AN EXAMINATION OF THE PHYSICAL AND TECHNICAL GAME PERFORMANCE OF A DIVISION I WOMEN'S SOCCER TEAM ACROSS VARYING REST PERIODS

by

Kelsie N. Roberts

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Dissertation Committee:

Jennifer L. Caputo, Ph.D., Chair

Sandy L. Stevens, Ph.D.

Adam L. Sayers, Ph.D.

Joey Gray, Ph.D.

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ABSTRACT

Soccer is one of the fastest growing women's sports in collegiate athletics. Under National Collegiate Athletic Association (NCAA) scheduling of games, players will often play twice per week on either a Thursday - Friday or Friday - Sunday schedule. The purpose of this dissertation was to examine the impact of the NCAA Women's Soccer game schedule on performance. In the first study, the physical performance of players was examined and in the second technical performance of teams was examined during both schedule types. Data were collected across the 2018-2019 and 2019-2020 seasons from a single Division I team. Physical performance data were collected using the 10 Hz Titan GPS sensors and all games were video recorded and technical performance variables were coded by the Vidswap software program. Physical performance was characterized as total distance, sprint distance, and high-speed running distance. Technical performance was characterized as passing percentage, possessions percentage, and shots on goal percentage. To investigate the differences in physical and technical performance, change variables were created by calculating the mean differences between the Friday - Sunday games (< 48 hours) and the Thursday - Sunday games (> 48 hours). Independent t-tests were run to evaluate for statistically significant differences. However, there were no statistically significant differences ($p < .05$) in any of the physical or technical variables when games were played with < 48 hours or > 48 hours between them. Overall, there were no negative effects of playing two matches per week, separated by different recovery periods, on either the physical or technical performances of Division I female soccer players. Given the academic responsibilities of student-athletes, there may be benefit to the Friday - Sunday schedule in minimizing athletic absences.

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CHAPTER I: INTRODUCTION

Women's soccer has only been recognized as a National Collegiate Athletic Association (NCAA) sport for the past 40 years. However, from its inaugural season in 1981-82 to the 2017-18 season, women's soccer has seen a 1,200% increase in college and university sponsorship (NCAA Report, 2019-20). Second, only to outdoor track field, women's NCAA soccer currently provides 28,310 opportunities for female athletes to compete and earn degrees (Schware, 2019). The NCAA itself has become an integral part of American society. Millions of people watch and attend NCAA contests each year (NCAA Report, 2019-20), and millions of dollars are invested by institutions (ope.ed.gov) into their athletic programs yearly.

Furthermore, research suggests that athletic program success on the field can translate into positive institutional outcomes such as better donor support and a greater number of prospective student applicants (Baumer & Zimbalist, 2019; Tucker, 2004). Unsurprisingly, colleges and universities strive to develop winning athletic programs, charging coaches and athletic directors to find some sort of edge over their opponents. The introduction of wearable technologies has been implemented by programs to capitalize and strengthen winning athletic programs on the field and with athlete recruitment. This trend will most likely continue to become more pervasive within NCAA sports. However, it should be noted that quantifying the physical demands of a team sport is a much more difficult task than quantifying the demands of a single activity, such as a track event (Lames et al., 2007).

Soccer, in particular, is a team sport where teams are competing for possession of the ball and, as such, players are in a constant state of acting and reacting to match play. Soccer has been described as a "highly complex team sport" (Modric et al., 2019) where a player's level of intensity is constantly fluctuating between high-intensity bouts of running and recovery periods (Di Salvo et al., 2007). The nature of the game requires players to be technically, tactically, and physically skilled to achieve optimum performance on the pitch (Dalen et al., 2020; Stolen et al., 2005). In addition to running, players must execute a combination of activities throughout the game such as kicking, shuffling, changing direction, jumping, tackling, and heading, which further characterizes soccer as an intermittent physical activity (Ishida et al., 2021).

Due to the physically demanding nature of the sport, researchers have revealed that muscle damage, fatigue, and a decrease in performance are a few of the possible consequences of the physical demands placed on players during match play (Andersson et al., 2008; Nedelec et al., 2014). Miller et al. (2007) revealed that collegiate female soccer players experience a decrease in both muscle mass and aerobic capacity over the duration of a competitive season. Unfortunately, the specific and unique demands of the women's collegiate game remain relatively unexplored. A disproportionate amount of the literature currently explores men's soccer (Abbott et al., 2017; Konefal et al.., 2019; Lago Penas et al., 2015) or women's soccer at the professional and international levels (Andersson et al., 2010; Bozzini et al., 2020; Bangsbo, 2006; Bradley, 2014; Mohr, 2008). A concern that exists at the collegiate level, is the degree of congestion within the NCAA women's soccer schedule. Women's teams generally play 1-2 matches per week within a 12–14-week span, totalling 20-25 matches a season (Ishida et al., 2021). Unfortunately, several NCAA conferences schedules do not currently allocate enough recovery time between matches, as an estimated 80% of teams will be scheduled to play at minimum one Friday evening - Sunday morning game series (Favero & White, 2018). With less than 48 hours of recovery time scheduled between games, NCAA women's players are currently facing a greater risk of injury and may experience a decrease in neuromuscular performance as well (Ishida et al., 2021).

Dupont et al. (2010) noted it took 72 to 96 hours of recovery time between matches for professional players to return to normal levels of physical performance. Ispirlidis et al. (2008), indicated 96 - 120 hours of recovery time was needed for professional players to return to their pre-match 20-m sprint performance. Additionally, Rollo et al. (2014) found that players' sprint and jump performances significantly decreased over a six-week period while playing two matches per week with only 72 hours between matches. Ishida et al. (2021) has suggested that the current scheduling issues of NCAA women's soccer matches is simply an unintended consequence of the NCAA's current academic and athletic regulations. All things considered, it is evident that greater research is needed to examine the effects of playing to matches per week on the physical and technical performance of collegiate women's soccer players.

Purpose

The present dissertation consists of two studies focusing on a Division I women's soccer team across the 2018-19 and 2019-20 seasons. The first study examined the physical demands of Division I Women's soccer games and explored the possible differences in players' physical performance when they have less than 48 hours between games and over 48 hours between games. The first hypothesis maintained that Division I female soccer players would have a greater decrease in total distance covered between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games. Secondly, it was hypothesized that with less than 48 hours following their first match of the week, Division I female soccer players will exhibit a significantly greater decrease in total high-speed distance during the second match of the week then when they have greater than 48 hours between games. Finally, the third hypothesis maintained that Division I female soccer players would display a greater decrease in total sprint distance covered between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games.

The second study evaluated the effect of the number of days in between matches on players' technical performance during the second match of the week. The first hypothesis maintained that Division I female soccer player's passing accuracy would show a greater decrease between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games. Secondly, with less than 48 hours following their first match of the week, Division I female soccer players will have a greater number of turnovers in the second match of the week then when they have greater than 48 hours between games. Finally, the third hypothesis maintained that Division I female soccer players would have a greater decrease in total number of shots on goal between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games. More specifically, the following research questions will be addressed by the proposed studies:

Article 1: Is there a difference in the physical performance (total distance covered, High-Speed distance, and Sprint Distance) of Division I soccer players during the second match of the week when playing with less than 48 hours between games vs greater than 48 hours between games?

