertation Purpose and Objectives

The purpose of this dissertation was to better understand position specific physical qualities and how they relate to high speed running performance throughout the course of a competitive collegiate soccer season. The initial study aimed to identify differences in physical attributes relative to playing position of both lab and field based testing measurements. From here, we explored differences between primary and secondary players, based on minutes played, and the effect of specific attributes and playing position on high speed running capabilities.

Operational Definitions

1. Change of Direction Ability: The ability to perform a pre-planned change of direction task
2. Countermovement Jump Height: The height the athlete raises their center of gravity off of the force plate as calculated by time in air.

3. High Speed Running: Distance covered above 15 $km{\cdot}h^{-1}$ (Alexander, 2014; Andersson et al., 2010; Krustrup et al., 2005)
4. Intermittent Endurance Capacity: One's ability to perform repeated high-intensity actions for prolonged durations
5. Isometric Mid-Thigh Pull: An assessment of overall maximum strength. The athlete is attached to a bar with their feet placed on force plates. The athlete is to pull as fast and hard as possible staying in a static, isometric position (Kraska et al., 2009).
6. Rate of force development: A measure of explosive strength which we be quantified by using the isometric mid-thigh pull.
7. Isometric Peak Force Allometrically scaled: Peak force will be quantified by using isometric mid-thigh pull and the peak force the athlete achieves and taking into account the athletes body mass raised to the 2/3 power (Jaric, 2003)

CHAPTER 2

REVIEW OF LITERATURE

Introduction

This review of literature is a review of the physical qualities of female soccer athletes as well as the match performances of female soccer players. Special attention will be given to how these relate to playing position for female soccer players to better identify if there are differences amongst playing positions that are currently known in the literature. Also, there will be an emphasis on the relationship between high speed running and its ability to distinguish between levels of play, playing position and the relationships of physical qualities to high speed running.

Physical Qualities

Strength and Explosiveness

There have been few investigations into measures of strength in female soccer athletes and their relationship to performance either on the field or with other testing assessments. The most common method of strength measurements is done using isokinetic dynamometers assessing the strength of a single joint, typically measuring knee extensor and/or knee flexor. To the researcher's knowledge only three studies assessed and reported strength utilizing a one rep maximum (1RM) or maximal strength values for multi-joint lower body assessments for female soccer athletes. Helgerud, Hoff, and Wisloff (2002) assessed female soccer players from the top Division in Norway and reported that for 90° squats, they had a 1RM of 112.5 ± 20.7 kg. Another study that utilized full squats using a Smith Machine reported a baseline 1RM level of 84.5 ± 13.8 kg for the control group and 78.9 ± 13.6 kg for the intervention group and following creatine supplementation intervention, both groups improved to 95.0 ± 18.4 kg and 94.5 ± 11.7 kg respectively (Larson-Meyer et al., 2000). A study assessing maximum strength in the back squat, Nesser and Lee (2009) reported the 1RM back squat to be 75.8 ± 14.0 kg. There was no information regarding squat depth or other than the information that the athletes achieved 1RM within five sets after starting with 50% of their previously measured 1RM.

With only three studies assessing maximal multi-joint, lower body strength in female soccer athletes, more investigations are needed in this area to determine normative values and determine whether or not maximal strength can be a discriminative quality for levels of play or playing position in female soccer athletes.

Although there is a paucity of research assessing strength in female soccer athletes, much more attention has been focused on the lower-body explosiveness capabilities of female soccer athletes, mainly through investigations of jumping performance. Andersson et al. (2008) assessed the lower-body explosiveness capabilities of Scandinavian female soccer athletes and reported the countermovement jump height (CMJ) of the individuals was 30.1 ± 1.2 cm when utilizing a force platform. The purpose of the investigation was to examine the impact of active vs. passive recovery following competition and the authors reported that CMJ height was suppressed for up to 69 hours following the first match leading into the second match. Haugen, Tonnessen, and Seiler (2012) reported similar CMJ values for national level, first division, and junior elite reporting 30.7 ± 4.1 cm, 28.1 ± 4.1 cm, 28.5 ± 4.1 cm respectively while also utilizing a force platform to assess CMJ. The authors reported that the first division and junior elite level athletes possessed inferior CMJ abilities compared to the national level athletes. The authors also reported that there were no differences when assessing differences amongst playing position (forwards, midfielders, defenders, and goalkeepers) for CMJ. In an investigation comparing the effects of a resisted sprint training plan to a resistance training plan, researchers reported CMJ values of 26.8 ± 3.3 cm prior to the resisted sprint training program and 27.2 ± 2.2 cm following the intervention. The strength training group reported a start CMJ values of 28.3 ± 4.2 cm and following the training intervention, they reported 29.9 ± 5.6 cm (Shalfawi, Haugen, Jakobsen, Enoksen, & Tønnessen, 2013). The authors reported no improvement in CMJ performance following the strength training or resisted sprint training intervention and cited the fact that the intervention was done in season and on-field training load was not quantified may have been the reason for not seeing any improvements since the overall training load may have been too high to observe improvements from the training intervention. The researchers utilized a force platform to assess CMJ height. A study investigating the effectiveness of an unstable training surface in female soccer players assessed CMJ height utilizing a force platform (Oberacker, Davis, Haff, Witmer, & Moir, 2012). The authors reported that for Division II women's collegiate soccer players, CMJ height was 23 ± 3 cm prior to intervention for both stable and unstable surface training groups and following intervention, CMJ decreased (1 cm) in the unstable surface training group and increased (4 cm) in the stable surface group. The authors concluded that there were no benefits to the unstable training surface intervention, in fact it likely inhibited the force production capabilities of the athletes since they saw a decrease in CMJ performance following the intervention whereas the stable surface group saw a 15-20% increase in CMJ performance.

An investigation of the top female league in Denmark reported CMJ values of 35 ± 1 cm from data collected using a jump mat (Time It; Eleiko Sport, Halmstad, Sweden) (Krustrup, Zebis, Jensen, & Mohr, 2010). The authors were assessing the impact of competition on jump performance and the results indicated that following competition, there were no difference in CMJ performance (Andersson et al., 2008). A study conducted by Vescovi et al. (2006) reported for Division I Women's Collegiate soccer athletes CMJ values of 41.9 ± 5.6 cm when collecting data using the Just Jump System (Probotics, Hunstville, AL). The researchers also assessed positional differences (forwards, midfielders, defenders and goalkeepers) and stated that although there were trends for forwards and midfielders to possess greater CMJ values than defenders and goalkeepers, this did not achieve statistical significance. Vescovi, Rupf, Brown, and Marques (2011) reported for a similar age group (18-21 years old) to the previous study CMJ values of 42.0 ± 5.0 cm, which were similar findings to the previously mentioned study that utilized similar methodologies to assess CMJ. The authors also investigated 12-13 year olds and 14-17 year olds as well and reported that the 18-21 year olds had superior CMJ abilities compared to both groups of female soccer players whereas there were no statistical differences between the 12-13 year olds and 14-17 year olds. Vescovi and McGuigan (2008) investigated Division I Collegiate Soccer player and high school soccer players and reported no differences in CMJ height between college or high school players (40.9 ± 5.5 cm vs. 39.6 ± 4.7 cm) while using a contact mat (JustJump System; Probotics, Huntsville, AL). A study conducted using Division I Women's Collegiate soccer athletes reported CMJ values of 48.8 ± 7.9 cm using a contact mat (Probotics, Huntsville, AL) whilst utilizing an arm swing (Sjökvist et al., 2011). The authors reported a significant decrease 24 hours following a high intensity interval training session in CMJ performance but following 48 hours, they appeared to be fully recovered to baseline CMJ performance. The JustJump System has been shown to be valid and reliable to measurements compared to values reported from a 3-camera motion analysis system (Leard et al., 2007). In a study assessing both elite (Spanish National Women's First Division) and non-elite (Spanish Regional First Division) female soccer player's, they reported CMJ values of 26.1 ± 4.8 cm and 27.3 ± 5.7 cm for the elite and non-elite groups respectively using a contact mat (SportJump System, DSD, 2006) (Sedano, Vaeyens, Philippaerts, Redondo, & Cuadrado, 2009). The authors reported that the higher level athletes achieved greater CMJ values compared to the lower level female soccer players and outfield players (fullback, center back, central midfielder, wide midfielder, forward) had superior CMJ performances compared to the goalkeeper position. The SportJump System has been shown to be both valid and reliable when compared to measurements reported from a force platform for calculating jump height based on flight time (García-López, Morante, Ogueta-Alday, & Rodríguez-Marroyo, 2013).

Castagna and Castellini (2013) conducted a study using Italian national team athletes from both the senior and youth level teams. They reported that the grouped average of all of the female soccer players was 30.2 ± 3.5 cm. The authors reported for the senior, U19, and U17 level players their CMJ values were 31.6 ± 4.0 cm, 34.3 ± 3.9 cm, and 29.0 ± 2.1, respectively, stating that the U19 level players had a significantly greater CMJ than the grouped average of all of the female athletes while using a portable optical timing system (Optojump Next; Microgate, Bolzano, Italy). This system had been tested previously and when compared to a force platform, the system underestimated jump height when calculated based on flight time, although the researchers reported a formula that can be used to make comparisons to data collected utilizing a force platform (Glatthorn et al., 2011). Mujika, Santisteban, Impellizzeri, and Castagna (2009) compared First Division and second division female soccer players and reported that the First Division females had a greater CMJ than the second division players (32.8 ± 3.7 cm vs. 28.41 ± 1.99 cm), possibly indicating that CMJ can be used as a discriminatory assessment to determine levels of play in female soccer athletes. McCurdy et al. (2010) assessed CMJ in Division I Women's collegiate soccer players and reported CMJ values of 31.0 ± 5.0 cm using an accelerometer attached to a waist belt (Inform Sport Training Systems, Victoria, BC, Canada). The authors did report that unilateral jump performance, which was assessed in this study, along with sprinting performance possessed greater relationships than did bilateral jumping performance to sprinting performance. The investigators did not report the reliability or validity of this method of assessing CMJ height, nor its ability to compare to other CMJ assessment methodologies that are more commonly used with this population. In a study investigating English soccer players playing in the Football Association Women's Northern Premier Division (Second division in English women's football at time of study, now is considered the Third division in English women's football) reported CMJ height of 38.8 ± 4.11 cm prior to an intervention and following a 10-week on field training intervention to enhance speed, agility, and quickness improved to 46.6 ± 4.81 cm (Polman, Walsh, Bloomfield, & Nesti, 2004). The methodology to assess CMJ height in this study was a digital vertical jump meter (Takei, 5105-Jump MD, Tokyo). The authors did not report the reliability or validity when compared to other methods of assessing CMJ height.

In an investigation of female high school soccer players, the researchers reported a CMJ height of 37.65 ± 4.77 cm during pre-test measurements to 39.37 ± 4.69 cm following a 10-week resistance and plyometric training intervention, however, the changes were not reported as statistically significant (Siegler, Gaskill, & Ruby, 2003). The method of assessment for CMJ height was using a wall tape and recording the difference between standing reach and the highest part reached on the tape during the CMJ with an arm swing. In a study assessing Turkish female soccer players, the authors reported CMJ values of 34.48 ± 7.11. However, this study utilized the arm-swing into their CMJ assessment differing from the previously mentioned studies and the subjects were instructed to touch the part of the wall at their highest point and this value was used for the CMJ assessment (Can, Yilmaz, & Erden, 2004). Hoare and Warr (2000) conducted a study in Australia in an attempt for talent identification for female soccer athletes. The investigators reported CMJ height values for all participants of 35.6 ± 6.8 cm and for the individuals that were selected to carry on in the process based on both physical, skill and competition based tests were reported to have a CMJ height of 41.1 ± 4.2 cm. The researchers for this study used a Yardstick device (Swift Performance, Lismore, Australia) to assess CMJ height that included the use of the arm swing. The authors did not utilize statistics to assess differences between groups to determine if the group selected possessed greater CMJ capabilities compared to the individuals that were not selected.

All of the articles that report CMJ height in this review used the best trial for CMJ assessment even though they reported assessing multiple trials. This can result in a decrease in reliability of the jumps (Taylor, Cronin, Gill, Chapman, & Sheppard, 2010) and may not be a true representation of the individuals that were being assessed since they are only reporting the best performance, not the average of multiple trials which could serve as a better indicator of the individual's typical performance.

Although the research is limited on strength values for female soccer players, there is a greater amount of research related to lower-body explosiveness assessments via CMJ height for this population. However, due to differences in methodological procedures such as equipment used to assess jump height (contact mat vs. camera systems vs. force platform vs. optical timing systems vs. accelerometer), reporting of best trial vs. averages of all trials, or with or without arm swing during the jump has made it difficult to make comparisons across studies. However, it does appear that CMJ performance can distinguish between levels of play in female soccer players based on the literature that currently exists. More research is needed to determine the abilities of CMJ performance to distinguish between playing position.

Speed/Agility/Change of Direction Ability

Speed and agility have been designated by many sport coaches, strength and conditioning practitioners, and sport scientists as an important component of on field performance for soccer athletes. Due to this proclamation, there have been a large number of studies investigating this quality via linear sprinting, agility, and change of direction ability tests in female soccer athletes.

Sprinting assessments have been utilized in several investigations of female soccer athletes as it has been identified as a vital component to soccer performance. McCurdy et al. (2010) conducted a study investigating the 10 m and 25 m sprint times of Division I Women's Collegiate soccer athletes and reported that they had a 10 m sprint time of 2.31 ± 0.25 s and a 25 m sprint time of 4.52 ± 0.20 s. The method used to assess sprint times was that the subject wore an accelerometer attached to a waist belt integrated with timing gates (Inform Sport Training Systems, Victoria, BC, Canada) and the time was started when the athlete moved and finished when the athlete passed through the final timing gate. The authors were looking at the relationship between sprint characteristics and various jumping assessments such as unilateral vs. bilateral and reported that unilateral jump assessments had greater relationships to sprint time than bilateral jump heights. Sjökvist et al. (2011) assessed 20 m sprint ability in Division I female soccer players and reported average 20 m sprint time for the group being 3.59 ± 0.17 s whilst using timing gates to assess the athletes (Brower, Salt Lake City, UT, USA). The investigators stated that the athletes started in a two-point stance and began on their own volition. They did not report any specific distance between the lead foot of the athlete and the first timing gate. The authors were investigating the impact of sprint time and its ability to detect changes in performance following high-intensity interval training and reported that sprint time was not acutely impacted following training. Sayers, Farley, Fuller, Jubenville, and Caputo (2008) assessed professional female soccer athletes that played in the U.S. to assess the impact of static stretching on different phases of a 30 m sprint. The athletes were assessed over 10 and 30 m distances using a pressure pad to initiate start time and timing gates at 10 and 30 m (Brower, Salt Lake City, UT, USA). The researchers reported that the 10 m sprint time was 1.88 ± 0.14 s during the no stretch condition and 1.93 ± 0.14 s during the static stretching condition. The 30 m sprint time was 4.81 ± 0.28 s during the no stretch condition and 4.91 ± 0.27 s during the static stretch condition. The 20 m fly time in the no stretch was 2.92 ± 0.17 s and 2.99 ± 0.15 s during the static stretch condition. Sayers et al. (2008) reported that the static stretching routine negatively impacted all phases of the sprint performance in professional female soccer athletes. Polman et al. (2004) investigated Second Division English football players in a 25 m sprint test and reported that 25 m sprint time was 4.32 ± 0.11 s before intervention and following a 10-week on field training program that was aimed to increase speed, agility, and quickness improved to 4.13 ± 0.10 s. The researchers utilized timing gates (Brower, Salt Lake City, UT, USA) to assess the individuals 25 m sprint. The researchers did not report starting distance from the first gate nor the stance at which the subjects started in prior to starting the 25 m sprint. An investigation into the impact of a training intervention comparing stable vs. unstable surface measured 30 m sprint time with splits at 10, 20 and 30 m intervals (Oberacker et al., 2012). The authors reported that prior to training the 0-10, 0-30 m times were 2.14 ± 0.14 and 5.14 ± 0.26 s for the unstable group and 2.11 ± 0.15 and 5.05 ± 0.31 s for the stable group. Following intervention, there were no differences observed for the split times between groups, however, following intervention both groups improved in the 20-30 m split time. The authors used timing gates (Brower, Salt Lake City, UT, USA) but did not report a distance from the start gate where the individual started. Siegler et al. (2003) measured a fly 20 m sprint time with a 10 m acceleration lead into the 20 m fly sprint time. They reported the 20 m fly time as 2.89 ± 0.13 s for high school female soccer players. The researchers used ALGE-Sports electronic timer to measure time to completion. The researchers were investigating the impact of a 10-week training intervention and reported a statistical improvement in sprint time following the intervention. An investigation of Scandinavian female soccer athletes reported a 20 m sprint time of 3.18 ± 0.03 s. The subjects started 88 cm behind a mechanical switch that would start the time of the test and times were measured with photocells every 10 m following the start starting in a staggered two-point stance (Andersson et al., 2008). This investigation was assessing the effectiveness of active vs. passive recovery techniques after competition and reported that although sprint performance was negatively impacted immediately following a soccer match, the recovery method did not have an impact on rate of recovery prior to the next competition that was 69 hours after the initial match. Vescovi and McGuigan (2008) investigated high school and college female soccer athletes over distances of 9.1, 18.2, 27.3 and 36.6 m. They reported that for the high school aged athletes their times over distances of 9.1, 18.2, 27.3 and 36.6 m were 1.96 ± 0.10 s, 3.33 ± 0.15 s, 4.63 ± 0.21 s, and 4.63 ± 0.21 s respectively. For the college athletes they reported times over the same distances of 2.00 ± 0.11 s, 3.38 ± 0.17 s, 4.69 ± 0.23 s, and 5.99 ± 0.29 s. The authors reported no statistical differences between any of the times comparing high school or college female soccer athletes. During an Australian talent identification camp, Hoare and Warr (2000) assessed female athletes over 5, 10, 20 m distances. For the entire group, they reported 5, 10, and 20 m times of 1.23 ± 0.09, 2.08 ± 0.18, and 3.63 ± 0.23 s and for those that were asked to continue on to the next level of evaluation following the physical, skill, and competition based assessments the averages were 1.18 ± 0.06, 2.01 ± 0.08, 3.47 ± 0.14 s for the 5, 10, and 20 m assessments. The researchers did not utilize any type of statistical processes to assess the differences between groups. They used an Alge-Sports electronic timer to assess the athletes sprint times. The researchers stated that the athletes started with a staggered, static, crouched position but were not allowed to shift weight from rear foot to forefoot prior to starting. They did not report a start distance from the beginning of the timing gates. Vescovi et al. (2011) investigated soccer athletes from ages 12-21 and grouped them into the following age group categories: 12-13, 14-17, 18-21 years. The researchers assessed 9.1, 18.2, 27.3, and 36.6 m sprint times. For the 12-13-year-old group, the researchers reported for 9.1, 18.2, 27.3, and 36.6 m sprint times of 1.98 ± 0.12, 3.40 ± 0.19, 4.76 ± 0.27, and 6.15 ± 0.36 s respectively. For the 14-17- year-old group they reported for 9.1, 18.2, 27.3, and 36.6 m sprint times of 1.94 ± 0.10, 3.32 ± 0.16, 4.63 ± 0.24, and 6.94 ± 0.33 s, respectively. For the 18-21-year-old group, the investigators reported 9.1, 18.2, 27.3, and 36.6 m sprint times of 1.96 ± 0.09, 3.31 ± 0.14, 4.6 ± 0.19, and 5.87 ± 0.26 s, respectively. The researchers concluded that for all but 9.1 m distance, the 14-17 and 18-21-year-old groups performed better than the 12-13-year-old group. For the 36.6 m sprint time, the 18-21-year-old group were faster than the 14-17-year-old age group as well, but performed similarly over the other reported distances. The authors suggested that the differences in top speed (36.6 m time) may be attributed to the fact that the 18-21 age group may have been participating in training strategies that may enhance this quality, referencing that college programs typically engage in resistance training programs highlighting resistance training as a method to enhance top speed performance, although they stated this with speculation since the athletes did not report whether or not they were actively taking part in a resistance training program. This study used timing gates (Brower, Salt Lake City, UT, USA) to assess the sprint times and did not report a start distance from the first timing gate. In one of the larger studies (N = 140) where sprint speed was assessed in female soccer athletes, Vescovi (2012) measured 35 m sprint speed with splits over