Article 2: Is there a difference in the technical performance (Pass completion rate, total number turnovers and total number of shots on goal) of Division I soccer players during the second match of the week when playing with less than 48 hours between games vs greater than 48 hours between games?

Significance of Studies

Over the past couple of decades there has not only been a sharp increase in the number of female players (at all levels; FIFA, 2011) but also more opportunity than ever before for women to train and compete at some of the highest levels of play in soccer (Martinez-Lagunas et al., 2014). As such, female players are increasingly subject to higher performance standards and expectations, creating a greater demand for quality sport science research dedicated specifically to the women's game (Martinez-Lagunas et al., 2014).

Despite the ever-growing popularity and demands of the women's game, match play at the collegiate level for women remains an understudied area within the literature (Jagim et la., 2020; Sausaman et al., 2019). Until this is remedied, coaches, trainers, practitioners and policy makers will lack the foundational knowledge necessary to know what an optimized schedule and environment that allows female athletes the opportunity to play at their highest potential while minimizing their risk of injury would look like.

CHAPTER II: REVIEW OF THE LITERATURE

This review of the literature begins with a general overview of the history of women's soccer, the laws of the game, and the positional responsibilities of soccer players. The following section overviews the evolution of the women's collegiate game as well as the current and important considerations of the way the game is currently governed under the NCAA. Special attention is given to highlight key differences in the NCAA rules of the game as opposed to FIFA's Laws of the game and outline the current debates surrounding the scheduling of NCAA women's soccer games. Succeeding sections include an examination of the physical demands of the game, the use of Global Positioning Systems (GPS), heart rate monitoring, and session rating of perceived exertion (sRPE) throughout sport and soccer literature, and the various components of technical match analysis and skill-related performance. This literature review concludes with a brief summary of the information presented and a succinct description of what is still unknown about the college women's game.

The Beautiful Game

The true origins of soccer, or as most of the world universally knows it: "futbol," is highly contested and fascinating. One of the most shocking stories told about its possible "invention" comes from neighbors across the pond. As the story goes, the English were said to have invented the game when they began to kick around the severed head of a defeated Danish Prince and used it as a ball in celebration of their victory in battle (Orejan, 2011). However, not all versions of soccer's early beginnings are as colorful as the English folklore about the Danish royal skull. In fact, some of the earliest possible forms of soccer were considered anything but violent. For instance, the ancient game of tsu chu (sometimes spelled cuju) played in China became ceremonial and dated back to the second and third centuries B.C (Chalcraft, 2012; Martin, 2016; Orejan, 2011; Schware, 2019). Around that same time, the Japanese game of Kemari was not only ceremonious but also a non-competitive game similar to tsu chu.

There are numerous examples of kicking games' variations throughout almost all of history and around the world. For instance, evidence suggests that kicking games such as "pasuckuakohowog," which when translated means "they gather to play ball with foot," were played among different Native American tribes (Martin, 2016; Orejan, 2011; Schware, 2019). There is also documented evidence of a game from the Mayans and Aztecs resembling soccer which was believed to conclude by sacrificing the losing team to the Gods (Guttman, 2012). While researchers have linked further examples and variations of soccer back to Egypt, Greece, and other parts of the world, it is widely accepted that the roots of modern soccer lay in England (Martin, 2016).

Sprouted up from those roots, soccer, also known as *the beautiful game*, has grown into the most popular sport around the world and has come a long way since its days of mob play and human sacrifices. One of the first significant steps towards becoming the beautiful game that millions worldwide enjoy today took place in May of 1904. This marked the Federation International de Football Association (FIFA) founding as the governing body to seven different member countries. Fast forward to 2020, and there are over 200 nations that have become members under FIFA. This is important, as one of FIFA's major roles is to oversee the standardization/ standardized rules of soccer, also known as the Laws of the Game.

As regulated by FIFA, a soccer match should be played for a total of 90 minutes, broken into 45-minute halves that are separated by no more than a 15-minute half-time interval. However, there are additional minutes that may be allotted to have a decisive winner of the game. This rule, in particular, varies significantly by the league. A high-quality (size 5) soccer ball is required. Further equipment includes but is not limited to shin guards worn by every player and entirely covered by the player's socks; jerseys distinguish one team from another and the referees, acceptable footwear, and shorts. In order to play, there must be a rectangular pitch (field of play) where the breadth does not exceed the length. Official field dimensions indicate that touch lines (length) should be a minimum of 100 yards and/or a maximum of 130 yards and that the goal lines (width) are a minimum of 50 yards and/or a maximum of 100 yards. The ball is in play while within these dimensions. The objective of the 90-minute game is for both teams to score goals against their opponent while attempting to prohibit their opponent from scoring. The team with the most goals at the conclusion of 90 minutes is declared the winner. While this is an oversimplification of the principles of the game, Figure 1 represents a more complete breakdown of the tactical principles as defined by Garanta and Pinto (1994) and used by da Costa et al. (2009). The standardization of the rules, playing area, and equipment in this way allows for easier comparisons to be made between the physical and technical demands of soccer across players and teams, as all of these extraneous factors could greatly impact the demands of the game. However, these are not the only factors