5, 10, 20, and 35 m in a group of high-level American female soccer players that were invited to a professional women's soccer league try-out. The researcher assessed the group as a whole as well as broken down between players that were drafted and players that were invited, but ultimately not selected in the draft process. The investigators found that for all of the measured split times (5, 10, 20, and 35 m), the players that were drafted were statistically faster than the players that were not drafted. For the entire group the 5, 10, 20, and 35 m times were 1.19 ± 0.08, 2.00 ± 0.10, 3.40 ± 0.14, 5.38 ± 0.20 s, respectively. For the drafted vs. non-drafted players split times for the 5, 10, 20, and 35 m times were 1.17 ± 0.07 vs. 1.22 ± 0.09, 1.97 ± 0.09 vs. 2.02 ± 0.10, 3.33 ± 0.11 vs. 3.43 ± 0.13, 5.27 ± 0.20 vs. 5.43 ± 0.21 s, respectively. The players started with their lead foot 5 cm behind the timing gate in a staggered start (Brower, Salt Lake City, UT, USA). This is the first study in female soccer athletes that was able to report statistical differences in such a homogenous group of high-caliber female soccer athletes for sprinting speed and shed light on the ability of a relatively simple assessment requiring minimal technology and set-up (timing gates) to determine differences between playing level. The authors did state that the coaches were given these results prior to the draft selection date and this could have been a reason as to why there was a difference, however due to the multi-faceted nature of the game of soccer needing to take into account many other factors, the fact that an individual was selected solely on this physical assessment is highly unlikely. Haugen et al. (2012) investigated the sprinting characteristics of Norwegian female soccer players that tested as part of the monitoring program at the Olympic training center in Oslo, Norway over the span of 1995-2010. The athletes were organized into four categories; Senior national team, First-Division, second-division, and junior elite athletes. The researchers assessed sprint times over 10, 20, 30 and 40 m distances. The investigators reported that the Senior national team players were 2% faster than the First-division players and 5% faster than the second-division players over 0-20 m distances and junior elite players were 3% faster than the second-division players over the same distances. For the 20-40 m distances, the Senior national team players were 5% faster than the second-division players and First-division players were 3% faster than the second-division players. The researchers also investigated differences in playing position (forwards, midfielders, defenders, and goalkeepers) and reported that forwards were 3% faster than midfielders and 4% faster than goalkeepers as well as defenders being 2% faster than midfielders over the 0-20 m distances. For the 20-40 m distances, similar differences existed between forwards and midfielders (4% faster) and forwards and goalkeepers (6% faster). Defenders were 3% faster than goalkeepers over the 20-40 m distances. The researchers used a pressure pad to initiate start time and reported that the center of gravity was approximately 50 cm in front of the start when sprint time was actually started. This may be a reason as to why some of the values reported in this study (1.67 – 1.77 s for 0-10 m) may be lower than previously reported numbers since they were starting with a .5 m head start compared to other investigations. This investigation shed light on the possibility of sprint assessments to be able to distinguish levels of play as well as positional differences in female soccer athletes. In an investigation of 64 Division I Women's Collegiate Soccer players, they were assessed on their 36.58 m sprint ability with splits at 9.14 m and 18.28 m. The researchers reported that the average 9.14 m, 18.28 m and 36.58 m times were 1.98 ± 0.11 s, 3.34 ± 0.17 s, and 5.90 ± 0.31 s, respectively. This study also investigated positional differences (forwards, midfielders, defenders, and goalkeepers) and did not report any statistical differences, however stated that there were trends for defenders to be slower than forwards and midfielders occurring at the 18.28 m and 36.58 m distances (Vescovi et al., 2006). The researchers utilized timing gates (Brower, Salt Lake City, UT, USA) in this study but did not report a start distance nor starting stance from the first set of timing gates. Mujika et al. (2009) investigated Senior and junior level Spanish female soccer players over a 15 m sprint distance. The authors reported that there were no differences in 15 m sprint times in Senior level (2.38 ± 0.09 s) compared to junior level players (2.43 ± 0.06 s). The athletes had a 3 m distance in front of the first set of timing gates that initiated the start of the 15 m sprint. This gave the athletes time to accelerate over the first 3 m prior to the start of the timer.

Based on the vast amount of literature that investigates sprinting characteristics of female soccer players, there appears to be a degree of discriminative validity to sprinting assessment over various distances to distinguish between levels of play (elite vs sub-elite, Senior National level vs. Youth National vs. non-National level athletes, drafted vs. non-drafted) as long as methodologies are consistent within the population that is being assessed. There still needs to be more investigations into the capabilities of sprint testing to distinguish between playing position in female soccer athletes. Due to differences in methodological differences (start stance, timing methods, distance from start gates (0-88cm), consistency in distances measured) make it extremely difficult to make comparisons across studies for different groups of athletes reported from different studies.

Agility has been identified as a key component in soccer (Mujika et al., 2009; Reilly, Williams, Nevill, & Franks, 2000; Sheppard & Young, 2006) due to the nature of soccer requiring the athlete to change direction constantly throughout the course of a match. This has resulted in several investigations assessing agility of female soccer players over the years. However, the term agility has been defined as “rapid whole body movement with change of velocity or direction in response to a stimulus” (Sheppard & Young, 2006). Many of the investigations that claim to be assessing “agility” are actually assessing change of direction ability (CODA) (Oliver & Meyers, 2009) since the individual is performing a pre-planned change of direction and not responding to a stimulus as stated by the definition of agility previously (Sheppard & Young, 2006). For the purposes of this review, the author will identify whether the assessment is a true assessment of agility (responding to a stimulus) or CODA.

Of the total number of studies that were found for assessments of agility in female soccer players (N = 13), only one study truly assessed agility as defined by Sheppard and Young (2006). Oberacker et al. (2012) assessed the effect of a training intervention utilizing either stable or unstable training surfaces. The results indicated that the unstable training surface provided no additional performance enhancement compared to the stable training surface. The researchers investigated both planned (CODA) and agility in a group of Division II female soccer athletes using a modified pro-agility. The athletes would stand on a .60 m box and upon landing would go to the right or left or react to a video clip of a soccer play kicking a ball to the right or left. Depending on the direction of the kick for the agility assessment, that is the way the athlete would start the test. The .60 m box was selected because the researchers reported that the start of the video to the time where contact was made with the ball in the video took about the same time for the athlete to step off of the box and land. This resulted in the athlete needing to make a decision about which way they were to go during the landing. A similar procedure was used for the CODA assessment; however, the athlete knew which direction they were to begin the test. The results did not differ for the CODA or agility (3.31 ± 0.18 vs. 3.28 ± 0.24 s) test prior to training intervention or after intervention (3.06 ± 0.18 vs. 3.05 ± 0.16) which was conflicting to previous research utilizing true assessments of agility (Oliver & Meyers, 2009), however different protocols were utilized in the studies and this may be the reason for not observing differences between CODA and agility assessments.

With limited research truly assessing agility in female soccer athletes, there have been more investigations into CODA in female soccer athletes aiming to identify differences between playing position as well as standards of play. In an investigation examining the effectiveness of a resisted sprint training program compared to a strength training program, the investigators assessed CODA by using the S180° Agility test designed by (Sporis, Jukic, Ostojic, & Milanovic, 2009) and reported that there were no differences in CODA in either group pre to post training (Shalfawi et al., 2013). The researchers used photocells to assess CODA and did not report any distance from the start line. Mujika et al. (2009) investigated Senior and junior Spanish female soccer players using a 15 m agility run to assess CODA. The investigators reported that the athletes had a 3 m run up prior to initiating the time of the start gates and had to maneuver through poles and over a .5 m hurdle and finish with a 7 m sprint through the final set of timing gates. The authors reported that the Senior players were statistically faster than the junior players in CODA (3.29 ± 0.18 vs. 3.55 ± 0.17 s). The authors did not report a similar difference when assessing 15 m sprint times between Senior and junior level players, possibly highlighting the importance of assessing both qualities separately. In a talent identification trial, Hoare and Warr (2000) assessed athletes in a 505 agility test to assess CODA. The group averages for the 505 test was 2.75 ± 0.15 s and for the selected group only was 2.64 ± 0.09 s. These results indicated that although it trended that the selected group possessed greater CODA, statistical significance was not reported. The researchers used timing gates (Swift Performance, Lismore, Australia) and the athletes had a 10 m run up prior to the initiation of the start timer. Polman et al. (2004) investigated the effectiveness of a training intervention and its impact on CODA. The researchers used two different assessments to assess CODA, one involving a 90° to either left or right (Williams et al., 1997) and the other involving a complete 180° turn. Results indicated that the training intervention improved both assessments of CODA. They reported using timing gates for both assessments (Brower, Salt Lake City, UT, USA) and did not report a start distance prior to the starting gates. In an investigation of Division I female soccer athletes, the researchers assessed CODA via the utilization of the Pro-Agility test (Nesser & Lee, 2009). The authors stated that the athlete stood in the middle of the start line and timing started when the athlete initiated movement to and finished when the subject crossed the start line for the second time covering a total distance of 20 yards. The researchers used two different timers and used the average from both timers for analysis. They reported CODA times of 5.30 ± 0.30 s for the Pro-Agility test. An investigation of Division I female collegiate soccer players, a modified Illinois agility test and a modified Pro-Agility test were used to assess CODA. The modified Illinois Agility test and modified Pro-Agility test were used to assess whether one or the other had the ability to distinguish between playing position (forwards, midfielders, defenders, and goalkeepers) (Vescovi et al., 2006). The results of the study indicated that neither of the tests were able to identify differences between playing position, however trends did exist that goalkeepers and defenders were slower compared to forwards and midfielders. The group average for the entire study for the modified Illinois-Agility test was 10.21 ± 0.37 s and for the modified Pro-Agility was 4.87 ± 0.02 s. Another study using similar methodologies and assessments (Vescovi & McGuigan, 2008) investigated the differences between college and high school female soccer players. The authors reported that there were no differences for the modified Illinois Agility test between high school (10.24 ± 0.42 s) and the Division I college athletes (10.24 ± 0.38 s), however the results did indicate that both of the soccer groups were statistically faster than the collegiate lacrosse athletes (10.45 ± 0.57 s). Similar results were observed for the modified Pro-Agility as the high school (4.91 ± 0.22 s) and college soccer (4.88

± 0.20 s) athletes were significantly faster than the collegiate lacrosse athletes (4.99 ± 0.24), but not statistically different from each other. The authors reported that for the collegiate athletes (both soccer and lacrosse) that both of the CODA tests explained a large amount of the variance (r^2 >.60), but had a weaker relationship for the high school soccer players (r^2 = .36), thus suggesting that for high school soccer athletes, both tests should be completed whereas for collegiate athletes, one or the other may be sufficient to assess CODA. Vescovi et al. (2011) investigated female soccer athletes of varying age groups (12-13, 14-17, and 18-21 years old), and used the same testing methodologies as the previous two studies. The researchers reported that the 18-21-year-old age group possessed greater CODA in both the modified Illinois Agility test and modified Pro-Agility test (10.2 ± 0.36 s and 4.87 ± 0.21 s) compared to the 12-13-year-old age group (10.8 ± 0.64 s and 5.17 ± 0.33 s). They also reported that the 18-21-year-old age group possessed greater CODA when assessed by the Illinois Agility test compared to the 14-17-year-old age group (10.36 ± 0.5 s) but not the Pro-Agility (4.92 ± 0.24 s). These assessments were able to distinguish between age groups, possibly indicating standards for certain levels of play throughout youth systems that are categorized by chronological age and if an individual performs at a certain level, this may indicate that they are able to handle the demands of an increased age population.

Although agility has been identified as an important component to soccer performance (Mujika et al., 2009; Reilly et al., 2000; Sheppard & Young, 2006), only one study in female soccer athletes has attempted to assess agility (Oberacker et al., 2012). Other investigations have investigated CODA and there have been conflicting reports based on its ability to distinguish between levels of play but may be able to differentiate between sport (soccer vs. lacrosse). Differences in assessments used as well as modification of similar protocols make it very difficult to compare across studies since many of the assessments of CODA are differing amongst studies. Much more research is needed into this area to identify the usefulness of CODA assessments as well as investigations into agility assessments in female soccer athletes are needed to definitively state the importance of agility to soccer performance.

Intermittent Endurance Capacity

Due to the duration of soccer matches (90 minutes in NCAA), the aerobic system is stressed during a match (Stølen, Chamari, Castagna, & Wisloff, 2005). This has resulted in investigations looking at aerobic capacity and aerobic power via direct and indirect methods utilizing continuous laboratory or field based assessments. The common field based assessments include the Leger shuttle-run (commonly referred to as multi-stage fitness test) (Leger & Lambert, 1982) or Cooper 12-minute run test (Cooper, 1968) and laboratory based assessments. Direct (Andersson et al., 2010; Gabbett & Mulvey, 2008; Ingebrigtsen, Dillern, & Shalfawi, 2011; Krustrup et al., 2005; Krustrup et al., 2010; McCormack et al., 2014) and indirect (Vescovi et al., 2006) measurements of aerobic power (VO_{2max}) have been reported in female soccer players to be in the range of 49.4 - 57.6 $ml \cdot kg^{-1} \cdot min^{-1}$ amongst a wide variety of athletes from various levels of play. The relevance of assessments that rely on continuous activity have been questioned due to their lack of specificity to the time-motion characteristics observed in team sports (Bangsbo, 1994; Castagna, Abt, & D'Ottavio, 2005; Krustrup et al., 2003). The lack of specificity in assessing field sport athletes led to the development of the Yo-Yo intermittent recovery tests (YYIRT) (Bangsbo, Iaia, & Krustrup, 2008). The test is similar to the Leger shuttle run in the fact that the participants are performing 2x20 m shuttles, however there is a recovery component (10 s) in between each shuttle whereas the Leger shuttle run was continuous. There are two different levels of the test. There is the YYIRT Level 1 (YYIRT1) which starts at a lower speed than the YYIRT Level 2 (YYIRT2). The YYIRT2 assessed the ability to perform repeated high intense bouts compared to the YYIRT1 which may assess the ability of the participants' intermittent endurance capacity depending on the training status of the individual.

To the researcher's knowledge, only six studies have been conducted that have assessed female soccer athletes in the YYIRT1. In a study by Krustrup et al. (2005) investigating the relationship between YYIRT1 performance and match performance, the authors reported that there was a strong relationship between high intensity running performance (>15 $km \cdot h^{-1}$) for the entire 90-minute match (r = 0.76) as well as the final 15 minutes of each half (r = 0.83) and YYIRT1 performance in female soccer players that play in the top league in Denmark. The authors reported that the average distance covered during the YYIRT1 was 1,379 m. In a study of Spanish League female soccer athletes, the authors investigated differences between Senior level and junior level players and found that Senior level players covered statistically more distance than the junior level players (1,224 ± 255 vs. 826 ± 160 m), respectively (Mujika et al., 2009). In a review by Bangsbo et al. (2008), the authors recommended the following classifications for performances during the YYIRT1 based on previous research (D. Kirkendall, 2000; D. T. Kirkendall, Leonard, & Garrett, 2003; Krustrup et al., 2005): Top-Elite ≥ 1,600 m; Moderate-Elite = 1,360 m; and Sub-Elite ≤ 1,160 m. This was based on the levels of play of the investigations and where those levels ranked for female soccer athletes. In an investigation of the Serbian female senior national team (Trajkovic, Sporis, Milanovic, & Jovanovic, 2010), the authors reported no positional differences in YYIRT1 result. The authors did report the average of the entire group to be 892 ± 197 m, far below previous reports of top levels of play for female soccer athletes. In an assessment of Division I collegiate athletes, the authors reported YYIRT1 values of 1040 ± 313 m while investigating the impact of high intensity interval training and its acute impact on speed and lower-body explosiveness measurements (sprint and CMJ performance) (Sjökvist et al., 2011). The authors did not assess if those individuals that performed better or worse responded any differently to the training stimulus in terms of recovery periods or performance across sessions.