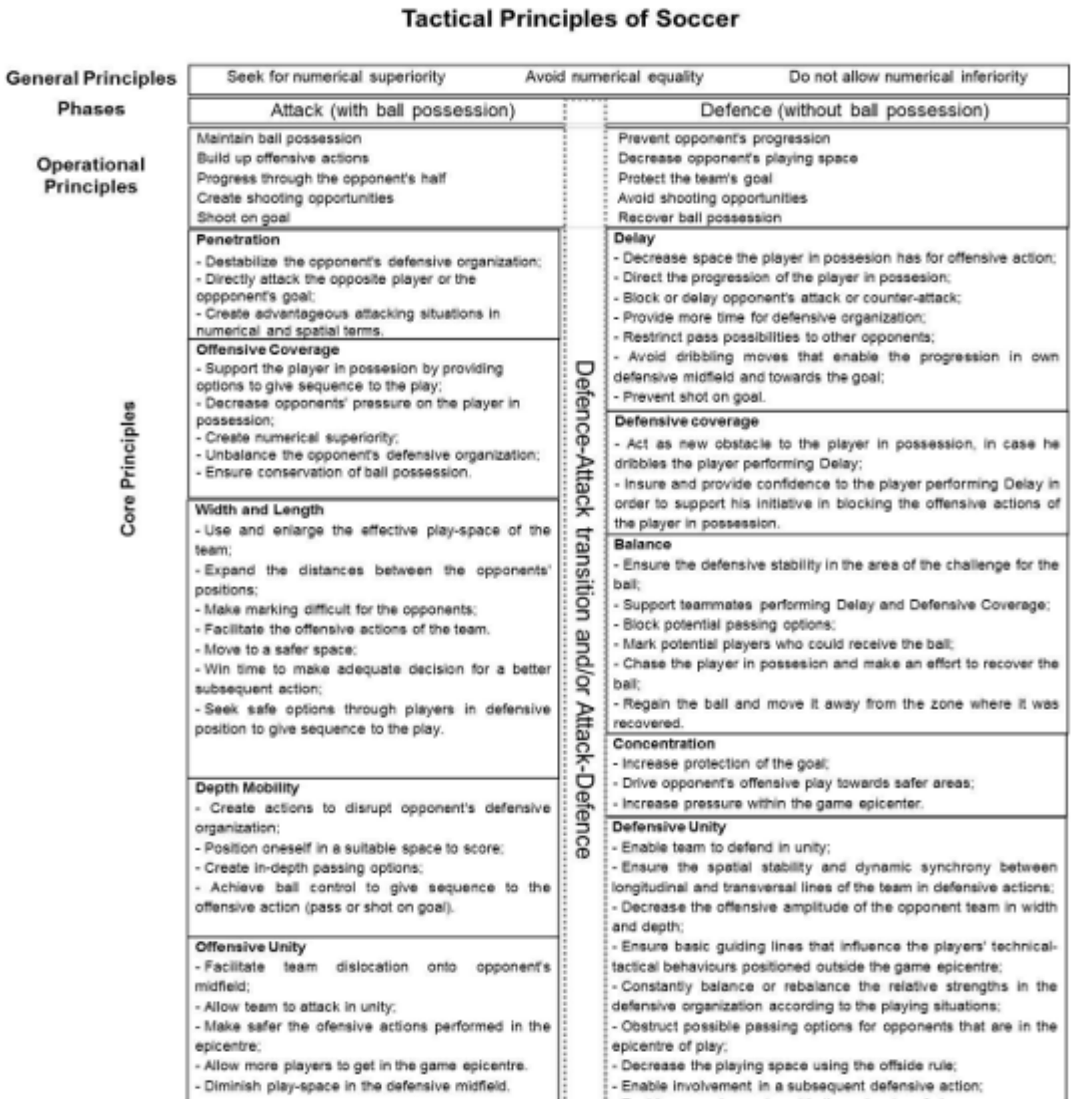

Figure 1. The Tactical Principles of Soccer

that should be considered when measuring players' physical and technical abilities. It has been well established in the literature, that for elite soccer players, the physical demands of the game can vary for several reasons including but not limited to a player's position (Abbott et al., 2017; Asian Clemente et al., 2019; Dalen et al., 2016), the tactical formation of the team, as well as the quality of the opposing team (Rampinini et al., 2007) and formation played by the opposing team.

Playing Positions

Traditionally, a team consists of 11 players (and no fewer than seven players to begin a match) that can be sub-grouped into one of the following four positions: defenders (fullback), midfielders (half-backs), attackers (forwards/ strikers), and goalkeepers (keepers). It should be noted that the roles and responsibilities and even physical demands of each of these positions vary depending on the team's formation, style of play, and opponent. Specifically, it is important to have a general understanding of players' various positional roles and responsibilities, as research has shown that the physical demands and requirements of players are impacted by the position they play (Bloomfield et al., 2007). It should be noted that team formations and positional responsibilities have evolved over time (Bradley et al., 2011) and will most likely continue to evolve.

Perhaps the most consistent role on the field, no matter the formation, would be that of a goalkeeper. Their primary responsibility is to prevent the other team from scoring in their net. This player is the only player on the field allowed to use their hands on the pitch (within the field of play) but is limited to do so only within the confines of the penalty/goal area (18-yard box). Keepers are generally responsible for organizing and communicating with their backline (defenders) and have increasingly become responsible for building play and serving as an outlet for their teammates to maintain possession of the ball.

Playing directly in front of the goalkeeper are the defenders/fullbacks. The general role of this position is to "prevent the opposition from scoring by delaying the penetration of the attacking forwards inside the scoring territory" (Orejan, 2011, p. 725). The number of fullbacks on the field depends on the formation of the team but generally includes three to four players. These players can be subdivided into outside backs (the two closest to either touchline) and center-backs (defenders playing between the two outside backs). The outside back position, in general, is often more involved in the offensive attack of the team as compared to the center-backs, who generally play a more defensive role.

Next, the attackers, also known as forwards and/or strikers, are the players who are most responsible for scoring goals and creating scoring opportunities. Once again, depending on a team's formation, there is generally one, two, or even three players occupying this position at a time. When there are 3 strikers, the two players nearest the touchlines (right or left) are sometimes referred to as wingers. The role of these players often differs from the central striker in that they are expected to deliver more crosses and runs out wide, while the center striker often looks to find balls in front of the backline and make plays. Finally, linking the defenders to the strikers are the players in the midfield. These players often serve as the playmakers on the field and depending on formation may have more offensive or defensive responsibilities. Like the defenders and strikers, teams playing in certain formations may have outside midfielders and central midfielders who have different roles. It is possible for a team to play with only central midfielders. When a team's formation does not include outside midfielders, the teams outside back and wingers will absorb the responsibilities that the players in that position would have held. Therefore, the demands of a game greatly depend on the formation and position that an individual is playing. However, all factors previously mentioned being equal, there remain additional factors that must be taken into account when measuring and analyzing the physical and technical demands of a game, and that is level of competition (Mohr et al., 2008; Sausaman et al., 2019; Todd et al., 2002) and the sex of the players (Sausaman et al., 2019). The physiological demands of soccer are complex and require contribution from both aerobic and anaerobic energy systems (Morgans et al., 2014). Unfortunately, when compared to their male counterparts, elite women soccer players have lower aerobic and anaerobic performance.

Women's NCAA Soccer

While soccer has clearly blossomed into a standardized and regulated game, the path was not one without detours. The history of the women's game, in particular, can be traced back to the "play days" on college campuses when sports were not meant to be competitive but rather serve as a form of physical education. During the early 20th century, playing soccer was limited for the strict purposes of exercise and socialization (not competition), as some feared too much physical exertion could negatively impact women's health. The first official intercollegiate game for men was held in 1869 between Rutgers University and Princeton (Baptista, 1962). In contrast, women were unable to even compete in an intramural competition until the 1920s when Smith allowed for women's dormitories and classes to compete against each other (Ladda, 2000). About 50 years later, in 1975, Brown became the first college to "grant full varsity level status" to a women's soccer team.

Nearly a century after the intramural experiences at Smith, Women's soccer, during the 2018-19 season, provided the second-most collegiate opportunities to women, second only to track and field, allowing 28,310 women to compete at the NCAA level (NCAA.org) and continues to grow. Where the competition rules for women's soccer once stated, "Middies and bloomers are also worn" (Ladda, 2000; Schware, 2019), today the rules are more similar to FIFA's Laws of the game. However, officially speaking, the NCAA is the governing body for women's collegiate soccer. Like FIFA, many of the equipment and field dimensions' rules remain similar. The 90-minute game is played divided into two 45-minute halves. In the event of a tie, the game can extend into overtime. However, this investigation will focus solely on the first 90 minutes of the game. Furthermore, the NCAA rules on substitution are more liberal than those of FIFA. Players that are substituted during the first half are allowed to return to the game during the second half, and a player substituted out of the game in the second half may also return once during the second half of play. Because of this, in NCAA matches, coaches often make three or more substitutions a game (Vescovi & Favero, 2014). Coach Sasho Cirovski of Maryland has described the uniqueness of the NCAA substitution rule as a "necessary evil" due to the fact that NCAA soccer schedules are often congested due to the high number of games that a team will play throughout a season (approximately 20-25; Obando, 2016).