The other version of the YYIRT is the YYIRT2, which aims at assessing the athletes ability to perform repeated high intensity activity with the test lasting between 5-15 minutes (Bangsbo et al., 2008). To the author's knowledge, only one study has assessed female soccer athletes in the YYIRT2 (Oberacker et al., 2012). The authors of this study reported that the athletes covered 732 ± 184 m for Division II female soccer players.

Based on the current literature that exists for female soccer athletes, the YYIRT1 appears to be able to distinguish between levels of play based on the distance covered during the tests (Bangsbo et al., 2008; Mujika et al., 2009). Results are unclear whether the YYIRT1 or YYIRT2 can differentiate between playing positions since there have not been any direct investigations into the ability of the YYIRT1 being able to distinguish between playing position on the field.

High Speed Running Performance

Relationship to Physical Qualities

High speed running (HSR) in female soccer has been determined as one of the performance variables that can distinguish between levels of play (Andersson et al., 2010; Gabbett & Mulvey, 2008; Mohr et al., 2008), meaning that those individuals that play at higher standards of play (national team vs. domestic league, senior national team vs. youth national team) cover greater distance at higher velocity thresholds than their lower level counterparts.

This has resulted in an interest into the physical qualities that can enhance the ability to cover distance at high velocities, possibly enhancing the chances of an individual being able to handle the demands of playing at a higher standard of play. There is also a difference in HSR demands based on the playing position of the athlete, which could provide insight into the importance of specific physical qualities needed to play that position. This review will aim to identify the relationship between physical qualities and HSR capabilities that currently exist in the literature as well as the differences of HSR demands based on playing position.

Krustrup et al. (2005) investigated a group of female soccer players in the top Danish league to determine the relationship between match performance and YYIRT1 performance. The authors found a large relationship (r = 0.56) with total distance covered during the match and YYIRT1 performance. Interestingly, the authors found a very large relationship (r = 0.76) with the amount of HSR (>15 km·h^{-1}) covered during the entire 90 minutes with YYIRT1 performance. The authors also reported a very large relationship (r = 0.83) between the amount of HSR distance covered during the final 15 minutes of the first half and second half and YYIRT1 performance. The authors reported a total distance covered for the 90-minute match of 10,300 m with 1,300 m being covered at HSR. The researchers used video analysis to quantify the total distance and HSR distance covered during competition. In a study investigating Division I women's soccer athletes, McCormack et al. (2014) assessed athletes using ultrasound to measure architectural characteristics of the vastus lateralis, an incremental treadmill test to measure aerobic power (VO_2max), and 30-second Wingate test to determine relationships between match performance. The authors measured maximum velocity prior to competition by having the athletes perform two maximum effort sprints from the goal to midfield and used the results of the maximum velocity recorded from the GPS unit (MiniMaxx 4.0, Catapult Systems, Victoria Australia, 10 Hz). The authors found that the VO_2max had a very strong relationship (r = 0.755) to HSR (>13 km·h^{-1}) and based on the results of a stepwise regression, the authors reported that VO_2max, vastus lateralis muscle thickness and pennation angle were the best predictors of HSR performance (R = 0.989) and that VO_2max was the strongest predictor (R = 0.888). McCormack et al. (2014) reported the average total distance covered was 8,953.9 ± 1,035.4 m and the HSR distance was 1,585.6 ± 594.6 m. These are the only two studies to the researcher's knowledge that have investigated the relationship of physical qualities to HSR performance in female soccer athletes. More research is needed in this area to determine the importance of physical qualities to HSR performance as well as the contribution of certain physical qualities to HSR performance.

Standards of Play

High speed running performance has been reported to be greater when assessing individuals of higher standards of play. An investigation of Scandinavian female soccer leagues assessed the differences between International level competitions to competitions of the top leagues in either Denmark or Sweden (Andersson et al., 2010). Results indicated that during International competition, the same players covered more HSR (>15 km·h^{-1}) distance than during domestic league play (1,530 ± 100 m vs. 1,330 ± 900 m). This shed light into the differences in demands placed on the individual athlete when playing for their respective National team when compared to playing in domestic league matches, indicating that there is a greater physical load imposed on the athlete when playing in international competition. An investigation of German League Two and German League Four found that the players in German League Two covered statistically greater total distance and HSR (>16 km·h^{-1}) distance than the players that played in League Four (960 m vs. 670 m) (Martínez-Lagunas, Niessen, & Hartmann, 2015). This indicated that players playing in different leagues in the same country displayed differences in HSR performance when compared to each other. Mohr et al. (2008) investigated top class players from a professional league in the United States and compared their HSR performance to high level players in the Danish and Swedish leagues. The authors reported that the top class players from the professional league in the U.S. covered more HSR distance compared to the Danish and Swedish league players (1,680 ± 90 m vs. 1,300 ± 100 m). Average total distance covered between both leagues was not statistically different in the U.S. league (10,330 ± 150 m) compared to the Danish and Swedish league (10,440 ± 150 m). This showed that even though total distance may be similar between top class and high class players, the way they cover that distance (> HSR in higher level competition) is different. Vescovi (2015) investigated differences between regular season competition and play-off competition in a professional women's soccer league in the U.S. The author reported that total distance was greater during playoff competition (10,100 ± 860 m vs. 9,300 ± 910 m) than regular season competition. However, even with total distance being greater, there was not a statistical difference between HSR (>16 $km \cdot h^{-1}$) performance comparing playoff to regular season competition (1,320 vs. 1,230 m). Table 2.1 displays a breakdown of current investigations that investigate differences in total distance as well as HSR performance in female soccer athletes.

It appears that there is a difference in HSR performance when comparing levels of play based on the current research that exists for female soccer players. Advancements in technology have allowed for greater number of investigations to occur and in hopes that they continue to

Table 2.1. Total and High Speed Running Distances Covered in Female Soccer Athletes

Author	Year	Nation	League	TD (km)	HSR (km)	Work Rate (m/min)	HSR Work Rate (m/min)	Position	Collection Method
Krustrup	2005	Denmark	Highest Division	10.30	1.30	114.44	14.44	ALL	Video, Computerized coding
Hewitt**	2007	Australia	Senior National	9.10	0.62	101.11	6.89	ALL	GPS, unit information not reported
				9.00		100.00		D	
				8.50		94.44		F	
				9.60		106.67		MF	
Andersson	2008	Sweden and Norway	Highest Division		1.10	0.00	12.22	ALL	Video, Computerized coding
Mohr	2008	Denmark and Sweden	Highest Division	10.44	1.30	116.00	14.44	ALL	Video, Computerized coding
		USA	Pro League	10.33	1.68	114.78	18.67	ALL	
		Grouped	Grouped	10.40	1.26	115.56	14.00	D	
		Grouped	Grouped	10.40	1.63	115.56	18.11	F	
		Grouped	Grouped	10.40	1.65	115.56	18.33	MF	
Andersson	2010	Scandinavian	Domestic	9.70	1.33	107.78	14.78	ALL	Video, Computerized coding
		Scandinavian	International	9.90	1.53	110.00	17.00	ALL	
		Scandinavian	Domestic	9.50		105.56	0.00	D	
		Scandinavian	International	9.50	1.30	105.56	14.44	D	
		Scandinavian	Domestic	10.10		112.22		MF	
		Scandinavian	International	10.50	1.90	116.67	21.11	MF	
Alexander	2014	USA	College	9.23	0.74	102.56	8.22	AM	GPS, MiniMaxx 4.0, Catapult Innovations, 10 Hz
				8.04	0.61	89.33	6.78	CD	
				9.95	0.84	110.56	9.33	CDM	
				9.69	1.41	107.67	15.67	F	
				9.30	1.32	103.33	14.67	FB	
				9.50	1.20	105.56	13.33	WM	
Bradley	2014	Europe	Champions League	10.80	1.65	120.00	18.33	ALL	Prozone, Digital Camera System
				10.20	1.33	113.33	14.78	CD	
				11.10	1.72	123.33	19.11	CM	
				10.80	1.91	120.00	21.22	F	
				10.70	1.65	118.89	18.33	FB	
				10.90	1.87	121.11	20.78	WM	
McCormack$	2014	USA	College	8.95	1.58	99.44	17.56	ALL	GPS, MiniMaxx 4.0, Catapult Innovations, 10 Hz
Vescovi*	2014	USA	College	9.50	1.01	105.56	11.22	D	GPS, SPI Pro, GPSports, 5 Hz
				10.20	1.26	113.33	14.00	F	
				10.10	0.96	112.22	10.67	MF	
Vescovi*	2014	USA	Youth National	7.80	0.78	86.67	8.67	D	GPS, SPI Pro, GPSports, 5 Hz
				7.90	0.94	87.78	10.44	F	
				8.50	0.73	94.44	8.11	MF	
Martinez**	2015	Germany	Fourth League	8.20	0.67	91.11	7.44	ALL	GPS, SPI Pro, GPSports, 5 Hz
		Germany	Second League	9.30	0.96	103.33	10.67	ALL	
		Germany	Fourth League	7.20	0.50	80.00	5.56	D	
		Germany	Second League	8.70	0.78	96.67	8.67	D	
		Germany	Fourth League	8.10	0.75	90.00	8.33	F	
		Germany	Second League	9.80	1.32	108.89	14.67	F	
		Germany	Fourth League	9.40	0.86	104.44	9.56	MF	
		Germany	Second League	9.90	1.08	110.00	12.00	MF	
Vescovi**	2015	USA	WPSL-Regular Season	9.10	1.20	101.11	13.33	ALL	GPS, SPI Pro, GPSports, 5 Hz
Vescovi**	2015	USA	WPSL - Playoff	10.10	1.30	112.22	14.44	ALL	

Note. $HSR>13 km·hr^{-1}; *HSR>15.6 km·hr^{-1}; **>16 km·hr^{-1}. TD = total distance, HSR = high speed running.

increase, a greater understanding of the importance of HSR capabilities can allow coaches and practitioners to better understand this quality and how it is in influenced during competition.

Positional Differences

Early research investigating distances covered in soccer when assessing outfield players based on playing position used only three positional subcategories (forward, midfielder, and defender). Recent investigations have begun to use more specific positional subgrouping, breaking down midfield and defender categories down further to more accurately represent their position on the field and demands placed on the individual during competition. Defenders are now broken down into central defender or centerback (CD or CB) and fullback or external defender (FB or ED). Midfielders are now broken down into three subcategories: central defensive midfielder (CDM), central attacking midfielder (CAM) and wide midfielder, external midfielder or outside midfielder (WM, EM, or EM). The results of the more granular subgrouping of playing positions has demonstrated that the "classical" positional breakdowns used in the initial investigations may not have accurately identified positional demands due to differences that have been observed within the positional subgroups that were traditionally grouped together.

Hewitt, Withers, and Lyons (2007) reported a group average of 9,140 ± 1,030 m for the Senior National Level Australian team during the 2006 Women's Asian Cup. Defenders, midfielders and forwards covered 9,010, 9,640, and 8,510 m respectively. The authors did not report positional values for HSR (>16 $km \cdot h^{-1}$) performance but did report for all players grouped together was 620 m. In an investigation examining differences between a U.S. women's professional league and leagues in Denmark and Sweden, the authors reported that although the total distance covered did not differ between playing positions (10,400 m), defenders covered less HSR (>15 km·h^{-1}) distance (1,260 m) compared to forwards (1,630 m) and midfielders (1,650 m) (Mohr et al., 2008). An investigation comparing domestic league play (Scandinavian countries) and International Level play, the researchers reported that defenders covered less total distance (9,500 m) than midfielders (10,300 m) during both domestic and International competitions. They also reported that defenders covered less HSR (>15 km·h^{-1}) compared to midfielders during International competition (1,300 ± 100 vs. 1,900 ± 200 m) (Andersson et al., 2010). In an investigation of Division I female soccer players, Vescovi and Favero (2014) reported that defenders (9,496 ± 175 m) covered less total distance compared to midfielders (10,125 ± 197 m) and forwards (10,297 ± 338 m). Forwards, midfielders, and defenders covered 1,260, 960, and 1,010 m respectively at HSR (>15.6 km·h^{-1}). However, the author reported the values for players that completed the entire half for that position, meaning that it did not have to be the same player that played the entire halves. This does not take into account any fatigue that may have accumulated by playing the entire 90 minutes, mainly in the second half. However, this does provide some insight into the positional demands required to play the entire 90 minutes in Division I women's collegiate soccer. In another investigation by Vescovi (2014), the author investigated youth female soccer players (15-17 years old) during a national championship tournament or talent identification camp. Results indicated that forwards (940 m) covered the most HSR distance (>15.6 km·h^{-1}) compared defenders (780 m) and midfielders (730 m). The duration of the games were only 80 minutes compared to the traditional 90 minutes that typically occur during NCAA or FIFA regulation matches. In an investigation of Second and Fourth league's in German women's soccer, the authors reported that forwards and midfielders covered more HSR (>16 km·h^{-1}) distance than defenders within their league and reported that all across all positions, the Second League covered more HSR distance than the same positions in the

Fourth League (Martínez-Lagunas et al., 2015). This investigation shed light on the fact that not just differences in positions occur, but differences between leagues across positions exist as well, highlighting the importance of this variable being a strong indicator of performance as well as physical requirements placed on the athletes relative to playing position.

There have been two investigations into female soccer athletes that have utilized more specific positional subgroupings. Alexander (2014) reported that CAM covered less total distance than CDM. The only other difference observed for total distance was the CD covered less total distance compared to all other playing positions (FB, CDM, CAM, and WM). For HSR performance, CAM (747.6 ± 196.5 m) and CDM (847.7 ± 234.9 m) covered HSR (>15 $km \cdot h^{-1}$) less distance than WM (1,208.2 ± 314.1 m) and FB (1,321.5 ± 173.7 m). Central defender (614.1 ± 98.9 m) covered less HSR distance than CDM, WM, and FB. This study was unique in the fact that it investigated the performances of a single player at each playing position throughout the course of a season rather than assessing values from various individuals from a single competition. In a study of the UEFA Champion's League tournament, Bradley, Dellal, Mohr, Castellano, and Wilkie (2014) investigated gender differences between both male and female teams that participated in the competition. The investigators used similar subcategories to the Alexander (2014) study, however they grouped CDM and CAM into a central midfielder category. Central midfielders covered 11,100 m with 1,720 m being covered during HSR (>15 $km \cdot h^{-1}$). For CD, F, FB and WM the authors reported total distances of 10,200, 10,800, 10,700, and 10,900 m respectively. For HSR performance for the CD, F, FB and WM the authors reported 1,330, 1,910, 1,650, and 1,870 m respectively. The authors did not use statistics to determine differences between positions of the same gender, they just ran differences between positions comparing males and females and reported that across all positions, the males covered more HSR distance than their female counterparts, but no differences were observed for the distances covered < 15 km·h^{-1}. This finding highlights the gender differences that exist, mainly being at the HSR thresholds and investigations as to why this exists still needs to occur, however the authors suggested that it was due to the fact that males typically achieve greater maximum velocities in competition compared to females, thus the abilities of the male athletes to achieve more distance at higher velocity thresholds can possibly be a result of greater sprinting capabilities.

Over the past 10 years, there have been investigations into the HSR capabilities of female athletes and although there is some literature investigating positional differences, more research is needed since there have only been two investigations using more specific positional subgroupings which highlight differences that may have existed with previous investigations but lack of appropriate positional subgroups may have not allowed these differences to be observed.

Summary

Based on the current research, it appears as though CMJ performance, sprinting assessments, CODA assessments, and YYIRT1 performance are able to distinguish between calibers of play in female soccer players. The ability of physical qualities to differentiate between playing positions appears to need more research as at the current time, as there does not appear to be enough research utilizing positional subgroupings that are specific enough to identify differences. High speed running appears to be different between calibers of play and playing position in female soccer players. However, the relationship of physical qualities to HSR performance appears to be lacking in research with only two studies that have investigated such parameters in female soccer players.

CHAPTER 3

DIFFERENCES IN PHYSICAL QUALITIES OF DIVISION I WOMEN'S COLLEGIATE SOCCER PLAYERS RELATIVE TO PLAYING POSITION

Title: Differences in Physical Qualities of Division I Women's Collegiate Soccer Players Relative to Playing Position

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Abstract

In recent years, more specific positional subgroupings have been applied to better understand competition demands as previous positional subgroupings were overgeneralized. With competition demands being different with respect to playing position, that may also mean that physical qualities are different with respect to playing position as well. Data from 57 Division I Women's Collegiate soccer players was used to assess positional differences between speed, change of direction ability, relative strength, rate of force development, countermovement jump performance and intermittent endurance capacity. Results demonstrated that goalkeepers were slower than forward, wide midfielder and attacking midfielder in sprint assessments and slower than forward, wide midfielder, attacking midfielder and fullback during change of direction assessments. Wide midfielder was faster than central defensive midfielder during sprint assessments and forwards and wide midfielders were statistically faster than central defender and central defensive midfielder during change of direction assessments. No other statistical differences were observed between playing position for other variables assessed although fullbacks may possess greater strength compared to central defensive midfielders and greater rate of force development compared to attacking midfielders based on calculated effect sizes. More specific tests that better mimic the demands of the goalkeeper should be implemented to better track relevant changes in physical qualities. Coaches and practitioners should utilize similar positional subgroupings used in this study to better identify physical qualities of importance associated with the individuals respective playing position as it appears that attacking based players (forward, wide midfielder, and attacking midfielder vs. central defender and central defensive midfielder) possess greater sprinting capabilities compared to the defensive based players.

Introduction

Soccer is a sport comprised of aerobic and anaerobic activities such as jogging, sprinting, rapid accelerations and decelerations, sliding, tackling, and jumping (Al-Hazzaa et al., 2001; Bloomfield et al., 2007; Wisløff et al., 2004). The amount of literature dedicated to women's soccer has increased over recent years with investigations of professional (Andersson et al., 2010; Bradley et al., 2014; Mohr et al., 2008) and youth levels (Vescovi, 2014). However, there have been only a few studies that investigated the match performances of collegiate soccer athletes (Alexander, 2014; McCormack et al., 2014; Vescovi & Favero, 2014). The majority of the studies used "classic" positional groupings of forward, midfielder and defenders. Recently there has been an effort to use more specific positional subgroupings in the soccer literature (Alexander, 2014; Dellal, Wong, Moalla, & Chamari, 2010) such as central defender, fullback, central defensive midfielder, central attacking midfielder, wide midfielder, and forward. Differences have been observed in match performance between positions that would have been grouped together based on the "classic" positional subgroupings such as fullbacks covering more high speed running distance compared to central defenders and wide midfielders covering more high speed running distance compared to central defensive and attacking midfielders (Alexander, 2014). These findings justify the need to utilize these positional subgroupings for analyses of match performances of female soccer players.

Previous research investigating differences in physical qualities related to playing position observed that forwards were faster than goalkeepers in 20 m sprint performance (Haugen et al., 2012) and outfield players possessed greater countermovement jump performances compared to goalkeepers (Sedano et al., 2009). Other research has found that there are no differences in aerobic power (VO2max), speed, change of direction ability, or countermovement jump performance between playing positions (defender, midfielder, forward and goalkeeper) (Vescovi et al., 2006). A reason could be that the positional subgroupings were too general, similar to that of previous research investigating match performance, to identify differences between playing positions. Since there are differences in the match performances of specific positions, one might expect there to be some differences in the physical qualities of those playing positions. However, to this point, no studies have investigated an array of assessments to identify the potential variances in physical qualities within the different positional subgroupings. Knowledge of differentiations in physical qualities with respect to playing position can allow for individualization of training plans specific to the needs of the position. For example, a player may need to increase strength or speed based on where their current performance is relative to their position whereas if they played a different position, their current status may be sufficient to meet the demands of the position. Therefore, the purpose of this study was to determine if there are differences in physical qualities relative to playing position in female soccer athletes. This will allow insight into the physical qualities of playing positions to ascertain if there any differences that exist since we know that there are differences in match performances relative to playing position according to the current literature.

Methods

Athletes

Data from fifty-seven Division I Collegiate Women's Soccer athletes from a single institution were used in this study. Data for this study were collected as part of an on-going athlete monitoring program from 2011 to 2015. All of the athletes were in the pre-season phase of training prior to the competitive season. Each athlete was placed into a positional subgrouping based on the primary playing position during competition. The player's primary position was determined based on the sport coaching staff's designation of playing position. The positional subgroups were: attacking midfielder (AM), central defender (CD), central defensive midfielder (CDM), fullback (FB), goalkeeper (GK), forward (F), and wide midfielder (WM).

Testing Protocol

All athletes went through a testing protocol that consisted of body composition including height (cm), mass (kg), body fat percentage (% BF) (*ACSM's guidelines for exercise testing and prescription*, 2006) unweighted countermovement jump, isometric mid-thigh pull (IMTP), 20 m sprint, Arrowhead Agility (Figure 1) (Chan, Lee, Fong, Yung, & Chan, 2011), and Yo-Yo Intermittent Recovery Test – Level 1 (Bangsbo, 1994). Since the collection of data spanned multiple years, the athlete jumped on either a single force-platform (91 x 91 cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) or dual-force platform (2 separate 45.5 x 91 cm, RoughDeck HP, Rice Lake, WI, USA) sampling at 1000 Hz. Prior to laboratory testing, the athlete went through a standardized warm-up consisting of 25 jumping jacks, five repetitions of dynamic mid-thigh pulls with 20 kg and three sets of five repetitions of dynamic mid-thigh pulls with 40 kg. Following the warm-up, the athlete would complete a 50% and 75% of perceived maximal effort of a countermovement jump with a PVC pipe. The PVC pipe was placed just below the 7^{th} cervical vertebrae similar to a back squat position and this was done to minimize the influence of the arm-swing during the countermovement jump. Countermovement depth was self-selected based on the depth the athlete felt as they could perform the highest jump. After completion of the warm-up jumps, the athlete rested for one minute and completed two, single maximal countermovement jumps with 30 seconds of rest in between each maximal jump.

For reliability purposes, additional trials were required if the first two jumps had a difference > 2 cm. Jump height was calculated using flight time using the following equation:

$$JH=(9.81\ m/s\cdot s)\cdot(ft\cdot ft)/8$$

ft= flight time (s)

Following the jump testing, measurements from the IMTP were done on a single force platform (91x91cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) or dual-force platform (2 separate 45.5 x 91cm, RoughDeck HP, Rice Lake, WI, USA) sampling at 1000 Hz in a custom designed power rack. The athlete was placed in the mid-thigh pull position with a knee angle of 125° ± 5° based on previous research (Bailey, Sato, Alexander, Chiang, & H. Stone, 2013; Kraska et al., 2009). The athlete used weightlifting straps and tape to keep the hands in a similar position as well as to minimize the likelihood of grip strength being a limitation. The athlete completed a 50% and 75% of maximum effort prior to the maximal efforts. Athletes were instructed to "pull as fast and hard as possible" based on previous research (Holtermann, Roeleveld, Vereijken, & Ettema, 2007). A minimum of two trials were performed. If there was >250 N difference in peak force between the first two trials, a third trial was performed. Other reasons for additional trials were if the athlete performed a countermovement prior to the initiation of the pulling movement or if the tape did not securely keep the athletes hands to the bar.

For the field based testing, tests were performed on a grass playing surface while wearing soccer boots. The athlete completed the field based testing within 24 hours of the laboratory based testing and there was a minimum of four hours of rest between the laboratory based testing and field based testing. The athlete would go through a standardized warm-up of jogging (150 m), dynamic stretching, high-knees, jockey, and sprint build-ups of 50%, 75%, and 100% of perceived maximum effort. Prior to performing the maximal trials for the 20 m sprint, the athlete performed a 50% and 75% effort through the timing gates to familiarize themselves with the testing protocol and running through the timing gates. The athlete started from a staggered two-point stance with the front foot 30 cm behind the first set of timing gates. The athlete would perform a minimum of two maximal trials for the 20 m sprint test. A third trial would be required if the timing gates did not collect data correctly at the start and finish of the trial. A minimum of three minutes of passive recovery took place between each trial to ensure the athlete was recovered prior to each trial.

After the completion of the 20 m sprint, the athlete had three minutes of rest prior to the start of the Arrowhead Agility test to assess the athletes' change of direction ability (CoD). For the CoD testing protocol, the athlete would perform a trial at 75% of perceived maximal effort to the left before performing two maximal trials to the left. The athlete started from a staggered two-point stance with the front foot 30 cm behind the first set of timing gates. A minimum of five minutes of passive recovery occurred between each maximal trial to ensure the athlete had enough time to properly recover. As the data in Table 3.3 indicates, the time to complete this test was longer than the 20 m sprint which is why longer recovery periods were given. After two successful trials of the CoD test to the left, the athlete would then complete two trials to the right. Prior to the first maximal trial, a 75% trial to the right was completed to familiarize the athlete with the different changes of direction.

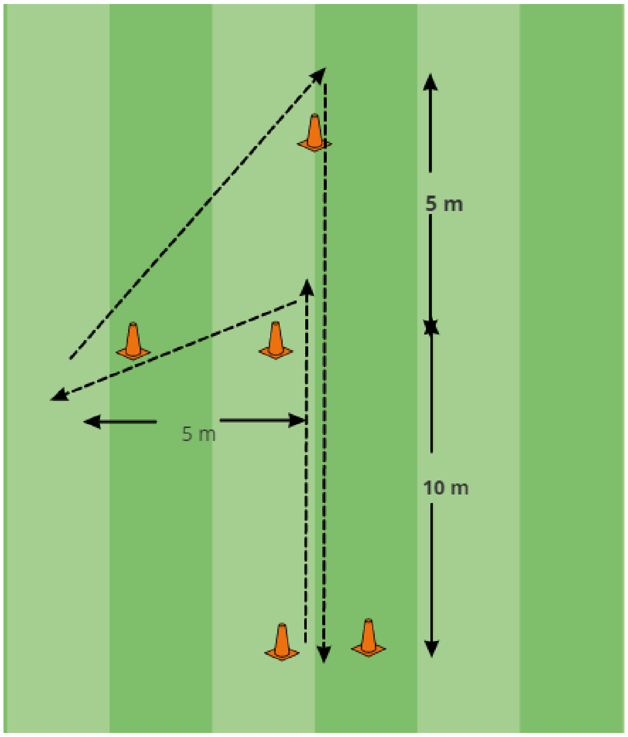

Figure 3.1. Arrowhead Agility Test.

After the completion of the 20 m sprint and CoD test, the athlete had a minimum of five minutes prior to the start of the Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT1). The test consists of a 20 m track where the athlete has a designated time based on audio signals to run down and back. There is also a 5 m "recovery" area where the athlete must go around a cone and back in ten seconds prior to the start of the next shuttle. As the test continues, the time to complete the 20 m down and back run becomes progressively more difficult as the time gets shorter. The ten second recovery time stays constant after each shuttle. Once the athlete is not able to complete a shuttle in the allotted time, a "warning" is given. The next time the athlete is not able to complete the shuttle in the allotted time, they stop and their score is recorded. Unlike the previous field based tests, only one trial was performed. However the YYIRT1 has been shown to be a reliable measurement based on previous research (Krustrup et al., 2003).

Variables

An average of two trials were used in order to reduce error inherent in all measurements and to reveal a truer performance value. Variables used for analysis were jump height (CMJH) from the unweighted countermovement jump, peak force allometrically scaled (IPFa) and rate of force development at 200 ms (RFD) will be used from the IMTP. The average of two successful trials for CMJH, IPFa, and RFD was used for the analysis. For the 20 m sprint, the average of the two successful trials were used for analysis and for the CoD test the times for the two successful trials to the left and the two successful trials to the right were averaged together for analysis. The total distance in meters covered during the YYIRT1 was used for analysis.

Statistical Analyses

Descriptive statistics were calculated on all subject demographic and anthropometric data (height, body mass, % body fat and lean body mass) (Table 3.1). Coefficient of variation (CV) and intra-class correlation coefficients (ICC) were calculated to indicate within-player variability between physical qualities for each playing position and the entire sample for CMJH, IPFa, RFD, Speed, and CoD (Table 3.2). A one-way analysis of variance (ANOVA) was run to determine the differences (20 m sprint time (seconds), CoD time (seconds), YYIRT1 score (m), CMJH (cm), RFD ($N \cdot s^{-1}$), IPFa ($N*kg^{-0.67}$) between the seven positional subgroups. Tukey-Kramer post-hoc analyses were performed to determine where significance occurred. Effect size (Cohen's d) was calculated to gain an idea of how well a variable can distinguish between the positional subgroups (0-0.2, Trivial; 0.2-0.6, Small; 0.6-1.2, Moderate; 1.2-2.0, Large; 2.0-4.0, Very Large) (Hopkins, 2002).

Table 3.1. Demographic Information by Playing Position

Playing Position	Mass (kg)	LBM (kg)	% BF	Height (cm)
Attacking Midfielder (n=5)	59.1 ± 2.7	47.8 ± 3.2	18.9 ± 6.1	162.8 ± 2.5
Central Defender (n=10)	68.3 ± 6.4	56.1 ± 4.1	17.6 ± 3.1	168.9 ± 2.8
Central Defensive Midfielder (n=9)	63.6 ± 10.0	51.0 ± 7.6	19.5 ± 6.1	163.0 ± 6.1
Fullback (n=8)	60.1 ± 6.5	50.2 ± 4.3	16.1 ± 3.5	167.5 ± 5.3
Goalkeeper (n=7)	75.4 ± 13.6	60.1 ± 9.4	19.9 ± 3.3	168.1 ± 4.3
Forward (n=8)	64.0 ± 4.4	52.4 ± 2.2	17.9 ± 2.9	166.8 ± 4.9
Wide Midfielder (n=10)	60.9 ± 8.3	49.8 ± 6.5	18.1 ± 4.1	165.8 ± 7.1
Total (N=57)	64.6 ± 9.2	52.6 ± 6.7	18.2 ± 4.2	166.3 ± 5.3

Note. Mean ± standard deviation

Table 3.2. Coefficient of Variations and Intra-class Correlation Coefficients on Physical Qualities

Variables		AM (n = 5)	CDM (n = 9)	WM (n = 10)	FB (n = 8)	CD (n = 10)	F (n = 8)	GK (n = 7)	Total (N = 57)
IPFa ($N \cdot kg^{-0.67}$)	CV	1.99%	1.54%	1.84%	1.20%	3.70%	1.50%	2.90%	2.16%
	ICC	0.971	0.989	0.990	0.993	0.955	0.966	0.954	0.975
RFD ($N \cdot s^{-1}$)	CV	18.50%	12.80%	14.21%	11.00%	15.40%	11.50%	11.40%	15.26%
	ICC	0.892	0.846	0.742	0.774	0.724	0.821	0.765	0.747
CMJH (cm)	CV	2.25%	1.78%	2.80%	3.60%	1.70%	2.80%	1.90%	2.41%
	ICC	0.958	0.992	0.937	0.949	0.981	0.983	0.964	0.983
Speed (s)	CV	1.88%	0.65%	0.51%	0.66%	0.90%	1.19%	0.72%	0.83%
	ICC	0.824	0.972	0.988	0.922	0.900	0.759	0.964	0.985
CoD (s)	CV	0.92%	1.02%	1.10%	0.94%	0.99%	1.04%	0.97%	0.99%
	ICC	0.975	0.893	0.914	0.891	0.830	0.876	0.960	0.970

Note. CV = Coefficient of variation, ICC = Intra-class correlation coefficient, CoD = Arrowhead Agility, IPFa = Isometric Peak Force Allometrically Scaled, CMJH = Unweighted Countermovement Jump Height, RFD = Rate of Force Development 0-200 ms, YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1, AM = Attacking Midfielder, CDM = Central Defensive Midfielder, WM = Wide Midfielder, FB = Fullback, CD = Central Defender, F = Forward, GK = Goalkeeper.

Results

No statistical differences were found based on the results of the ANOVA for IPFa ($F_{6,50} = 1.213$, $p = 0.315$), RFD ($F_{6,50} = 0.744$, $p = 0.617$), and CMJH ($F_{6,50} = 1.313$, $p = 0.269$) (Table 3.2). However, effect sizes indicated that there was a large effect between FB and CDM ($d = 1.21$) for IPFa. Also a large effect was observed between the FB and AM ($d = 1.83$) for RFD. The effect size calculations can be found in Table 3.4 for all of the variables between the positions.

Results from the ANOVA for the field based variables indicated significant main effects for Speed ($F_{6,50} = 4.532$, $p = 0.001$) and Agility ($F_{6,50} = 6.435$, $p < 0.001$). Results of the ANOVA for YYIRT1 revealed no significant main effects ($F_{5,44} = 0.480$, $p = 0.789$). *Post hoc* analyses revealed GK was statistically slower than F ($p = 0.037$), AM ($p = 0.017$), and WM ($p = 0.003$) and WM was statistically faster than CDM ($p = 0.033$) in the 20 m sprint testing (Table 3.3). *Post hoc* analyses revealed GK was statistically slower than F ($p < 0.001$), FB ($p = 0.001$), AM ($p = 0.042$) and WM ($p < 0.001$) during the CoD testing and F was statistically faster than the CD ($p = 0.035$) (Table 3.3). Cohen's d effect sizes demonstrated a very large effect for F and WM between GK for both speed ($d = 2.11$ and $d = 2.11$) and CoD ($d = 2.24$ and $d = 2.13$). A

Table 3.3. Descriptive Statistics, Physical Qualities by Playing Position for Laboratory Based Testing

Playing Position	IPFa ($N \cdot kg^{-0.67}$)	RFD ($N \cdot s^{-1}$)	CMJH (cm)
Attacking Midfielder (n=5)	172.03 ± 32.2	3611.18 ± 693.6	27.41 ± 5.4
Central Defender (n=10)	158.14 ± 35.1	4554.67 ± 1850.1	23.92 ± 2.7
Central Defensive Midfielder (n=9)	155.36 ± 26.9	4668.61 ± 1480.3	24.16 ± 4.0
Fullback (n=8)	185.73 ± 23.2	5194.26 ± 1004.6	25.83 ± 3.7
Goalkeeper (n=7)	166.32 ± 20.7	4165.2 ± 1648.3	23.20 ± 3.5
Forward (n=8)	170.13 ± 30.1	4708.36 ± 1588.7	26.55 ± 2.7
Wide Midfielder (n=10)	154.24 ± 33.2	4908.67 ± 1570.6	26.19 ± 3.8
Total (N=57)	164.80 ± 29.9	4615.52 ± 1485.9	25.21 ± 3.7

Note.Values are expressed as mean ± standard deviation. IPFa = Isometric Peak Force allometrically scaled; RFD = Rate of Force Development; CMJH = Unweighted Countermovement Jump Height.

Table 3.4. Descriptive Statistics, Physical Qualities by Playing Position for Field Based Testing

Playing Position	Speed (s)	CoD (s)	YYIRT1 (m)
Attacking Midfielder (n=5)	3.36 ± 0.15*	9.01 ± 0.49*	1000.0 ± 508.3
Central Defender (n=10)	3.52 ± 0.14	9.26 ± 0.35	1088.0 ± 202.0
Central Defensive Midfielder (n=9)	3.56 ± 0.17	9.21 ± 0.31	1173.3 ± 263.8
Fullback (n=8)	3.45 ± 0.13	8.93 ± 0.19*	1205.0 ± 190.5
Goalkeeper (n=7)	3.62 ± 0.14	9.63 ± 0.48	NA
Forward (n=8)	3.41 ± 0.05*	8.73 ± 0.30**$$	1130.0 ± 207.0
Wide Midfielder (n=10)	3.36 ± 0.12**$	8.79 ± 0.28**	1172.0 ± 293.3
Total (N=57)	3.47 ± 0.15	9.07 ± 0.43	1136.0 ± 266.0

Note. Values are expressed as mean ± standard deviation. YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1; CoD = Arrowhead Agility Test *$p \leq 0.05$ statistically faster than GK; **$p \leq 0.01$ statistically faster than GK; \$p ≤ 0.05 statistically faster than CDM; \$\$ $p \leq 0.05$ statistically faster than CD.

large effect was observed for AM between CDM (d = 1.21) and GK (d = 1.86) as well as between WM and CDM (d = 1.31) and between FB and GK (d = 1.27) for Speed testing. A large effect was observed for CoD for F between CD (d = 1.60) and CDM (d = 1.56) as well as for WM between CD (d = 1.46) and CDM (d = 1.40). A large effect for AM and FB was also observed between GK (d = 1.30 and d = 1.91) for the CoD testing.