As outlined by Ishida et al. (2021), teams will often play 1 to 2 games per week across a span of a 12-14-week season. These schedules become even more unfavorable, especially within certain conferences where there is an insufficient amount of recovery time allotted between matches during the weeks when teams must play two games. In these cases, NCAA Division I female soccer teams will often play late on a Friday night and then have a second game scheduled for Sunday mornings or early afternoons. This is a quick turnaround for athletes, which can lead to fatigue and an increased risk of injury (Dupont et al., 2010; Ekstrand et al., 2004). Researchers have suggested that somewhere between 38 and 72 hours of recovery time is necessary between matches in order to minimize injuries and maximize physical performance (Dupont et al., 2010; Ishida et al., 2021; Rollo et al., 2014). However, one study conducted by Ispirlidis et al. (2008) with male soccer players found that it actually took a minimum of 96 hours for players to return to pre-match status across several different variables (e.g., uric acid levels, etc.).

Unfortunately, as it stands, the NCAA does not appear to be making any type of changes to the length and density of the women's soccer season schedules. As suggested by Ishida et al. (2021), the current scheduling issues may simply be an unintended outcome of both the educational and the athletic regulations placed on teams. However, this reasoning provides little to no comfort when considering the possible consequences of insufficient recovery time, especially considering that women's NCAA soccer accounts for the highest number of injuries per year of all of the NCAA women's sports. Specifically, the NCAA (n.d.) provided a report using data collected from the 2004-05 season to the 2008-09 season, indicating that NCAA women's soccer overall injury rate was 7.3 per 1,000 athlete exposures (practices and games). The report also suggested that the majority of injuries that occurred during games took place primarily in the second half (51.2%) rather than the first half (32.9%). While one can only speculate on the reasons for the discrepancy between injury rates by half, it seems fair to conclude that fatigue may have played a role either directly or indirectly (fatigue may have led to a worsening technique that may have caused the injury). Additionally, it should be noted that there were also noticeable differences between injury rates by season (NCAA.org, n.d). Where the majority of injuries (rate of 9.1 per 1000 athletes' exposures) occurred during pre-season, followed by in-season (rate of 6.8 per 1000 athletes' exposures), and the least taking place during the postseason (3.8 per 1000 athletes' exposures). While it is impossible to definitively attribute the discrepancies between injury rates per season to any one thing in particular, it is reasonable to suggest that the high rate of injury during pre-season could be, at least in part, a result of increasing training demands too quickly. In both cases, conditioning and periodization are evidently two important factors that should be considered when discussing appropriate schedule adjustments and the physical and technical performance of players.

Periodization in the NCAA

At the NCAA collegiate level, coaches are limited to only a handful of weeks to train with their teams prior to the beginning of the season, forcing a team's preseason to be short but intense. Once in season, athletes are only allowed up to 20 contact hours per week with their respective teams and the women's soccer season generally only lasts about three months in total. Having such a congested and condensed schedule is just one of the many reasons why proper periodization can be difficult for collegiate soccer teams. In these situations, teams must dedicate a significant amount of their training time between matches to more low-intensity recovery, tactical, and technical training while in season (Anderson et al., 2016; Moreira et al., 2015). Furthermore, student-athletes face additional external factors during the season as they are confronted with balancing not only their athletic responsibilities but their academic and personal responsibilities as well. Favero and White (2018) estimated that in addition to the 20h of week allocated to athletics, student-athletes are also charged with an additional 15-30 hours of academic responsibilities (class time, internships, group projects, etc.). Furthermore, students in general, and female students in particular, are described as having compromised sleep patterns. Sleep problems, in addition to a highly charged daily schedule of athletics and academics is a prime recipe for lack of recovery and adaptations (Bubolts et al., 2001; Favero & White, 2018). Therefore, traditional methods of planning training programs by mimicking the programs of successful teams (Powers & Howley, 2012) or professional clubs will not suffice. Instead, the implementation of a proper monitoring system can arm coaches with the information necessary to create a well-designed periodization program.

It should be noted however, that periodization programs (theoretical model that sets a framework for the systematic planning of an athletes training) for team sports is not only an area that is underexplored in relation to individualized sports (e.g. track and field; Morgans et al., 2014) but it also presents a unique variety of problems for implementation as well (Favero & White, 2018; Gamble, 2006). With college soccer in particular, external factors such as the teams' style of play, individual positional roles, congested scheduling, extended summer breaks, and academic schedules can all impact periodization (Di Salvo et al., 2007; Favero & White, 2018; Vesscovi & Favero, 2014). Nevertheless, proper periodization allows teams to optimize their training and minimize risk of injury. For coaches to properly implement periodized programming, they must first quantify the physiological demands placed on their teams throughout the seasons (Halson et al., 2014). This involves different forms of performance analysis that will be discussed in the following section.

Performance Analysis

The NCAA is the largest non-profit collegiate sports organization in the United States of America, housing over 1,000 different colleges and universities. All of which invest thousands to millions of dollars into their sport programs (Almujahed et al., 2013). All the affiliate schools are further divided into three distinct divisions: I, II, or III based on several different factors, including ensuring fairness. Due to the financial investments and the generally slight variations across player performance levels, it is no surprise that schools and teams seek to improve and develop new methods to gain a competitive advantage that they will be able to sustain.

In order to maximize team and player potential, coaches must carefully balance challenging their team and pushing their athletes to their limits without exceeding those limits. Put another way; coaches are tasked with prescribing an appropriate combination of training time, recovery time, and competition play to minimize injuries and maximize performance (Scott et al., 2014). There are now a variety of tools available to coaches at the NCAA level, some more expensive than others, to assist in monitoring and evaluating players' performance and workload. Specifically, as noted by Gaudino et al. (2015), to properly evaluate the physical demands of a team sports (e.g., soccer), both internal and external load should be considered in the evaluation. The following sections introduce valid and reliable methods to accurately measure these workloads in soccer.

Time-Motion Analysis (TMA)

Long gone are the days when coaches rely solely on memory, gut, and intuition to coach their teams, or in other words, their subjective observations, and analyses. Video analysis has been an accepted and primary tool for coaches for several decades. The importance of the technological advancements that have built upon video analysis cannot be overstated. For instance, in a study by Franks and Miller (1991), less than 50% of critical factors in a game could be remembered correctly by international soccer coaches. Moreover, a similar study was conducted by Laird and Waters (2008) who found the pool of qualified coaches in their study could only recall approximately 59% of the critical events within a single half (45 minutes) of a game. It has been suggested that the lack of accuracy by the coaches in these studies and other similar sport performance studies is caused by attentional focus errors, higher arousal levels, and observer bias, much like the way inaccurate eyewitness accounts of a crime are thought to be affected (Maslovat & Franks, 2008). Despite the advancements provided by video, Kuper and Szymanski (2018) maintained there is "still widespread suspicion of the numbers in soccer" (p. 2). Time-Motion Analysis allows coaches to overcome subjective limitations by providing valid, objective, and impartial information that can be used to gain a better understanding of performance (Asian Clemente et al., 2019; O'Donoghue, 2010).