Table 3.5. Cohen's d Effect Sizes for All Variables

Variable	Speed	CoD	YYIRT1	IPFa	RFD	CMJH
AM-CD	1.06*	0.61*	0.23	0.41	0.68*	0.82*
AM-CDM	1.21**	0.51	0.43	0.56	0.92*	0.68*
AM-FB	0.65*	0.19	0.53	0.49	1.83**	0.34
AM-GK	1.86**	1.30**		0.21	0.44	0.93*
AM-FB	0.46	0.66*	0.34	0.06	0.90*	0.20
AM-WM	0.00	0.52	0.41	0.54	1.07*	0.26
CD-CDM	0.26	0.15	0.36	0.09	0.07	0.07
CD-FB	0.45	1.15*	0.60	0.93*	0.43	0.59
CD-GK	0.81*	0.88*		0.28	0.22	0.23
CD-F	0.96*	1.60**	0.21	0.37	0.09	0.97*
CD-WM	1.18*	1.46**	0.33	0.11	0.21	0.69*
CDM-FB	0.60*	1.07*	0.14	1.21**	0.42	0.43
CDM-GK	0.46	1.04*		0.46	0.32	0.26
CDM-F	1.12*	1.56**	0.18	0.52	0.03	0.70*
CDM-WM	1.31**	1.40**	0.01	0.04	0.16	0.52
FB-GK	1.27**	1.91**		0.88*	0.75*	0.73*
FB-F	0.48	0.79*	0.38	0.58	0.37	0.22
FB-WM	0.77*	0.57	0.13	1.10*	0.22	0.10
GK-F	2.11$	2.24$		0.15	0.34	1.07*
GK-WM	2.11$	2.13$		0.44	0.46	0.82*
F-WM	0.53	0.21	0.17	0.50	0.13	0.11

Note. *=moderate effect; **=large effect; $=very large effect.

Discussion

The results indicated that for the 20 m sprint, the GK were statistically slower than the AM, F, and WM. This may be explained by the fact that GK rarely have to cover >20 m during competition (V Di Salvo, Benito, Calderon, Di Salvo, & Pigozzi, 2008). Considering the GK’s positional demands, a GK may be assessed over shorter distances (i.e. 5 or 10 m). These findings are in agreement with Haugen et al. (2012) that reported that F were statistically faster than GK in a 20 m sprint. The authors in the previous study failed to find any statistical differences between midfielders and GK. Their failure to find statistical differences may be due to grouping together midfielder subgroups. The present study found that WM was statistically faster than CDM, which suggests the need to breakdown the midfielders into more specific subgroupings.

Results from the CoD test indicated that the GK was statistically slower than the F, WM, AM, and FB. In female soccer athletes, previous research reported a strong relationship between speed and change of direction (Gunnar & Svein, 2015; Mujika et al., 2009; Vescovi & McGuigan, 2008). Thus, it is not surprising that F, WM and AM possessed better CoD results than the GK. Also, the work durations for GK during a single bout are typically less than the duration of the CoD test (9.07 s for the group average), indicating that GK may be better assessed with a shorter duration CoD test (V Di Salvo et al., 2008). Forwards and WM were statistically faster than CD and CDM during the CoD test. While no previous studies reported similar findings due to the lack of using subgroupings of midfielders and defenders at the collegiate level among female soccer players, the results of the present study appear to suggest the importance of positional subgroupings in speed and change of direction assessments.

In contrast to 20 m sprint and CoD results, there were not any statistical differences observed in IMTP, CMJ, and YYIRT1. The IMTP variables (IPFa and RFD) failed to distinguish between positions. However, the calculated effect sizes suggest that the difference can be large between FB and CDM for IPFa and for RFD between FB and AM. Previous research has shown a strong relationship between relative strength and sprint speed (Wisløff et al., 2004). The reported strong relationship could be in part due to the fact that Wisløff et al. (2004) measured strength utilizing a 1RM back squat whereas in this study we utilized the IMTP. Previous research has found that there is a weak to moderate relationship between isometric and dynamic tasks (Thomas, Jones, Rothwell, Chiang, & Comfort, 2015; Wilson, Lyttle, Ostrowski, & Murphy, 1995). This could be one reason as to why we did not see any statistical differences between positional subgroups in IMTP variables despite observing statistical positional differences in the 20 m sprint time. In this study, CMJH and YYIRT1 also did not distinguish between the playing positions. The lack of statistical differences in CMJH agree with previous research reporting no differences between playing positions in CMJH (Haugen et al., 2012; Vescovi et al., 2006). It is possible that simply measuring CMJH may not be a useful method of distinguishing playing positions. The findings from the results of the YYIRT1 were interesting because previous research has reported positional differences in high speed running performance in female soccer athletes (Alexander, 2014; Andersson et al., 2010; Martínez-Lagunas et al., 2015) as well as a strong relationship between YYIRT1 performance and high speed running performance during competition in female soccer players (Krustrup et al., 2005). It is possible that the differences in high speed running for this population can be attributed to the differences in speed and change of direction ability since those positions that had faster 20 m sprint and CoD times in this study (F, WM, AM vs. CD and CDM) may achieve greater high speed running distance during competition (Alexander, 2014).

Conclusion

This is the first study to assess collegiate female soccer players in various physical qualities based on playing position with more specific positional subgroupings. The classification of more specific subgroupings allowed the researchers to observe differences in physical qualities that may not have been previously reported as a result of playing positions being overgeneralized. The results of this study indicate that the main differences between playing position lie within the speed and change of direction ability. Despite the lack of statistical differences, there can be a large difference in relative strength and explosiveness between positional subgroupings. Coaches and practitioners should utilize similar positional subgroupings as those in this study when investigating positional differences to develop more individualized training programs to better meet the demands of the positions as well as developing more specific assessments for the GK position that better mimic the demands of competition. Coaches may be able to utilize the 20 m sprint to identify players that are faster and assign them to the F, WM, or AM positions as those positions tended to be faster than the central defensive players (CDM and CD). This could help with talent identification and assigning players to roles that better suit their physical attributes and ultimately increase the chances of success by having players in roles that better meet the positional requirements. More research should be performed with a greater sample size per positional subgrouping with a wider range of levels of play (youth vs collegiate vs professional) to see if the differences observed in this study are consistent across all levels of play.

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CHAPTER 4

DIFFERENCES IN PHYSICAL QUALITIES OF DIVISION I WOMEN'S COLLEGIATE SOCCER PLAYERS BETWEEN PRIMARY AND SECONDARY PLAYERS

Title: Differences in Physical Qualities of Division I Women's Collegiate Soccer Players Between Primary and Secondary Players

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Abstract

Previous research has demonstrated that higher caliber players jump higher, sprint faster, and possess greater change of direction ability when comparing players from various leagues or age groups. Very little research has been done at the collegiate level to assess the discriminative ability of specific physical qualities. Data from 57 Division I Women's Collegiate soccer players was used to assess differences between speed, change of direction ability, relative strength, rate of force development, countermovement jump performance and intermittent endurance capacity between high and low caliber players based on minutes played per competition. Results indicated that higher caliber players possess greater Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT1) scores than lower caliber players. There were no statistical differences observed for any of the other variables. There were significant correlations between speed, change of direction ability, speed and countermovement jump performance, change of direction ability and countermovement jump performance and relative strength and rate of force development. No other correlations were statistically significant and none of the correlations were statistically different between groups. Performance during the YYIRT1 may be an indication of caliber of player if those players that perform better are typically the athletes that play more during competition. Countermovement jump performance may be a good indication of sprinting and change of direction capabilities since these actions require high levels of lower-body explosiveness to perform these movements to a greater level. Coaches and practitioners should assess physical qualities over a wider range of levels of play (Division I vs. Division II vs. Division III) to determine if these physical qualities assessed in this study can differ between levels of collegiate female athletes since this study only utilized athletes from a single institution.

Introduction

Soccer is a sport comprised of aerobic and anaerobic activities such as jogging, sprinting, rapid accelerations and decelerations, sliding, tackling, and jumping (Al-Hazzaa et al., 2001; Bloomfield et al., 2007; Wisløff et al., 2004). The quantity of research investigating the physical qualities of female soccer athletes has increased over recent years in professional (Mujika et al., 2009; Sedano et al., 2009; Vescovi, 2012), collegiate (Vescovi, 2012; Vescovi et al., 2006; Vescovi & McGuigan, 2008), and youth levels (Castagna & Castellini, 2013; Haugen et al., 2012). Findings from these studies have highlighted the validity of sprinting (Haugen et al., 2012; Vescovi, 2012), lower-body explosiveness (Haugen et al., 2012; Vescovi et al., 2011), change of direction (Mujika et al., 2009; Vescovi et al., 2011), and intermittent endurance capacity assessments (Bangsbo et al., 2008; Mujika et al., 2009) to differentiate caliber of player whether it be senior national team vs youth national team (Haugen et al., 2012), drafted vs. non drafted players (Vescovi, 2012) or level of play (Mujika et al., 2009) in female soccer players.

Of the few studies dealing with physical qualities at the collegiate level, there were differences observed when assessing high level female soccer players (Vescovi, 2012). The author of this study investigated various sprint distances in college-aged female soccer players at a try-out for a professional women's soccer league prior to their draft and found that the players that were ultimately drafted performed better across all but one of the assessed sprinting splits (Fly 5-10 m velocity), highlighting the discriminative ability of sprinting assessments in high level soccer athletes. However, previous research found no differences between high school and collegiate soccer players when assessing sprint ($p = 0.083$), change of direction ability ($p = 0.95$) or countermovement jump performance ($p = 0.36$) (Vescovi & McGuigan, 2008). Other research that previously demonstrated discriminative ability to determine caliber of player using a variety of assessments was performed using professional athletes from teams that played at different standards of play (Mujika et al., 2009) or youth level athletes (Haugen et al., 2012) from various backgrounds. Haugen et al. (2012) found that senior national level female players performed better during countermovement jump assessments compared to youth national level players (30.7 ± 4.1 vs. 28.1 ± 4.1 cm), highlighting lower-body explosiveness being greater in higher caliber players and possibly being a discriminative variable. In a study comparing First Division and Second Division Spanish league soccer players, Mujika et al. (2009) found that the First Division players performed better during countermovement jump performance, change of direction assessments and intermittent endurance capacity indicating the use of change of direction assessments and intermittent endurance capacity as discriminative variables for higher and lower caliber female soccer players.

No study to date has investigated specific physical qualities such as speed, strength, lower-body explosiveness or intermittent endurance at the collegiate level to assess the discriminative ability of those specific qualities. Knowledge of the ability of certain variables to differentiate between caliber of play may aid coaches in team selection as well as training considerations. If certain variables indicate higher caliber of player, coaches can prescribe training aimed at enhancing these qualities at certain time points to increase likelihood of success. Therefore, the purpose of this study was to give insight into the discriminative ability of specific physical qualities to distinguish between higher and lower caliber players by examining differences in physical qualities between caliber of players based on minutes played per match.

Methods

Athletes

Data from fifty-seven Division I Collegiate Women's Soccer athletes from a single institution were used in this study. Data for this study were collected as part of an on-going athlete monitoring program from 2011-2015. All of the athletes were in the pre-season phase of training prior to the competitive season. Each athlete was placed into either a primary (PRI) or secondary (SEC) group based on the percentage of minutes played per match during the competitive season (Table 4.1).

Testing Protocol

All athletes went through a testing protocol that consisted of body composition assessment including measurements of height (cm), mass (kg), body fat percentage (% BF) (*ACSM's guidelines for exercise testing and prescription*, 2006), unweighted countermovement jump, isometric mid-thigh pull (IMTP), 20 m sprint, Arrowhead Agility (Figure 1) (Chan et al., 2011), and Yo-Yo Intermittent Recovery Test – Level 1 (Bangsbo, 1994). Since the collection of data spanned multiple years, the athlete jumped on either a single force-platform (91x91 cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) or dual-force platform (2 separate 45.5 x 91 cm, RoughDeck HP, Rice Lake, WI, USA) sampling at 1000 Hz. Prior to laboratory testing, the athlete went through a standardized warm-up consisting of 25 jumping jacks, five repetitions of dynamic mid-thigh pulls with 20 kg and three sets of five repetitions of dynamic mid-thigh pulls with 40 kg. Following the warm-up, the athlete would complete 50% and 75% of perceived maximal effort of a countermovement jump with a PVC pipe. The PVC pipe was placed just below the 7th cervical vertebrae similar to a back squat position and this was done to minimize the influence of the arm-swing during the countermovement jump. Countermovement depth was self-selected based on the depth the athlete felt as they could perform the highest jump. After completion of the warm-up jumps, the athlete rested for one minute and completed two, single maximal countermovement jumps with 30 seconds of rest in between each maximal jump. All jumps were recorded and analyzed using a custom program (LabView 2010, 2014, National Instruments Co., Austin, TX). For reliability purposes, additional trials were required if the first two jumps had a difference > 2 cm in jump height. Jump height was calculated using flight time using the following equation:

$$JH=(9.81\ m/s\cdot s)\cdot(ft\cdot ft)/8$$

ft= flight time (s)

Following the jump testing, measurements from the IMTP were performed on a single force platform (91x91 cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) or dual-force platform (2 separate 45.5 x 91 cm, RoughDeck HP, Rice Lake, WI, USA) sampling at 1000 Hz in a custom designed power rack. The athlete was placed in the mid-thigh pull position with a knee angle of 125° ± 5° based on previous research (Bailey et al., 2013; Kraska et al., 2009). The athlete used weightlifting straps and tape to keep the hands in a similar position as well as to minimize the likelihood of grip strength being a limitation. The athlete completed a 50% and 75% of maximum effort prior to the maximal efforts. Athletes were instructed to “pull as fast and hard as possible” based on previous research (Holtermann et al., 2007). A minimum of two trials were performed. If there was >250 N difference in peak force between the first two trials, a third trial was performed. Additional trials were also given if the athlete performed a countermovement prior to the initiation of the pulling movement or if the tape did not securely keep the athletes hands on the bar. All pulls were recorded and analyzed using a custom program (LabView 2010 and 2014, National Instruments Co., Austin, TX).

For the field based examination, tests were performed on a grass playing surface while wearing soccer boots. The athlete completed the field based testing within 24 hours of the laboratory based testing and there was a minimum of four hours of rest after the laboratory based testing and before the field based testing. The athlete would go through a standardized warm-up of jogging (150 m), dynamic stretching, high-knees, jockey, and sprint build-ups of 50%, 75%, and 100% of perceived maximum effort. Prior to performing the maximal trials for the 20 m sprint, the athlete performed a 50% and 75% effort through the timing gates to familiarize themselves with the testing protocol and running through the timing gates (Brower, Salt Lake City, UT, USA). The athlete started from a staggered two-point stance with the front foot 30 cm behind the laser of the first set of timing gates. The athlete would perform a minimum of two maximal trials for the 20 m sprint test. A third trial would be required if the timing gates did not collect data correctly at the start and finish of the trial. A minimum of three minutes of passive recovery took place between each trial to ensure the athlete was recovered prior to each trial.

After the completion of the 20 m sprint, the athlete had three minutes of rest prior to the start of the Arrowhead Agility test to assess the athletes' change of direction (CoD) ability. For the CoD testing protocol, the athlete would perform a trial at 75% of perceived maximal effort to the left before performing two maximal trials to the left. The athlete started from a staggered two-point stance with the front foot 30 cm behind the laser of the first set of timing gates (Brower, Salt Lake City, UT, USA). A minimum of five minutes of passive recovery occurred between each maximal trial to ensure the athlete had enough time to properly recover. As the data in Table 4.2 indicates, the time to complete this test was longer than the time for the 20 m sprint which is why longer recovery periods were given. After two successful trials of the CoD test to the left, the athlete would then complete two trials to the right. Prior to the first maximal trial, a 75% trial to the right was completed to familiarize the athlete with the different changes of direction.

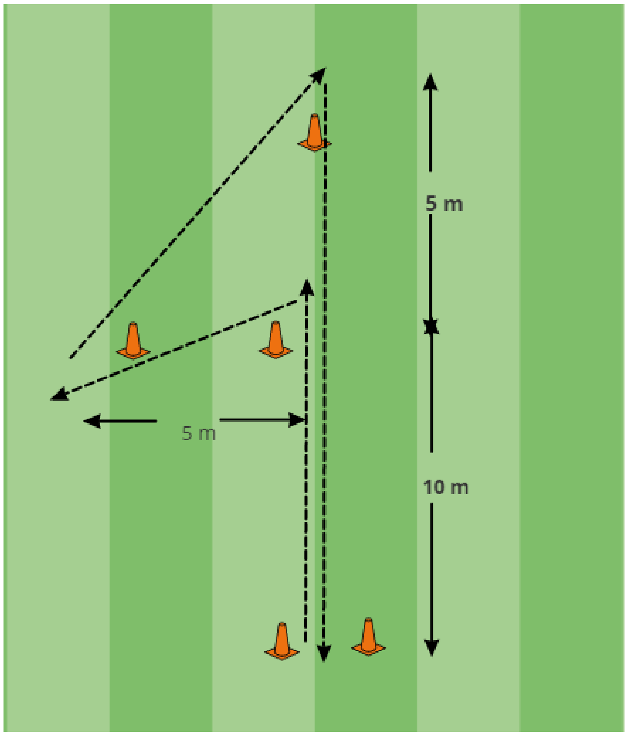

Figure 4.1. Arrowhead Agility Test.