Specifically, TMA is a popular method used to assess and quantify the external workloads of players in a variety of sports (Duthie et al., 2005; Rienzi et al., 2000). In the early days of TMA, researchers and coaches were limited to analyzing a single player's performance, usually captured by video cameras aimed at the field (Carling et al., 2008). Today, with the continued advancements in technology, multiple players can be tracked during a single training session or match (Rienzi et al., 2000). In fact, today, coaches have an alternative to the newly improved computer-based tracking systems and instead use global positioning system (GPS) units. These units are often worn during training and games in a specially designed harness and allow for data to be collected and analyzed in real-time or at a later date.

Global positioning system units are satellite-based navigational systems that were initially conceived and used by the military (Cummins et al., 2013; Hofmann-Wellenhof et al., 2007). These systems rely on over 20 different satellites within the Earth's orbital planes that are equipped with atomic clocks and continuously work to send and transmit information down to earth (Hofman-Wellenhof et al., 2007). Accurate positional coordinates can be determined by calculating the differences in time and distances between the GPS devices and the satellites (Hofman-Wellenhof et al., 2007; Larson, 2003) and can also be calculated by what is known as the Doppler shift (Larson, 2003). The specific inner workings of these systems are slightly more complex than what is described above; however, the details of which are beyond the scope of this study. Yet, it is important to note that the rate by which a GPS unit can sample per second is used to classify the unit itself (e.g., 1Hz, 5Hz, 10Hz, etc.; Macfarlane et al., 2015).

Although the original intended purpose of GPS systems was for military use, these systems found their way into athletics as early as 1997 (Schutz & Chambaz, 1997) and have continued to be increasingly used in sport (Cummins et al., 2013). These systems are often used in the refinement and prescription of training and injury prevention programs for athletes, and thus the importance of the reliability and the validity of these systems is paramount and extends beyond simply producing valid research. Duthie et al. (2003) and Macfarlane et al. (2015) have recommended that reliability can be considered good when the typical error of measurement (TEM) is less than 5%, considered moderate at 5-10%, and should be considered poor when TEM is less than 10%.

Specifically, this study will use Titan Sports Titan 2 sensors, which are GPS units that use high-resolution sampling (10 Hz sampling rate) as well as a 1 KHz accelerometer. In their study, Castellano et al. (2011) found that 10 Hz GPS units had good inter-unit reliability and that data were accurate in measuring distance covered, though they only measured athletes over short distances and only had them run in a straight line. However, Johnston et al. (2014) conducted a pilot study addressing the validity and reliability of 10Hz GPS units for athlete-specific movements for sport teams. They confirmed previous findings, suggesting that 10Hz GPS units were both valid and reliable instruments to measure athletes' total distance (< 1% error). Furthermore, previous literature has established that higher sampling rates generally provide greater validity and reliability when measuring athlete movements (Cummins et al., 2013), with the exception that 10Hz generally performs better than 15Hz GPS units (Johnston et al., 2014). This was further made evident with conclusions drawn by Johnston et al. (2014) as they stated, “the 10 Hz GPS units provide more valid and reliable feedback on training and match movements demands to coach and conditioning staff” (p. 1654). Additionally, 10 Hz units have been found to have good validity when measuring distances for short sprints (Castellano et al., 2011), moderate distances during intermittent running (Rampinini et al., 2014), and even when incorporating changes of direction (Vickery et al., 2014). They also have strong inter-unit reliability when measuring the distance covered for low-speed and high-speed running (Johnston et al., 2014). However, several researchers have cited issues in measuring distance covered at high speeds (Johnston et al., 2014; Rampinini et al., 2014) when using a 10 Hz GPS unit. Finally, it should be acknowledged there are other limitations of GPS use, both from a practical and a technological standpoint. The reliability of the GPS measurements significantly decreases if there is an obstruction between the receiver and the satellite. Obstructions could be environmental, such as tall buildings and nearby structures that can impact the transmission or simply atmospheric, such as a cloudy day.

The Physical Demands of the Game

As the technology continues to improve and prices continue to drop, coaches and sport scientists are increasingly contributing to the literature exploring the physical demands of the game using GPS devices. Currently, a large portion of this literature has examined the men's game in particular (Sausaman et al., 2019). Unfortunately, as Pederson et al. (2019) have pointed out, the physical performance between male and female soccer players can vary dramatically, despite being one of few team sports where men and women use the same equipment and same set of rules to compete. For instance, female players will generally perform approximately 30% less high-intensity activities throughout a game (Mohr et al., 2008) and the endurance level of male soccer players is approximately 12% better than that of female players (Haugen et al., 2014; Tonnessen et al., 2013). However, it is noteworthy that this difference in endurance levels is much smaller between male and female soccer players than it is for the general population (23%; Aspenes et al., 2011; Loe et al., 2013). Nevertheless, in a study conducted by McFadden et al. (2020), Division I male soccer players were found to have covered greater distance at higher speeds than their Division I female soccer counterparts. Specifically, a study by Curtis et al. (2018) found that male NCAA Division I players averaged 87-97 m/min and covered a total of 8,900 - 9,900 meters a game. This further highlights the necessity for greater research into the women's collegiate game, as findings from the men's game do not accurately reflect those of their female counterparts.

Furthermore, several studies have shown that physical performance variables (e.g., aerobic power and sprint ability) will vary by competition level (Todd et al., 2002). Sausaman et al. (2019) echoed this sentiment, indicating that the physical demands of the game are greater at the professional and international women's level, where the majority of this literature is focused. Women at the elite levels (professional and international levels) have been shown to cover around 10,000 m in a match, where approximately 1530-1680 m of that distance was covered during high intensity running and approximately 380-460 m was covered while sprinting (Andersson et al., 2008; Datson et al., 2014; Mohr et al., 2008). Conversely, studies by Vescovi et al. (2014) and Sausaman et al. (2019) have observed college female athletes on average covering between 9,486 - 9,930 m total distance and only about 1,014 - 1,086 m at high-speed and 267-428 m while sprinting.

Finally, several studies have also shown that variability in physical performance can also be seen among playing positions (Abbott et al., 2017). Research has consistently indicated that central midfielders generally cover the most overall distance in a match while central defenders generally cover the least amount of distance (Andrzejewski et al., 2016; Bradley et al., 2009). Center defenders have also been found to cover the least amount of distance at high-intensity speeds, while outside backs generally cover the highest amount of distance at high-intensity speeds (Bradley et al., 2010; Dalen et al., 2016). Strikers have also been described as the position that completes the greatest amount of sprinting (Mohr et al., 2008). Overall, it is evident that a complete and comprehensive understanding of the female collegiate game is necessary for coaches to be able to systematically plan training.

Technical Match Analysis

Rampinini et al. (2009) conducted a study and observed not only a decline in the physical performance of players during match play but also a decline in skill-related performance as well. This highlights the importance of expanding investigations beyond just the physical performance of athletes in order to obtain a better understanding of the impacts of fatigue on players' overall performance. The literature surrounding the technical analysis of soccer players at any level is scarce in comparison to the ever-growing body of literature about soccer players' physical performance (Alcock, 2010;

Ibanez et al., 2018; Mara et al., 2012). This is a serious gap within the literature, as technical ability is an important ingredient in the recipe for success in soccer (Rampinini et al., 2007). Some technical variables such as passing accuracy (Sokora & Bergier, 2010) and shots on goal (Lago-Penas et al., 2011; Liu et al., 2016), that will be included in the present study, have even been found to impact the final outcome of a game. More specifically, several studies (Castellano et al., 2012; Lago-Penas & Lago-Ballesteros, 2010; Liu et al., 2015) have indicated that the number of shots taken and the total number of shots on goal are two technical variables most closely linked to match outcome.

Specifically, a number of studies have examined a variety of technical skills during match play, such as pass completion rates and total number of passes completed (Bradley et al., 2013), total number of ball interactions (Dellal et al., 2011), passing precision (Rampinini et al., 2008) and ball possessions, possessions gained or lost, and number of touches per possession (Carling & Dupont, 2011). Furthermore, other studies have revealed that scoring first increases a team's probability of winning (Ibanez et al. 2018) and that at least a quarter of the goals scored in women’s high-level soccer comes from a cross (Mara et al., 2012). However, as highlighted by de Jong et al (2020), there is disparity within the literature between the number of technical variables generally examined within studies of the women’s game (n = 1 - 9) as compared to the men's games (n = 15 - 25).

Of the limited studies that exist on technical performance in Division I women’s soccer, there have been no significant differences in the passing accuracy percentage, dribbling success, or challenges won during in-conference (IC) games as compared to out-of-conference games (OC; Bozzini et al., 2020). Therefore, this study will include both IC and OC games as part of the analyses in order to increase sample size. That being said, in a study conducted by Thomas et al. (2009), dribbling was identified as one of the most important skills to create scoring chances, followed by first touch, then passing based on their proposed model. Unfortunately, this is the extent of technical performance research for women's collegiate soccer that has been published to date. The only other study using collegiate women's soccer was a dissertation (Alexander, 2014) that had similar findings to those of studies using elite male players (Bradely et al., 2013; Dellal et al., 2010) stating that center defensive midfielders had the highest pass completion rate on the field.

Conclusion

In sum, the importance of understanding the physical and technical demands of NCAA Women's Division I Soccer has lasting implications for the overall safety of players and the effectiveness of training. There is a large amount of variability between the men and women's game, and between the elite levels for women and the collegiate level for women. Because of this, a significant amount of information is still unknown about the physical and technical demands of a congested NCAA women's schedule. While there is currently debate about the possibility of changing the NCAA scheduling, these decisions should be made based on a deeper understanding of the game and the specific needs of the players. Scheduling and training programs should be adjusted to accommodate the specific demands of the women's collegiate game, and thus more information is needed.

CHAPTER III: ARTICLE II – HOW DOES REST BETWEEN SOCCER MATCHES EFFECT TECHNICAL PERFORMANCE? COMPARING LESS THAN 48 HOURS REST VS MORE THAN 48 HOURS REST BETWEEN MATCHES

Introduction

With 28,310 Division I female soccer players across the nation, National Collegiate Athletic Association (NCAA) soccer is second only to track and field in the number of opportunities provided to female athletes (Schware, 2019). However, there is debate over the NCAA match schedules for women's soccer that have been described as undesirable (Ishida et al., 2021) and congested (Favero & White, 2018). Women's Division I teams will, on average, play 1.66 matches per week, or approximately 20-25 matches within the span of 12-14 weeks (Favero & White, 2018; Ishida et al., 2021). When a team is scheduled to play two games in the same week, they will either play on a Thursday night - Sunday early afternoon or a Friday night - Sunday early afternoon schedule (Bozzini et al., 2020; Favero & White, 2018). The Friday - Sunday scheduling in particular allows players less than 48 hours to recover following their first match in the week. This is concerning as some research shows a minimum of 48 - 72 hours is needed between matches to allow for proper recovery in soccer players (Andersson et al., 2008; Rollo et al., 2014), while other researchers have suggested it may require as many as 96 to 120 hours for players to return to pre-match values (Ispirlidis et al., 2008).

Soccer is an intermittent, physiologically demanding physical activity (Bozzini et al., 2020; Ishida et al., 2021). Players often experience muscle damage and fatigue due to the physical demands of match play (Andersson et al., 2008; Nedelec et al., 2014). Collegiate female soccer players also experience a decrease in both muscle mass and aerobic capacity over the duration of a competitive season (Miller et al., 2007). Further, studies have also indicated the physical performance (total distance [TD]covered, high-speed running distance [HSRD], and sprinting distance [SD]) of soccer players decreases during the second half of match play (Bangsbo, 1994; Datson et al., 2014; Mohr et al., 2003; Stolen et al., 2005) as well as throughout various phases of a game (Mohr et al., 2005).

To our knowledge, no studies have examined the impact of the NCAA's Friday - Sunday scheduling versus Thursday - Sunday scheduling on the physical performance of collegiate female players. Therefore, the aim of the current investigation was to explore possible differences in match physical performance of Division I female players when they have less than 48 hours between games and more than 48 hours between games. Specifically, it was hypothesized: (1) Division I female soccer players would have a greater decrease in TD covered between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games, (2) as a result of playing less than 48 hours following their first match of the week, Division I female soccer players will exhibit a significantly greater decrease in total HSRD during the second match of the week then when they have greater than 48 hours between games, and (3) Division I female soccer players would display a greater decrease in total SD covered between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games.

Study Design

Data from 41 competitive matches were collected during the 2018-2019 and 2019-2020 competitive seasons of a NCAA Division I women's soccer team from a single southeastern university. Only games played on a Thursday - Sunday or Friday - Sunday schedule were included in the analyses. Data were collected as a part of the team's general day-to-day procedures, as instituted by the coaching staff. From the beginning of the 2018-2019 preseason, players wore a GPS-based monitoring unit (Titan2, Titan Sensor) sampling at 10 Hz during all outdoor training sessions and outdoor match play. Units were secured to players using a customized "jersey," over (or under) their team kits, that secured the GPS unit between the shoulder blades on the upper-back. Players wore the same GPS unit for the entire season, an important standard that has been highlighted within the literature (Akenhead et al., 2014; Varley et al., 2012). Total distance, HSRD, and SD were the metrics included in the analyses for the purposes of this study as they have been previously associated with match performance (Andersson et al., 2010; FIFA, 2012; Krustrup et al., 2008; Strauss et al., 2019) and Sausamna et al., 2019 has described them as "the most pertinent variables affecting match outcomes as well as those which are most easily understood by coaches and commonly explored by researchers" (p. 3). Total distance was calculated using the sum of all distances covered by an athlete in kilometers. High-speed running was categorized as 15.0-18.0 km/h and sprinting was defined as > 18.0 km/h in accordance with previous literature (Andersson et al., 2010; Krustrup et al., 2008; Sausaman et al., 2019). The reliability and validity of 10 Hz GPS units used to measure distance are strong (Scott et al., 2015). However, it should be noted that previous research has demonstrated that regardless of sampling frequency, GPS devices become less accurate as the speed of the athlete increases, especially over shorter distances (Coutts et al., 2009; Duffield et al., 2010; Vickery et al., 2014).