After the completion of the 20 m sprint and CoD test, the athlete had a minimum of five minutes prior to the start of the Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT1). The test consists of a 20 m track where the athlete has a designated time based on audio signals to run down and back. There is also a 5 m “recovery” area where the athlete must go around a cone and back in ten seconds prior to the start of the next shuttle. As the test continues, the time to complete the 20 m down and back run becomes progressively shorter while the ten second recovery time stays constant after each shuttle. Once the athlete is not able to complete a shuttle in the allotted time, a “warning” is given. The next time the athlete is not able to complete the shuttle in the allotted time, they stop and their score is recorded. Unlike the previous field based tests, only one trial was performed. However the YYIRT1 has been shown to be a reliable measurement based on previous research (Krustrup et al., 2003)

Variables

The average of two successful trials for CMJH, IPFa, and RFD was used for the analysis. Countermovement jump height was used as a way to assess the lower body explosiveness of the athletes. Analysis for the IMTP consisted of isometric peak force allometrically scaled (IPFa) for body mass (Jaric, 2003) and rate of force development (RFD) from 0-200 ms. Isometric peak force allometrically scaled can be defined as the peak force achieved during the IMTP scaled to the individual's body mass$^{-0.67}$. Isometric peak force allometrically scaled was used as a method to assess maximal strength and RFD was used to assess the ability of the athlete to produce force quickly from 0-200 ms. Allometrically scaling for body mass allows for similar comparisons to be made for maximum strength between individuals with differences in body mass (Jaric, 2003). An average of two trials was used in order to reduce error inherent in all measurements and to reveal a truer performance value. For the 20 m sprint, the average of the two successful trials were used for analysis and for the CoD test the times for the two successful trials to the left and the two successful trials to the right were averaged together for analysis. The 20 m sprint and CoD tests were chosen to assess the athletes speed and ability to change direction. These qualities have been shown previously to distinguish between levels of play in female athletes (Mujika et al., 2009; Vescovi, 2012). The total distance covered during the YYIRT1 was used for analysis. The YYIRT1 was used due to its ability to distinguish between levels of play in women's soccer (Bangsbo et al., 2008) and its relationship to high speed running performance during competition (Krustrup et al., 2005).

Statistical Analyses

Descriptive statistics and minutes played per match were calculated on all subject demographic and anthropometric data (body mass, lean body mass, % BF, and height) (Table 4.1). Independent samples t-tests were run on an all of the performance variables to determine differences between PRI and SEC groups. Effect size (Cohen's d) was calculated to gain an understanding to how well a variable can distinguish between PRI and SEC (0-0.2, Trivial; 0.2-0.6, Small; 0.6-1.2, Moderate; 1.2-2.0, Large; 2.0-4.0, Very Large) (Hopkins, 2002). Pearson-product moment correlations were calculated between variables to compare the strength of the relationships between PRI and SEC. The same set of correlations were calculated per group in order to examine whether a relationship between two variables would differ based on the caliber of an athlete. Comparisons of correlations between PRI and SEC were then performed as suggested by Cohen, Cohen, West, and Aiken (1983) using Fisher r-to-z transformations (Preacher, 2002). The critical alpha level was set at $p \leq 0.05$ for all analyses.

Table 4.1. Demographic Data and Minutes Played per Match by Group (N = 57)

Variable	Primary (n=27)	Secondary (n=30)
Mass (kg)	63.2 ± 6.1	65.7 ± 11.4
LBM (kg)	52.6 ± 4.4	52.6 ± 8.3
% BF	16.7 ± 2.9	19.6 ± 4.7
Height (cm)	166.9 ± 4.8	165.8 ± 5.9
Minutes Played (minutes)	80.7 ± 7.4	28.7 ± 18.0

Note. Values are expressed as mean ± standard deviation, LBM = lean body mass; % BF = body fat percentage

Table 4.2. Coefficient of Variations and Intra-class Correlation Coefficients on Physical Qualities

Variables		Primary (n = 27)	Secondary (n = 30)	Total (N = 57)
IPFa ($N \cdot kg^{-0.67}$)	CV	1.80%	2.50%	2.16%
	ICC	0.966	0.954	0.975
RFD ($N \cdot s^{-1}$)	CV	15.40%	15.10%	15.26%
	ICC	0.821	0.765	0.747
CMJH (cm)	CV	2.22%	2.64%	2.41%
	ICC	0.982	0.982	0.983
Speed (s)	CV	1.15%	0.62%	0.83%
	ICC	0.898	0.983	0.985
CoD (s)	CV	0.99%	1.02%	0.99%
	ICC	0.946	0.968	0.970

Note. CV = Coefficient of variation, ICC = Intra-class correlation coefficient, CoD = Arrowhead Agility, IPFa = Isometric Peak Force Allometrically Scaled, CMJH = Unweighted Countermovement Jump Height, RFD = Rate of Force Development 0-200 ms.

Results

Results of the independent samples t-test indicated that there was a statistically significant difference between the PRI and SEC groups for the YYIRT1 (t = 2.739, p = 0.009, d = 0.775) (Table 4.2). There was no statistically significant difference for Speed (t = -0.766, p = 0.447, d = 0.199), IPFa (t = -0.232, p = 0.817, d = 0.061), and RFD (t = -1.061, p = 0.293, d = 0.282). Although not achieving statistical significance, trends towards significance existed for both CoD (t = -1.866, p = 0.067, d = 0.498) and CMJH (t = 1.792, p = 0.079, d = 0.474).

There were statistically significant relationships for both PRI and SEC between Speed and CoD, Speed and CMJH, CoD and CMJH, and IPFa and RFD (Table 4.3). None of the correlations were statistically different than each other between the groups.

Table 4.3. Physical Qualities between Primary and Secondary Players (N =57)

Variables	Primary (n = 27)	Secondary (n = 30)
Speed (s)	3.45 ± 0.13	3.48 ± 0.17
CoD (s)	8.96 ± 0.33	9.17 ± 0.48
IPFa ($N \cdot kg^{-0.67}$)	163.82 ± 32.62	165.68 ± 27.78
RFD ($N \cdot s^{-1}$)	4395.64 ± 1480.17	4813.39 ± 1487.78
CMJH (cm)	26.13 ± 3.82	24.39 ± 3.49
YYIRT1 (m)	1233.60 ± 267.75*	1040.00 ± 230.65

*Note.*Values are expressed as mean ± standard deviation. IPFa = Isometric Peak Force allometrically scaled; RFD = Rate of Force Development; CMJH = Unweighted Countermovement Jump Height; YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1, *p ≤0.01, statistically greater in the PRI group.

Table 4.4. Correlations between variables for Primary and Secondary

Interaction	PRI	SEC	PRI vs. SEC
SPEED-CoD	0.688**	0.824**	*p* = 0.246
SPEED-YYIRT1	-0.156	-0.218	*p* = 0.831
SPEED-IPFa	-0.138	0.015	*p* = 0.583
SPEED-RFD	0.077	-0.047	*p* = 0.658
SPEED-CMJH	-0.733**	-0.618**	*p* = 0.446
CoD-YYIRT1	-0.204	-0.280	*p* = 0.788
CoD-IPFa	0.029	-0.129	*p* = 0.571
CoD-RFD	-0.107	-0.018	*p* = 0.749
CoD-CMJH	-0.551**	-0.533**	*p* = 0.927
YYIRT1-IPFa	-0.060	-0.024	*p* = 0.904
YYIRT1-RFD	0.066	0.276	*p* = 0.471
YYIRT1-CMJH	-0.013	0.156	*p* = 0.572
IPFa-RFD	0.419*	0.461*	*p* = 0.852
IPFa-CMJH	0.372	0.077	*p* = 0.263
RFD-CMJH	0.208	0.011	*p* = 0.476

*p ≤ 0.05; **p ≤ 0.01. CoD = Arrowhead Agility Test; IPFa = Isometric Peak Force allometrically scaled; RFD = Rate of Force Development; CMJH = Unweighted Countermovement Jump Height; YYIRT1 = Yo-Yo Intermittent Recovery Test – Level 1.

Discussion

Results showed only one statistical difference that PRI performed better than SEC in the YYIRT1, indicating that the higher caliber players possessed greater intermittent endurance capacity. This is in agreement with previous research that has shown that female soccer players of high caliber covered greater distance during the YYIRT1 (Bangsbo et al., 2008; Mujika et al., 2009). One reason as to why we may have observed these differences is because due to their superior levels of intermittent endurance capacity, the PRI group was better able to maintain match performance (Krustrup et al., 2005) and spend more time on the field compared to the SEC group (Table 4.1).

All other variables assessed were not different between PRI and SEC. If there were differences between CMJH and CoD, the size of the difference would be small according to the effect sizes. The lack of finding statistical significance differs from previous research reporting differences between caliber of play for CMJH (Haugen et al., 2012; Mujika et al., 2009; Sedano et al., 2009; Vescovi et al., 2011), CoD (Mujika et al., 2009; Vescovi et al., 2011), and sprinting assessments (Haugen et al., 2012; Vescovi, 2012; Vescovi et al., 2011). The previous research utilized players from different teams or different levels of play. Thus there is a likelihood that the training programs differed between groups within the same study. This study utilized individuals from a single institution under the guidance of the same coaching staff. Although not evaluated, this may have contributed to the lack of statistical differences since it is likely they were all on a similar resistance training program aimed at enhancing the qualities that were assessed such as strength, RFD, and lower-body explosiveness. However, it appears that the team examined in this study consisted of a more homogenous group of players with respect to the physical qualities assessed in this study.

Results indicated that CMJH demonstrated large to very large relationships between speed and CoD for both PRI and SEC. This is in agreement with previous research with female soccer athletes that reported the relationships to CMJH and speed (Haugen et al., 2012; Vescovi & McGuigan, 2008) and CoD (Vescovi & McGuigan, 2008). With CMJH being used as an indirect measurement of lower-body explosiveness, one would expect those individuals jumping higher (i.e. possess greater lower-body explosiveness relative to their body mass) to run faster and possess greater CoD results since these assessments also require high levels of lower-body explosiveness (Stølen et al., 2005; Wisløff et al., 2004). Results also indicated that IPFa and RFD demonstrated a moderate relationship for both PRI and SEC but did not display any relationships with the other variables. The relationship between IMTP variables is in agreement with previous research (Stone et al., 2004). In a review on the importance of muscular strength on athletic performance (Suchomel, Nimphius, & Stone, 2016), the authors reported that increases in maximal strength resulted in positive improvements in RFD (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002; Andersen, Andersen, Zebis, & Aagaard, 2010). The resultant improvement in RFD following increases in maximal strength highlights the relationship between the two qualities and provides likely rational for the observed statistical relationship in the current study. The lack of statistically significant relationships between IMTP variables and other assessed variables is in agreement with previous research that has shown weak to moderate relationships between isometric and dynamic tasks assessed in this study (Kraska et al., 2009; Thomas et al., 2015; Wilson et al., 1995). However, previous research has shown moderate to large relationships between relative strength and similarly assessed variables such as sprinting and CMJH when relative strength was assessed using a 1RM back squat (Wisløff et al., 2004). If coaches are interested in the relationship to relative strength and dynamic tasks for soccer players, they may be better suited to assess relative strength utilizing a dynamic movement such as a 1RM back squat.

Results from the comparisons of correlations (Table 4.3) showed that the relationships were not statistically different between groups. Previous research suggested that similar variables as to those assessed in this study are able to differentiate caliber of players with success. However, to the researchers' knowledge there have not been any studies that have examined differences in the magnitude of correlations between different caliber of female soccer players when looking to differentiate between levels of play. Although we failed to find differences, investigation into differences in correlations between different levels of athletes might provide useful information for talent identification. For example, if an individual performs well in both sprinting assessments and intermittent endurance capacity assessments, this may highlight the importance of possessing both of these qualities as an indicator for caliber of player.

Conclusion

The results from this study indicated that YYIRT1 performance may be an indicator of caliber of player within a team, which has been shown previously. Although no differences were observed for other variables, CMJH and CoD were trending towards statistical significance. Coaches and practitioners should still assess these variables as they have been shown in other research to be important indicators of caliber of play and may aid in assessing the development of athletes over time. They may also be able to use YYIRT1 performance as a way to determine playing time as those players that perform better are likely better able to maintain physical performance throughout the match. Since this study used athletes from a single institution, the homogeneity of the group may have made it difficult to observe differences since they are all Division I athletes, thus more research should be performed with a wider range of players to determine the discriminative ability of certain variables at the collegiate level (Division I vs. Division II vs. Division III). Also, using positional subgroupings to determine if certain variables are able to differentiate between PRI and SEC players with respect to playing position may aid in identifying the discriminative ability of certain variables with respect to specific positions.

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CHAPTER 5

THE RELATIONSHIP BETWEEN IN-GAME HIGH SPEED RUNNING PERFORMANCE AND PHYSICAL QUALITIES IN DIVISION I WOMEN'S COLLEGIATE SOCCER PLAYERS

Title: The Relationship between In-Game High Speed Running Performance and Physical Qualities in Division 1 Women's Collegiate Soccer Players.

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Abstract

High speed running performance has been demonstrated in previous research to be influenced by a variety of technical and tactical factors such as possession, pass completion percentage and score line. High speed running performance has also been demonstrated to be indicative of higher levels of play in female soccer players. Thus, we aimed to identify the contribution of both tactical (playing position) and physical factors that may play a role in high speed running performance throughout the course of a collegiate women's soccer season. Data from thirty-two Division I Women's Collegiate soccer players was used to assess the influence of playing positon and physical qualities on high speed running performance. Results indicated that playing position had the greatest contribution to high speed running performance accounting for almost 70% of the explained variance for both absolute and relative high speed running. Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT1) contributed 14-19% of the explained variance in both models with other physical qualities that were assessed accounting for < 6% of the variance in high speed running performance. The forward playing position had the strongest relationship to high speed running performance which is in agreement with previous research investigating high speed running performance with respect to playing position. As indicated by the point-biserial correlations, attacking midfielder and wide midfielder possessed a moderate relationship to YYIRT1 performance, indicating that for these positions, this test may be a valid assessment tool for evaluating these playing positions as well as sprinting assessments for attacking midfielder and central defensive midfielder as it appears that central defensive midfielders performed worse than the attacking midfielder role. Coaches and practitioners should look to utilize position specific testing batteries to more effectively evaluate physical qualities that are specific to their respective playing position.

Introduction

Soccer is a sport that includes a variety aerobic and anaerobic activities such as jogging, sprinting, rapid accelerations and decelerations, sliding, tackling, and jumping (Al-Hazzaa et al., 2001; Bloomfield et al., 2007; Wisløff et al., 2004). Research investigating the physical qualities of female soccer athletes has increased over recent years in professional (Mujika et al., 2009; Sedano et al., 2009; Vescovi, 2012), collegiate (Vescovi, 2012; Vescovi et al., 2006; Vescovi & McGuigan, 2008), and youth levels (Castagna & Castellini, 2013; Haugen et al., 2012). Findings from these studies have highlighted the discriminative ability of sprinting (Haugen et al., 2012; Vescovi, 2012), lower-body explosiveness (Haugen et al., 2012; Vescovi et al., 2011), change of direction (Mujika et al., 2009; Vescovi et al., 2011), and intermittent endurance capacity assessments (Bangsbo et al., 2008; Mujika et al., 2009) as players that play at higher standards of play tend to perform better during these assessments.

According to previous research, high speed running during competition has been demonstrated to be higher across higher standards of play in female soccer players (Andersson et al., 2010; Mohr et al., 2008). Andersson et al. (2010) reported that during international competition, high speed running was greater compared to domestic level competition in Scandinavian soccer players. Mohr et al. (2008) found that elite level female soccer players playing in the United States professional league covered more distance at high velocities when compared to the highest level of play in Danish and Swedish professional leagues. This information has led coaches and sport scientists to believe that an individuals' ability to cover distances at high speeds may be a discriminative variable for determining caliber of player in female soccer athletes (Bangsbo et al., 2008).

Although certain physical qualities have been identified to be greater in higher caliber players, there is a paucity of research related to the influence of certain physical qualities on high speed running performance in female soccer players (Krustrup et al., 2005; McCormack et al., 2014). Krustrup et al. (2005) reported that Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT1) performance demonstrated a strong relationship to high speed running performance for the entire match as well as final 15 minutes of each half during a single competition. McCormack et al. (2014) reported that based on the results of a stepwise regression analysis, the greatest contributor to high speed running performance was aerobic power (VO_2max) when assessing high speed running performance from a single competition. Previous research has shown that there can be up to 30% variation of high speed running from match to match (Alexander, 2014; Gregson et al., 2010). Thus, investigating a single match may not provide accurate insight into the high speed running capabilities of an individual throughout a competitive season. Therefore, the purpose of this study was to assess the contribution of physical qualities to high speed running performance during a full competitive season. Gaining knowledge in this aspect can help identify the importance of certain physical qualities to physical match performance and possibly aid in enhancement of talent identification if certain physical qualities are more important to physical match performance.

Methods

Athletes

Data from 32 Division I Collegiate Women's Soccer athletes from a single institution were used in this study. Data for this study were collected as part of an on-going athlete monitoring program from 2013-2015. The athlete must have played the entire match without substitution or change in playing position for a minimum of four matches within the same competitive season (Table 5.1). Only matches where the player stayed in the same tactical position and played the entire duration of the match without substitution was used for analysis to better represent the demands of a full match. The athletes playing position was based on where they started the game as one of the following: attacking midfielder (AM), central defender (CD), central defensive midfielder (CDM), fullback (FB), forward (F), and wide midfielder (WM).