Participants

Data from 33 NCAA Division I college female soccer players from a southeastern university were collected for this study. Data from goalkeepers (n = 4) were not included in the analysis due to their unique role and responsibilities during match play. Furthermore, only field players that participated in the full 90 minutes of the match were included in the final analyses (N = 5; age: 19.6 ± 0.6 years). These inclusion criteria were included to consistently and accurately measure the impact of playing time on physical performance. Retrospective analysis of the training load data was approved by the university institutional review board (see Appendix A), and permission was granted by the Head Coach.

Procedures

All players were assigned their own individual GPS unit (Titan2, Titan Sensor, Houston, Texas) at the beginning of the 2018-2019 pre-season, distinguished by a numbered sticker (one through 30) and their own "jersey" harness. Players kept their assigned GPS unit across both the 2018-2019 and 2019-2020 seasons, with the exception of replacement of broken units and incoming freshmen for the 2019-2020 season. Each GPS unit sampled at 10 Hz (with a 1 KHz accelerometer), which has been described by

Scott et al. (2015) as being a valid method to measure varying distances at varying speeds in team sport environments. All units benefited from a compact design (3" X 1.5" X .25"; mass = 42 g) and were secured to players between their shoulder blades, using a polyester and elastane "jersey" with a pocket, provided by Titan. It should be noted that the Titan jersey was worn over the team's training kit but was worn underneath the team jersey during matches. All devices were switched on 10 minutes prior to training and games to attain satellite signals as per Titan Sensor directions. Players were also informed that devices had to be placed within their titan vest pocket so that the side with the light was facing away from their backs, to ensure maximum efficiency of the device.

Data were collected during all training sessions and games that took place outside. Matches consisted of 10 home games and 14 away games, with a record of 10 wins, 1 draw, and 13 losses. Matches included a warm-up, two 45-minute halves, possible overtime periods, and a cool-down. However, for the purposes of this study, only the data obtained from the first and second halves (90 minutes) of 24 matches were included for analysis. During these games, the team primarily played in a 4-3-3 formation but at times switched to a 4-4-2 formation when needed. Following the cool-down after a game, sensors were turned off and the data were downloaded within 48 hours to a computer using proprietary software and a multi-unit docking/charging port. Match data were categorized using the software into warm-up, first half, second half, overtime, or cool-down segments.

Statistical Analysis

Data were downloaded from the proprietary software into an Excel file and uploaded into the statistical software SPSS (IBM SPSS v. 27). Descriptive statistics for the physical performance variables (TD, HSRD, and SD) are expressed as mean values ± standard deviation (mean ± *SD*), unless otherwise stated. To investigate differences in physical performance, change variables were created by calculating the mean differences between player performance during the Friday - Sunday games (< 48 hours) and the Thursday - Sunday (> 48 hours) games. Prior to analyses, data were evaluated for normality using the kolmogorov-smirnov test with Lilliefors' correction.

Independent sample t-tests were conducted to compare in match physical performance of players between the Friday-Sunday change variables and the Thursday - Sunday change variables. Statistical significance was set at $p < .05$.

Results

Summary statistics (*M* ± *SD*) for TD, HSRD, and SD during matches by game night are presented in Table 1.

Table 1.

Physical Demands by Game Night

Variable	TH	FR	> 48 hours	< 48 hours
TD (km)	7.07 ±1.61	7.32 ±1.92	6.41 ±1.33	6.89 ±1.71±
SD (m)	489 ±270	417 ±185	441 ±220	458 ±215
HSRD (m)	572 ±433	689 ±528	484 ±315	551 ±383

Note. TH = Thursday; FR = Friday; TD = Total Distance; SD = Sprint Distance; HSRD = High-Speed Running Distance; m = meters; km = kilometers.

On average, players covered a greater TD during Friday night games (7.32 ±1.92 km*)* than they covered during games played less than 48 hours later (6.89 ±1.71 km*)* by a magnitude of 0.24 km, although this difference was not statistically significant, t (8) = 0.366, p = .724, 95% CI [-2.24, 3.08]. Players also covered a greater total distance during Thursday night games (7.07 ±1.61 km*)* than during games played greater than 48 hours later (6.41 ±1.33 km*)* by a magnitude of 0.45 km. This difference was also not statistically significant, t (18) = 0.996, p = .698, 95% CI [-0.73, 2.04]. Similarly, there were no statistically significant differences observed in the SD covered during the first games of the week and the second games of the week played less than 48 hours later, t (8) = -0.326, p = .753, 95% CI [-3335.05, 252.16] or greater than 48 hours later, t (18) = 0.436, p = .668, 95% CI [-183.74, 279.99]. Finally, there were also no statistically significant differences observed in the HSRD covered during the first games of the week and second games of the week played less than 48 hours later, t (6) = 0.424, p = .687, 95% CI [-660.75, 937.38] or greater than 48 hours later, t (16) = 0.493, p = .629, 95% CI [-290.55, 466.59].

No statistically significant differences were observed between the change variables (< 48 hours and > 48 hours) for TD, HSRD, and SD (p >.05). A summary of the results are presented in Table 2.

Table 2.

Physical Performance by Schedule Type

	< 48 hours	> 48 hours			
Variable	*M*(*SD*)	*M*(*SD*)	Mean Diff.	*t*	95% CI
TD (km)	0.42(0.74)	0.66(0.83)	-0.24	-0.53	[-1.19, 0.72]
HSRD (m)	138(152)	88(144)	50	0.57	[-143.69, 244.29]
SD (m)	-41(148)	48(218)	-89	-0.82	[-325.46, 146.32]

Note. TD = Total Distance; HSRD = High-Speed Running Distance; SD = Sprint Distance; m = meters; km = kilometers.

Discussion

The purpose of this study was to explore the effects of playing two matches per week, separated by different recovery periods, on the physical performances of Division I female soccer players. It was hypothesized there would be a statistically significant greater decrease in the physical performance of Division I female soccer players, as characterized by TD, SD, HSRD, during the second match of the week when consecutive games were played less than 48 hours apart as opposed to when players had greater than 48 hours between matches. All three hypotheses were rejected as there were no statistically significant differences between the TD, SD, or HSRD in consecutive games played less than 48 hours later and greater than 48 hours later.

The present study, to our knowledge, was the first to specifically examine the effects of the two most common NCAA playing schedules for Division I women's soccer (Thursday - Sunday and Friday - Sunday) on physical performance. Previous research on physical performance characteristics of elite female soccer players has continued to grow, while research into the collegiate level of women's soccer remains limited (Bradley et al., 2015). A unique and important distinction between college and elite level of play (professional and international) is the NCAA's substitution rule that allows for unlimited substitutions. This simple difference in rules makes it difficult to draw direct comparisons between the playing levels as substitution patterns are distinctive to level of play. Furthermore, unlimited substitutions at the college level makes it more difficult to investigate the in-match demands of a Division I soccer game as there is greater variability in playing times and match-to-match performances of players. In fact, a limitation of this study is sample size due to the high number of substitutions made in each game, leaving only 5 players who played the full 90 minutes. Nevertheless, findings from this study are similar to findings from previous investigations. For example, HSRD and SD are two variables that have been highlighted throughout previous literature as important factors in investigating game performances and yet make up only a small percentage of the TD covered by players in this study and others (Gentles et al., 2017; Mohr et al., 2005).