Testing Protocol

All athletes went through a testing protocol that consisted of body composition assessment including measurements of height (cm), mass (kg), body fat percentage (% BF) (*ACSM's guidelines for exercise testing and prescription*, 2006), unweighted countermovement jump, isometric mid-thigh pull (IMTP), 20 m sprint, Arrowhead Agility (Figure 1) (Chan et al., 2011), and Yo-Yo Intermittent Recovery Test – Level 1 (Bangsbo, 1994). Since the collection of data spanned multiple years, the athlete jumped on either a single force-platform (91x91cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) or dual-force platform (2 separate 45.5 x 91cm, RoughDeck HP, Rice Lake, WI, USA) sampling at 1000 Hz. Prior to laboratory testing, the athlete went through a standardized warm-up consisting of 25 jumping jacks, five repetitions of dynamic mid-thigh pulls with 20 kg and three sets of five repetitions of dynamic mid-thigh pulls with 40 kg. Following the warm-up, the athlete would complete 50% and 75% of perceived maximal effort of a countermovement jump with a PVC pipe. The PVC pipe was placed just below the 7th cervical vertebrae similar to a back squat position and this was done to minimize the influence of the arm-swing during the countermovement jump. Countermovement depth was self-selected based on the depth the athlete felt as they could perform the highest jump. After completion of the warm-up jumps, the athlete rested for one minute and completed two, single maximal countermovement jumps with 30 seconds of rest in between each maximal jump. All jumps were recorded and analyzed using a custom program (LabView 2010, 2014, National

Instruments Co., Austin, TX). For reliability purposes, additional trials were required if the first two jumps had a difference > 2 cm in jump height. Jump height was calculated using flight time using the following equation:

$$JH=(9.81\ m/s\cdot s)\cdot(ft\cdot ft)/8$$

ft= flight time (s)

Following the jump testing, measurements from the IMTP were done on a single force platform (91x91cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) or dual-force platform (2 separate 45.5 x 91cm, RoughDeck HP, Rice Lake, WI, USA) sampling at 1000 Hz in a custom designed power rack. The athlete was placed in the mid-thigh pull position with a knee angle of 125° ± 5° based on previous research (Bailey et al., 2013; Kraska et al., 2009). The athlete used weightlifting straps and tape to keep the hands in a similar position as well as to minimize the likelihood of grip strength being a limitation. The athlete completed a 50% and 75% of maximum effort prior to the maximal efforts. Athletes were instructed to "pull as fast and hard as possible" based on previous research (Holtermann et al., 2007). A minimum of two trials were performed. If there was >250 N difference in peak force between the first two trials, a third trial was performed. Additional trials were also given if the athlete performed a countermovement prior to the initiation of the pulling movement or if the tape did not securely keep the athletes hands to the bar. All pulls were recorded and analyzed using a custom program (LabView 2010 and 2014, National Instruments Co., Austin, TX).

For the field based testing, tests were performed on a grass playing surface while wearing soccer boots. The athlete completed the field based testing within 24 hours of the laboratory based testing and there was a minimum of four hours of rest between the laboratory based testing and field based testing. The athlete would go through a standardized warm-up of jogging (150 m), dynamic stretching, high-knees, jockey, and sprint build-ups of 50%, 75%, and 100% of perceived maximum effort. Prior to performing the maximal trials for the 20 m sprint, the athlete performed a 50% and 75% effort through the timing gates to familiarize themselves with the testing protocol and running through the timing gates (Brower, Salt Lake City, UT, USA). The athlete started from a staggered two-point stance with the front foot 30 cm behind the laser of the first set of timing gates. The athlete would perform a minimum of two maximal trials for the 20 m sprint test. A third trial would be required if the timing gates did not collect data correctly by the laser not being broken at the start and finish of the trial. A minimum of three minutes of passive recovery took place between each trial to ensure the athlete was recovered prior to each trial.

After the completion of the 20 m sprint, the athlete had three minutes of passive rest prior to the start of the Arrowhead Agility test to assess the athletes' change of direction ability (CoD). For the CoD testing protocol, the athlete would perform a trial at 75% of perceived maximal effort to the left before performing two maximal trials to the left. The athlete started from a staggered two-point stance with the front foot 30 cm behind the laser of the first set of timing gates (Brower, Salt Lake City, UT, USA). A minimum of five minutes of passive recovery occurred between each maximal trial to ensure the athlete had enough time to properly recover. As the data in Table 5.1 indicates, the time to complete this test was longer than the 20 m sprint which is why longer recovery periods were given. After two successful trials of the CoD test to the left, the athlete would then complete two trials to the right. Prior to the first maximal trial, a 75% trial to the right was completed to familiarize the athlete with the different changes of direction. The 20 m sprint and CoD tests were chosen to assess the athletes speed and ability to change direction. These qualities have been shown previously to distinguish between levels of play (Mujika et al., 2009; Vescovi, 2012).

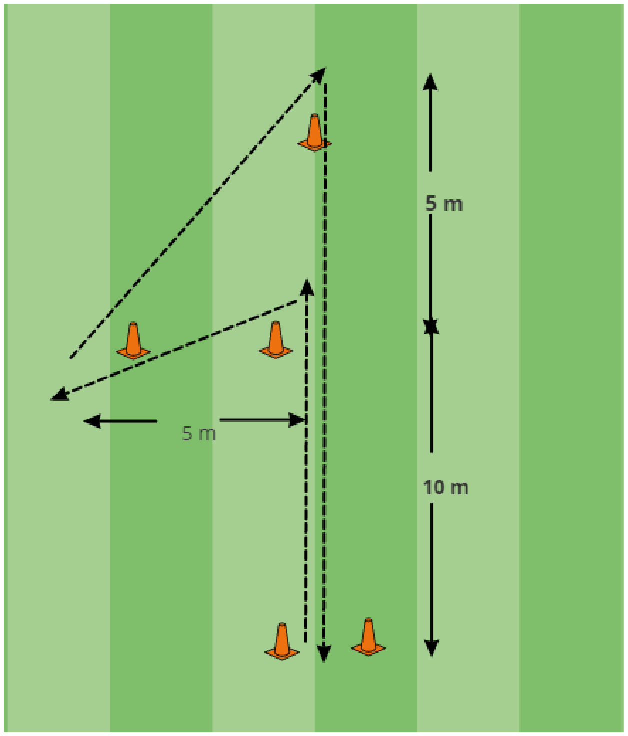

Figure 5.1. Arrowhead Agility Test.

After the completion of the 20 m sprint and CoD test, the athlete had a minimum of five minutes prior to the start of the Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT1). The test consists of a 20 m track where the athlete has a designated time based on audio signals to run down and back. There is also a 5 m "recovery" area where the athlete must go around a cone and back in ten seconds prior to the start of the next shuttle. As the test continues, the time to complete the 20 m down and back run becomes progressively shorter while the ten second recovery time stays constant after each shuttle. Once the athlete is not able to complete a shuttle in the allotted time, a "warning" is given. The next time the athlete is not able to complete the shuttle in the allotted time, they stop and their score is recorded. Unlike the previous field based tests, only one trial performed. However the YYIRT1 has been shown to be a reliable measurement based on previous research (Krustrup et al., 2003). The YYIRT1 was used due to its ability to distinguish between levels of play in women's soccer (Bangsbo et al., 2008) and its relationship to high speed running performance during competition (Krustrup et al., 2005).

Match Analysis

A Global Position System (GPS) device (minimax-10 Hz, Catapult Innovations, Melbourne, Australia) was used to measure distance covered and running velocity. The GPS device was worn during competition in a fitted undergarment with the device placed between the scapulae of the athlete and fit snug against the back. The GPS device used has been assessed for interunit reliability in previous research and has been shown to demonstrate sufficient reliability for measuring high speed running distance (typical error of measurement = 4.8%, intraclass correlation coefficient = 0.88) (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014). This device has also been demonstrated to be valid when assessing maximum velocities when compared to a 3-D motion analysis system (VICON, Oxford Metrics, Oxford, United Kingdom) (Vickery et al., 2014).

Variables

The average of two successful trials for countermovement jump height (CMJH), isometric peak force allometrically scaled (IPFa) and rate of force development 0-200 ms (RFD) as used for the analysis. Countermovement jump height was used as a way to assess the lower body explosiveness of the athletes. Analysis for the IMTP consisted of IPFa and RFD. Isometric peak force allometrically scaled can be defined as the peak force achieved during the IMTP scaled to the individual's body mass$^{-0.67}$ where peak force is the highest instantaneous force output achieved during the IMTP. Isometric peak force allometrically scaled was used as a method to assess maximal strength and RFD was used to assess the ability of the athlete to produce force quickly from 0-200 ms. Rate of force development was calculated by the change in force divided by the change in time which started at the onset of the maximal pulling action. Allometrically scaling for body mass allows for similar comparisons to be made for maximum strength between individuals with differences in body mass. An average of two trials was used in order to reduce error inherent in all measurements and to reveal a truer performance value. For the 20 m sprint time (Speed), the average of the two successful trials were used for analysis and for the CoD test the times for the two successful trials to the left and the two successful trials to the right were averaged together for analysis. The total distance covered during the YYIRT1 was used for analysis.

In this study, absolute high speed running (HSRA) will be defined as the average of distance covered above 15 $km \cdot h^{-1}$ per match for each individual. This threshold has been used in previous literature to assess high speed running (HSR) in professional (Andersson et al., 2010; Krustrup et al., 2005) and collegiate (Alexander, 2014) female soccer players. High speed running has been demonstrated in previous literature to distinguish levels of play of female soccer players (Andersson et al., 2010; Gabbett & Mulvey, 2008; Mohr et al., 2008) amongst female soccer players. Relative high speed running (HSRR) will be calculated based on methods previously used by Buchheit, Mendez-villanueva, Simpson, and Bourdon (2010). The peak-game velocity (PGV) will be considered the greatest achieved velocity during the competitive season being used for analysis. To determine individualized HSRR thresholds, a 15 $km \cdot h^{-1}$ reference point was used to determine the group's average % of PGV at which this reference point occurred. A group mean average of 57.7% was calculated and applied as the individual's HSRR threshold (Table 5.2). The average of distance covered at or above the individualized HSRR threshold per match was used for analysis.

Statistical Analyses

Descriptive statistics were calculated on height, body mass, LBM, % BF, HSRA, HSRR, IPFa, RFD, CMJH, speed, CoD, and YYIRT1 with for each respective playing position (Table 5.1). Coefficient of variation (CV) and intra-class correlation coefficients (ICC) were calculated to indicate within-player variability between matches for each playing position and the entire sample for HSRR and HSRA as well as for CMJH, IPFa, RFD, Speed, and CoD (Table 5.2). Pearson-product moment correlations were run to determine the relationships of the variables being assessed. Point-biserial correlations were run between position and physical qualities. Multiple regression analysis was used to examine the amount of variance explained by the variables for HSRR and HSRA. Playing position was included in the model to help control for the explained variance of playing position and physical qualities were entered in standard method with the variables being entered simultaneously. Inclusion of playing position as an independent variable was done by using dummy variables for each playing position with the exception of CD which was used as our reference group (Lindeman, Merenda, & Gold, 1980). For each position, the player was assigned a "1" if they were assigned to that respective playing positon and a "0" if they were not assigned to that playing position. Central defender was used as our reference group as previous research has shown that position typically covers the least distance at high velocities (Alexander, 2014). This allows for the effect of playing position to be assessed in the multiple regression analysis. Playing positon has been shown to play a significant factor in determining HSRA in previous research, thus to better quantify the importance of physical qualities, we included playing position to help control for the variance that can be explained by playing positon. Variables that produced multicollinearity were removed from the model and a new model was produced. The relative contribution of each variable to predict the variance of the dependent variable was calculated as relative importance using methods explained by Lindeman et al. (1980). Cohen's f^2 effect size was calculated to assess the magnitude of the model (Cohen, 1988).

Table 5.1. Descriptive Statistics on Anthropometrics, High Speed Running and Physical Qualities

	AM (n = 3)	CDM (n = 6)	WM (n = 6)	FB (n = 7)	CD (n = 7)	F (n = 3)	Total (N = 32)
Height (cm)	166.7 ± 0.6	162.5 ± 4.5	171.9 ± 5.2	167.1 ± 5.6	169.4 ± 3.1	165.0 ± 1.7	167.2 ± 4.9
Body Mass (kg)	60.6 ± 1.4	61.5 ± 4.4	62.9 ± 9.3	58.9 ± 6.5	67.7 ± 4.3	58.3 ± 2.5	62.1 ± 6.4
LBM (kg)	52.3 ± 0.6	50.9 ± 1.8	53.8 ± 5.7	49.9 ± 4.5	56.4 ± 3.0	50.2 ± 1.2	52.5 ± 4.2
% BF	13.6 ± 1.1	17.1 ± 4.0	13.9 ± 5.0	15.0 ± 3.0	16.6 ± 1.7	13.8 ± 1.6	15.3 ± 3.3
HSRA (m)	906.1 ± 125.0	842.8 ± 232.8	1286.1 ± 261.7	1155.7 ± 217.5	738.1 ± 106.3	1456.7 ± 112.9	1034.9 ± 307.1
HSRR (m)	795.3 ± 101.2	1005.0 ± 337	1152.0 ± 243.0	1028.7 ± 221.7	668.1 ± 191.4	1354.3 ± 158.6	977.1 ± 303.2
IPFa ($N*kg^{-0.67}$)	176.1 ± 7.4	159.3 ± 22.6	170.9 ± 24.2	175.5 ± 25.8	148.9 ± 28.3	136.3 ± 13.1	162.1 ± 25.6
RFD ($N·s^{-1}$)	3935.5 ± 352.7	4713.6 ± 193	5426.1 ± 1602.2	4578.3 ± 1333.2	4393.1 ± 2283.9	3480.7 ± 504.4	4558.9 ± 1450.7
CMJH (cm)	33.1 ± 1.2	23.5 ± 7.6	26.5 ± 1.4	26.1 ± 3.9	24.7 ± 3.1	27.5 ± 1.0	26.1 ± 4.6
Speed (s)	3.24 ± 0.04	3.60 ± 0.19	3.5 ± 0.11	3.45 ± 0.13	3.4 ± 0.11	3.35 ± 0.07	3.46 ± 0.15
CoD (s)	8.36 ± 0.27	9.17 ± 0.49	8.86 ± 0.28	8.93 ± 0.19	9.1 ± 0.17	8.9 ± 0.07	8.93 ± 0.34
YYIRT1 (m)	1720.0 ± 183.3	1280.0 ± 242.7	1540.0 ± 326.7	1262.8 ± 163.1	1188.5 ± 166.1	1320.0 ± 174.3	1350.0 ± 264.9
Matches played per athlete	12.3 ± 0.6	12.5 ± 5.5	6.3 ± 1.8	10.6 ± 4.0	11.3 ± 5.1	5.0 ± 1.7	9.9 ± 4.6

Note. Values are mean ± standard deviation. LBM = lean body mass, % BF = body fat percentage, CoD = Arrowhead Agility, IPFa = Isometric Peak Force Allometrically Scaled, CMJH = Unweighted Countermovement Jump Height, RFD = Rate of Force Development 0-200 ms, YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1, AM = Attacking Midfielder, CDM = Central Defensive Midfielder, WM = Wide Midfielder, FB = Fullback, CD = Central Defender, F = Forward.

Table 5.2. Coefficient of Variations and Intra-class Correlation Coefficients on High Speed Running and Physical Qualities

Variables		AM (n = 3)	CDM (n = 6)	WM (n = 6)	FB (n = 7)	CD (n = 7)	F (n = 3)	Total (N = 32)
HSRA (m)	CV	22.0%	23.0%	24.6%	19.8%	20.4%	11.4%	34.7%
HSRR (m)	CV	24.0%	21.0%	19.1%	25.3%	24.1%	12.7%	31.3%
IPFa ($N·kg^{-0.67}$)	CV	1.8%	6.0%	3.2%	4.2%	2.3%	7.2%	4.2%
	ICC	0.982	0.979	0.824	0.834	0.914	0.939	0.958
RFD ($N·s^{-1}$)	CV	8.9%	10.8%	15.5%	12.9%	19.7%	10.5%	16.2%
	ICC	0.931	0.779	0.714	0.813	0.718	0.819	0.882
CMJH (cm)	CV	1.3%	4.7%	1.9%	2.8%	4.8%	2.0%	2.5%
	ICC	0.991	0.906	0.932	0.976	0.945	0.923	0.971
Speed (s)	CV	1.9%	2.1%	1.2%	2.8%	1.1%	1.4%	1.6%
	ICC	0.941	0.884	0.995	0.895	0.916	0.956	0.903
CoD (s)	CV	2.1%	1.1%	0.9%	1.5%	3.3%	1.1%	1.3%
	ICC	0.978	0.964	0.761	0.918	0.814	0.945	0.948

Note. HSRA = Absolute High Speed Running, HSRR = Relative High Speed Running, CoD = Arrowhead Agility, IPFa = Isometric Peak Force Allometrically Scaled, CMJH = Unweighted Countermovement Jump Height, RFD = Rate of Force Development 0-200 ms, YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1, AM = Attacking Midfielder, CDM = Central Defensive Midfielder, WM = Wide Midfielder, FB = Fullback, CD = Central Defender, F = Forward

Table 5.3. Relative High Speed Running and Peak-Game Velocity

Athlete	PGV ($km \cdot h^{-1}$)	15 $km \cdot h^{-1}$ (%)	HSRR ($km \cdot h^{-1}$)	Position
1	23.4	64.1	13.5	CDM
2	25.4	59.1	14.7	WM
3	25.9	57.9	14.9	CDM
4	25.1	59.8	14.5	FB
5	25.1	59.8	14.5	CD
6	27.2	55.1	15.7	FB
7	25.9	57.9	14.9	CD
8	27.6	54.3	15.9	AM
9	24.4	61.5	14.1	CDM
10	26.8	56.0	15.5	FB
11	26.7	56.2	15.4	CDM
12	26.8	56.0	15.5	CD
13	26.0	57.7	15.0	FB
14	26.3	57.0	15.2	WM
15	26.6	56.4	15.3	WM
16	26.9	55.8	15.5	AM
17	26.9	55.8	15.5	F
18	26.9	55.8	15.5	CD
19	23.4	64.1	13.5	CDM
20	25.5	58.8	14.7	F
21	27.4	54.7	15.8	CD
22	25.7	58.4	14.8	CD
23	27.6	54.3	15.9	WM
24	28.1	53.4	16.2	FB
25	25.3	59.3	14.6	FB
26	24.3	61.7	14.0	FB
27	26.3	57.0	15.2	WM
28	25.3	59.3	14.6	WM
29	27.1	55.4	15.6	FB
30	27.0	55.6	15.6	AM
31	27.7	54.2	16.0	F
32	23.9	62.8	13.8	CD
Mean ± standard deviation	26.2 ± 1.3	57.7 ± 2.9	15.0 ± 1.0	

Note . PGV = peak-game velocity, HSRR = relative high speed running

Results

The calculated correlation coefficients revealed that HSRR, one of the dependent variables in the multiple regression analysis, were statistically correlated with F and YYIRT1 (Table 5.3). Similarly, HSRA was statistically correlated with F, WM, and YYIRT1. Among the independent variables for the regression analyses, AM was statistically correlated with speed, CoD, CMJH, and YYIRT1. Central defensive midfielder and WM were statistically correlated with speed and YYIRT1 respectively. Furthermore, speed was correlated with CoD, CMJH, and YYIRT1. The variables from the IMTP (IPFa and RFD) were statistically correlated as well. There were no other significant statistical correlations between either of the dependent variables (HSRR and HSRA) and the other physical qualities assessed (speed, CoD, CMJH, IPFa, and RFD). The multiple regression model for HSRA as a dependent variable included playing position and all of the physical characteristics ($F_{11,20}$ = 12.057, *SEE* = 138.42 m, $p < 0.001$, f^2 = 6.633) (Table 5.4). Independent variables that produced statistically significant coefficients in the model were F (t = 5.801, $p < 0.001$), FB (t = 5.295, $p < 0.001$), WM (t = 2.471, p = 0.023), IPFa (t = -2.627, p = 0.016) and YYIRT1 (t = 5.225, $p < 0.001$).

Table 5.4. Pearson-Product Moment Correlations between Variables

Variable	HSRA	HSRR	AM	CDM	F	FB	WM	Speed	CoD	IPFa	CMJH	RFD
HSRR	0.832**											
AM	-0.137	-0.195										
CDM	-0.305	0.044	-0.154									
F	0.449**	0.406*	-0.103	-0.154								
FB	0.211	0.091	-0.170	-0.254	-0.170							
WM	0.399*	0.281	-0.154	-0.230	-0.154	-0.254						
Speed	-0.195	0.052	-0.467**	0.426*	-0.223	-0.025	0.109					
CoD	-0.132	0.115	-0.549**	0.334	-0.031	-0.001	-0.117	0.671**				
IPFa	0.013	0.012	0.177	-0.054	-0.329	0.279	0.167	-0.139	-0.276			
CMJH	0.189	0.050	0.490**	-0.279	0.097	-0.018	0.033	-0.781**	-0.616**	0.412*		
RFD	0.053	0.190	-0.140	0.052	-0.242	0.007	0.291	0.103	0.042	0.528**	-0.050	
YYIRT1	0.492**	0.371*	0.456**	-0.128	-0.037	-0.176	0.350*	-0.425*	-0.322	0.287	0.424*	0.135

Note. $p \leq 0.05$, $p \leq 0.01$, HSRA = Absolute High-Speed Running; HSRR = Relative High-Speed Running; AM = Attacking Midfielder; CDM = Central Defensive Midfielder; F = Forward; WM = Wide Midfielder; Speed = 20 m sprint; CoD = Arrowhead Agility Test; IPFa = Isometric Peak Force Allometrically Scaled; CMJH = Unweighted Countermovement Jump Height; RFD = Rate of Force Development 0-200 ms; YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1.

A separate multiple linear regression model was calculated to predict HSRR. The initial model included playing position and all of the physical characteristics ($F_{11,20}$ = 4.957, *SEE* = 195.55 m, p = 0.001). However, examination of the associated condition indexes along with variance portions indicated the presence of multicollinearity. Subsequently, multicollinearity was re-examined without CoD, which was removed due to its highest variance proportion in the initial examination. However, multicollinearity was still suspected and thus the data were examined for the third time for multicollinearity without Speed, which had the highest correlation with CoD and the second highest variance proportion in the first examination. As a result, the condition indexes and variance proportions met the suggested criteria. With the resulting data set, a statistically significant model was produced ($F_{10,21}$ = 4.513, *SEE* = 207.59 m, p = 0.002, f^2 = 2.154) (Table 5.5). Independent variables that produced statistically significant coefficients were CDM (t = 2.505, p = 0.021), F (t = 4.167, p < 0.001), FB (t = 3.340, p = 0.003), WM (t = 2.556, p = 0.018), and YYIRT1 (t = 2.427, p = 0.024).

Relative contribution was calculated to determine relative importance of each variable in the final models for HSRR and HSRA (Table 5.6). The playing position variables and YYIRT1 were the largest contributors in both models.

Table 5.5. Multiple Regression Results for Absolute High Speed Running

Model	R^2	B	Standard Error	β	p value
Step 1	0.869				
Constant		-1509.49	1413.17		0.298
Attacking Midfielder		-192.87	142.02	-0.19	0.190
Central Defensive Midfielder		17.03	88.55	0.02	0.849
Forward		592.64	102.17	0.57	0.001**
Fullback		439.92	83.08	0.60	0.001**
Wide Midfielder		265.86	107.61	0.34	0.023*
Speed		684.50	382.47	0.35	0.089
CoD		-111.60	121.33	-0.12	0.369
IPFa		-4.45	1.69	-0.37	0.016*
CMJH		20.73	11.30	0.31	0.081
RFD		0.03	0.02	0.15	0.184
YYIRT1		0.75	0.14	0.65	0.001**

Note. *$p \leq 0.05$, ** $p \leq 0.001$; Speed = 20 m sprint; CoD = Arrowhead Agility, IPFa = Isometric Peak Force Allometrically Scaled, CMJH = Unweighted Countermovement Jump Height, RFD = Rate of Force Development 0-200 ms, YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1

Table 5.6. Multiple Regression Results for Relative High Speed Running

Model	R^2	B	Standard Error	β	p value
	0.683				
Constant		-1779.49	1548.23		.263
Attacking Midfielder		46.11	206.05	.045	.825
Central Defensive Midfielder		302.77	120.85	.396	.021*
Forward		638.43	153.21	.624	.000**
Fullback		415.90	124.53	.576	.003*
Wide Midfielder		357.02	139.71	.467	.018*
CoD		203.95	156.87	.231	.208
IPFa		-3.31	2.35	-.279	.174
CMJH		11.34	12.41	.173	.371
RFD		0.06	0.03	.278	.106
YYIRT1		0.47	0.19	.407	.024*

Note. *$p \leq 0.05$, ** $p \leq 0.001$; CoD = Arrowhead Agility, IPFa = Isometric Peak Force Allometrically Scaled, CMJH = Unweighted Countermovement Jump Height, RFD = Rate of Force Development 0-200 ms, YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1.

Table 5.7. Relative Contribution to Multiple Regression Models

	Relative Importance	
Variable	HSRA	HSRR
Attacking Midfielder	7.78%	6.77%
Central Defensive Midfielder	5.51%	5.37%
Forward	28.09%	34.16%
Fullback	13.35%	8.65%
Wide Midfielder	16.91%	13.97%
Speed	2.34%	N/A
CoD	0.90%	5.96%
RFD	1.01%	5.93%
IPFa	3.37%	3.62%
CMJH	1.65%	1.55%
YYIRT1	19.03%	14.01%
Explained Variance	86.90%	68.30%

Note. Speed = 20 m sprint; CoD = Arrowhead Agility Test; RFD = Rate of Force Development 0-200 ms; IPFa = Isometric Peak Force Allometrically Scaled; CMJH = Unweighted Countermovement Jump Height; YYIRT1 = Yo-Yo Intermittent Recovery Test - Level 1.

Discussion

Playing position and YYIRT1 performance collectively provided over 90% of the explained variance of HSRR and HSRA with playing position alone accounting for approximately 70% of the explained variance for both HSRA and HSRR. Previous research has demonstrated that there are differences in high speed running profiles in female soccer players with respect to playing position (Alexander, 2014; Martínez-Lagunas et al., 2015; Mohr et al., 2008; Vescovi & Favero, 2014) with a trend towards F performing the greatest amount of high speed running distance during competition. The results of the current investigation appear to agree with previous research as the F playing position had the greatest positive correlation with HSRR and HSRA (Table 5.3). Previous research has reported that the F playing position performs more high-intensity activity when their team has possession (Dellal et al., 2010), and although this was not investigated as a part of this study, this could be a possible reason for the observed relationship of playing position with HSRR and HSRA depending on the tactical influences of the team's playing style. Previous research has reported that more successful teams tend to have more possession of the ball (Bate, 1988; Collet, 2013), and the win-loss-draw record of the team over the course of the investigation was 31-24-3, possibly supporting the previous notion of the team having greater possession of the ball. However, with only three players observed at the F position, this may limit the ability of these findings to be generalized to forwards in collegiate women's soccer. Other research has also indicated that many other technical and tactical parameters can influence high speed running performance such as ball interactions and pass completion percentage (Alexander, 2014), playing position (V. Di Salvo et al., 2007; V. Di Salvo et al., 2009), tactical formation (Bradley et al., 2011; Bradley, Lago-Peñas, Rey, & Gomez Diaz, 2013; Bush, Barnes, Archer, Hogg, & Bradley, 2015) matches being played on home or away fields (Lago & Martín, 2007), and score line (Bradley & Noakes, 2013; Lago & Martín, 2007). This highlights the multi-faceted nature of high speed running performance and how it is influenced by a variety of technical and tactical factors which appear to play a larger role in impacting high speed running performance.

Of the physical qualities assessed, YYIRT1 showed the greatest contribution by accounting for 14 to 19% of the explained variance for HSRR and HSRA. Previous research in female soccer players demonstrated a strong relationship between YYIRT1 performance and high speed running during competition as well as during the final 15 minutes of each half (Krustrup et al., 2005). The authors reported that the relationship between high speed running performance during the final 15 minutes of each half was stronger with YYIRT1 performance compared to VO_2max, highlighting the importance of assessing intermittent endurance capacity compared to maximal aerobic power. It appeared that AM and WM tended to perform better than other positions during the YYIRT1 (Table 5.3) and this may indicate that for AM and WM, YYIRT1 performance is important but is not as important for the other playing positions that were observed. It is possible that these positions covered more total distance which has been previously reported in central midfielders and WM due to their connecting role to attacking and defending players (V. Di Salvo et al., 2007), thus needing to possess high levels of intermittent endurance capacity to meet the overall demands of the game is required. However, as the results indicate, playing position has a greater relationship with HSRR and HSRA than any of the physical qualities assessed including YYIRT1 performance and YYIRT1 performance may be a more suitable evaluator of total distance covered rather than distance covered at high velocities. However, with only three athletes at the AM position, these findings may be specific to this sample and more research is necessary to determine the extent that these findings exist in the population of collegiate female soccer players.

A possible explanation for other physical qualities not contributing to HSRR or HSRA could be that the opportunities to perform to a player’s physical abilities as observed in physical tests are determined by tactical influences. The importance of certain physical qualities may also be position-dependent as indicated by the correlations demonstrating that certain physical qualities may be more important for specific playing positions. Central defensive midfielder was positively correlated with speed, indicating that those athletes at that specific playing position tend to perform slower during 20 m sprint testing. Interestingly, the AM tended to perform better during the 20 m sprint assessment, CoD, CMJH and YYIRT1, indicating that this position may need to possess high levels of lower-body explosiveness as well as intermittent endurance capacity. Typically, the AM and CDM are grouped together for studies analyzing differences in physical qualities or overall match demands. However, this may provide rational for examining these positions separately rather than as one central midfielder position. Identifying position specific qualities still needs to be performed with caution as none of the physical qualities by themselves can explain more than 25% of the variance in playing positon as indicated by the strength of the correlations.

Conclusion

This was the first study to assess the contribution of preseason fitness testing to high speed running performance for the length of an entire competitive season in women's collegiate soccer. Playing position appears to have the greatest contribution to the amount of high speed running performed with a small contribution (14-19 %) of YYIRT1 performance to high speed running capabilities in Division I Women's Collegiate soccer players. Also, it appears that high speed running performance appears to be more reflective of technical and tactical factors rather than physical qualities. Thus monitoring high speed running performance may not accurately assess physical qualities such as those examined in this study. Although the other physical variables contributed < 6% of the explained variance by themselves to high speed running performance, these physical qualities demonstrated relationships with certain playing positions and may aid in developing position specific testing batteries. Coaches and practitioners should utilize testing batteries that are position specific to better assess physical qualities that are important for respective playing positions. For example, utilizing sprint assessments for identifying AM and CDM position as well as YYIRT1 for AM and WM as these positions may require better performance to meet the overall demands of the game than other positions and may aid in implementing more efficient evaluation methodologies. However, future research should investigate the importance of high speed running compared to tactical formation, team success, amount of possession in an attempt to gain a holistic understanding of physical, technical and tactical aspects of the game of soccer as well as the ability of certain assessments to identify position specific physical qualities that are important for physical match performance.

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CHAPTER 6

SUMMARY AND FUTURE INVESTIGATIONS

Soccer is a sport comprised of a variety of anaerobic and aerobic activities (Al-Hazzaa et al., 2001; Bloomfield et al., 2007; Wisløff et al., 2004). The ability of coaches and sport scientists to quantify these activities has become less problematic in recent years due to advancements in Global Positioning Systems (GPS), accelerometers, and digital camera systems. The quantity of investigations into the demands of the women's game has increased over recent years as well at the professional (Andersson et al., 2010; Mohr et al., 2008), youth (Vescovi, 2014) and collegiate game (Alexander, 2014; McCormack et al., 2015; Vescovi & Favero, 2014). At the collegiate level, Alexander (2014) reported differences between fullbacks and central defenders and central defensive midfielders in that the fullback position covered greater distance at high velocities (>15 $km \cdot h^{-1}$). Until recently, the majority of the research investigating the physical demands with respect to playing position may have missed out on such a finding due to the lack of use of specific playing positions. Previous research utilized more "classic" positional subgroupings of forward, midfielder, and defender whereas Alexander (2014) used positional subgroups of central defender, fullback, central defensive midfielder, wide midfielder, central attacking midfielder and forward. With there being differences in the physical demands during competition, investigations into the differences in physical qualities such as speed, strength, and lower-body explosiveness may shed light on the importance of specific physical qualities with respect to playing position. The current investigation found that in fact there are differences in physical qualities with respect to playing position, indicating that the more attacking based playing positions (forward, wide midfielder and attacking midfielder) tend to be faster than more defensive based players (central defenders and central defensive midfielders and goalkeepers) when assessed during a 20 m sprint and change of direction assessment (Arrowhead Agility Test) (Chan et al., 2011). This contrasted to previous research that did not find differences in physical qualities with respect to playing position (Vescovi et al., 2006). However, this may have been a result of different positional subgroupings used between the studies. Findings from the current investigation were in agreement with the previous research that indicated that higher caliber players possessed greater Yo-Yo Intermittent Recovery – Level 1 (YYIRT1) performances compared to lower caliber players (Bangsbo et al., 2008; Mujika et al., 2009). Mujika et al. (2009) reported that First Division Spanish League players performed better during the YYIRT1 compared to Second Division Spanish League players. The current investigation demonstrated that playing positon has a large influence on the amount of high speed running that is performed during competition, indicating that tactical systems instilled within the team may be the largest determining factor of high speed running performance, with YYIRT1 performance contributing 14-19% of the explained variance in high speed running performance. Previous research has demonstrated large relationships of both high speed running performance throughout an entire competition and the final 15 minutes of each half with YYIRT1 performance in female soccer players (Krustrup et al., 2005). It has also been reported that high speed running performance being greater at higher standards of play (Andersson et al., 2010; Mohr et al., 2008). The findings from the current investigation highlight the positional differences that exist and may not have been observed previously due to lack of use of specific positional subgroupings as well as the influence of tactical and technical factors on high speed running performance with some influence of intermittent endurance capacity. Also, the findings from the final investigation indicate that certain positions may require varying degrees of physical qualities such as attacking midfielder and wide midfielder needing to possess higher levels of intermittent endurance capacity compared to other positions as well as attacking midfielder needing to perform well during sprinting assessments compared to the central defensive midfielder. However, due to small sample sizes for forward (n = 3) and attacking midfielder (n = 3), more research is required to determine if these findings are consistent in other populations. This finding may have not been observed in previous research as the attacking midfielder and central defensive midfielder are typically grouped in a more common central midfielder playing position or a group of three with the wide midfielder position as a very generalized midfielder positional category.

Future investigations should attempt to utilize a more heterogeneous group of athletes. Since the athletes used in this investigation were from a single team, some differences in terms of playing position and caliber of player may have not been able to be observed due to the homogeneity of the group and may not be consistent across all levels of play. Utilizing different levels of collegiate soccer players (Division I vs. Division II vs. Division III) may shed light on the ability of certain physical qualities to differentiate between levels of caliber of players. This can assist coaches and strength and conditioning practitioners with identifying physical qualities that are important to develop at younger ages to aid in the likelihood of playing at a higher collegiate level. Also with a broader range of athletes, the importance of certain physical qualities to high speed running performance may be better identified since the athletes being used may have a larger variance in specific physical qualities or the importance of certain physical qualities with respect to playing position.

Future investigations should continue to utilize similar positional subgroupings due to the observed differences in the current investigation as well as differences observed in previous research with respect to high speed running performance (Alexander, 2014). This can aid in developing specific training programs to enhance specific physical qualities with respect to playing position. Also, research investigating differences between higher and lower caliber players with respect to playing position may more readily identify the importance of certain physical qualities with respect to playing position with the more specific positional subgroupings to aid with talent identification.

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APPENDIX

ETSU Institutional Review Board Approval

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

May 10, 2016

Jacob Grazer

Re: Identifying Determinants of Match Performance in Division I Women's Collegiate Soccer Players
IRB#:c0316.36sw
ORSPA #:

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

- New protocol submission xForm, References, PI Resume, Data collection sheet, waiver of alteration request

On **April 4, 2016**, a final approval was granted for a period not to exceed 12 months and will expire on **April 3, 2017**. The expedited approval of the study will be reported to the convened board on the next agenda.

The following **enclosed stamped, approved Informed Consent Documents** have been stamped with the approval and expiration date and these documents must be copied and provided to each participant prior to participant enrollment:

- n/a retrospective

A **waiver or alteration of informed consent** has been granted under category 45 CFR 46.116(d). The research involves no more than minimal risk because it involves a retrospective analysis of data only. The waiver or alteration will not adversely affect the rights and welfare of the subjects as the athletes whose data is involved have already given consent to have their data added to the research repository whereby data may be drawn for research purposes. The research could not practicably be carried out without the waiver or alteration as many of the athletes have already graduated, as this study involves data from 2011-2015. Providing participants additional pertinent information after participation is NOT appropriate.

Federal regulations require that the original copy of the participant's consent be maintained in the principal investigator's files and that a copy is given to the subject at the time of consent.

Full AAHRPP Accreditation

Accredited Since December 2005

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.

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, Chair
ETSU Campus IRB

cc: Satoshi Mizuguchi

VITA

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Education: William Allen High School, Allentown, PA, 18103, 2007

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