These running data are also in line with other findings from studies conducted on Division I female soccer players. Vescovi et al. (2013) found that Division I players covered approximately 1,080 m at high-speed (> 15.5 km/h) while players from this study covered approximately 1026 m at speeds >15 km/h. Furthermore, the players from the Vecsovi et al (2013) study were reported as covering 267 m while sprinting (> 20km/h), while the players in the present study covered an average distance of 451 ± 30 m while sprinting. However, the threshold used in our study for sprinting was lower (> 18km) than that utilized by Vescovi et al (2013), and thus a direct comparison is more difficult. However, a more recent study by Sausaman et al (2019) used a similar threshold (> 18 km/h) and observed players covering a mean sprint distance of 428±70 m, which is similar to the results of the present study. However, the TD covered in the present study (6,922± 384 m) was less than the distances reported in both the Vescovie et al (2013; 9,930 m) and Sausaman et al (2019; 9,486 ± 300 m) studies. Discrepancies between these findings are likely due in part to methodological differences as well as differences in defined thresholds for HSRD and SD among the studies. Vescovi et al (2013) only used data collected during a single match and Sausaman et al (2019) included a larger sample of midfield and strikers, positions that generally cover a greater distance than center backs, which was the primary position of players included in the current sample.

Finally, our findings support the likelihood that the physical demands of women's soccer at a Division I collegiate level are not significantly impacted by playing multiple games in a week. These findings are further supported by Dellal et al. (2015) and Dupont et al. (2010). In both studies, researchers found no significant differences in the physical performances of soccer players in successive games. Specifically, Dupont et al. (2010) concluded 72 - 96 hours between consecutive matches allowed enough recovery time for elite male players to maintain their level of physical performance, while Dellal et al (2015) observed no differences in the physical activity of players during a prolonged period of congestion. These findings are in conflict with the observations made by Andersson et al., (2008) and Rollo et al. (2014), who have recommended a minimum of 48 - 72 hours is required between consecutive matches for players to properly recover and Ispirlidis et al. (2008) suggested that as many as 96 - 120 hours is required for players to return to pre-match physiological values. However, these studies did not specifically examine the impact of successive games on in-game physical performances (as characterized by TD, SD, and HSRD) but rather used various methodological approaches to more closely examine the impact of the physical match demands on variables such as muscle swelling, uric acid levels, neuromuscular fatigue, and biochemical changes, which were beyond the scope of this study.

The results of this study suggest l in-game performances of players were unchanged, whether the recovery time between successive games was greater or less than 48 hours. While this finding warrants further research, it does support the use of a Friday - Sunday schedule at the NCAA level. Also, important to note is the more educational friendly nature of the Friday - Sunday scheduling, leading to fewer missed days during the semester. Student-athletes face external factors throughout a season that their elite counterparts do not experience. Favero and White (2018) have estimated that in addition to the 20 hours a week allocated to their athletic responsibilities, student-athletes are also charged with an additional 15 - 30 hours of academic responsibilities (class time, internships, group projects, etc.) as well as any personal responsibilities. Because of this, a Friday - Sunday schedule allows athletes to miss less class time when traveling and may be beneficial to helping them balance their responsibilities. That being said, further research is necessary before drawing any final conclusions, as there were several important limitations in this study.

As noted, the unlimited substitution rule in NCAA women's soccer contributed to the small sample size in the present study. However, future research should consider analyzing the physical demands of all players regardless of playing time, as substitutions are a part of the game at this level and the impact of substitution should be assessed. Furthermore, the majority of the players included in the analyses were centerbacks, which is not representative of the various and generally more physically demanding positions on the field.

In conclusion, this study was the first to our knowledge to examine the impact of the most commonly scheduled successive games at the NCAA Division I collegiate level on the physical performances of players. There were no significant differences in physical performance, as characterized by TD, SD, HSRD, when players played a Friday - Sunday or a Thursday - Sunday schedule. Furthermore, there were no significant differences between first matches of the week and the second match of the week, regardless of if it was played > 48 hours or < 48 hours later. While further research is warranted to explore additional factors that may have impacted physical performance levels such as sample size, quality of opposition, playing tactics, formation and playing position, the present study will broaden the current body of knowledge on the Division I female collegiate soccer level

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CHAPTER IV: ARTICLE II – HOW DOES REST BETWEEN SOCCER MATCHES EFFECT TECHNICAL PERFORMANCE? COMPARING LESS THAN 48 HOURS REST VS MORE THAN 48 HOURS REST BETWEEN MATCHES

Introduction

Soccer is a high-intensity, intermittent, and physiologically demanding sport (Bozzini et al., 2020; Ishida et al., 2021; Lockie et al., 2016). Research suggests players will experience a decrease in physical performance throughout matches and across a season due to factors such as muscle damage and fatigue (Andersson et al., 2008, Bangsbo, 1994., Datson et al., 2014; Miller et al., 2007; Mohr et al., 2003; Nedelec et al., 2014; Stolen et al., 2005). In fact, some have suggested that a player's ability to quickly recover from the high physical demands placed upon during match play is a key factor in subsequent performance (Mohr et al., 2005). It is also suggested that technical and tactical activity are important in predicting successful match play (Bradley et al., 2013; Hoppe et al., 2015; Rampinini et al., 2009). Fatigue, from inadequate recovery, not only affects physical performance but also decreases a player's technical skills during match play (Rampinini et al., 2009). There is concern within National Collegiate Athletic Association (NCAA) women's soccer that the current schedule of play does not provide sufficient time for athletes to fully recover.

The NCAA women's soccer schedule has been described as congested and undesirable (Bozzini et al., 2020; Ishida et al., 2021). Specifically, teams will generally schedule 20-25 matches during a brief 12- 14-week window, resulting in an average of 1.66 games played per week with only a few days between games (Bozzini et al., 2020; Favero & White, 2018; Ishida et al., 2021). When a team is scheduled for two games in the same week, they generally play on a Thursday-Sunday (> 48hours) or a Friday-Sunday (< 48 hours) schedule (Bozzini et al., 2020). Research currently suggests that scheduling two games within less than 48 hours does not provide sufficient time for athletes to fully recover (Andersson et al., 2008; Ishida et al., 2021; Rollo et al., 2014). However, the overwhelming majority of these studies have focused on physical performance and physiological recovery. There are a limited number of studies on the way fatigue may impact the technical aspects of match play, especially within Division I women's players.

Technical components of a game such as the total shots taken and shots on goal are highly related to match outcome (Castellano et al., 2012; Lago-Penas et al., 2010; Liu et al., 2015). The team that scores first is more likely to win the match (Ibanez et al., 2018) and passing effectiveness as well as ball possession are also related to game outcomes (Castellano et al., 2012; Liu et al., 2015). Rampinini et al. (2008) documented junior soccer players experience a decline in passing accuracy as a result of a 90-minute game or high-intensity, 5-minute activity. Stone and Oliver (2009) showed similar findings with professional players.

To our knowledge, there is only one published study of the technical performance of Division I female players. Bozzini et al. (2020) explored the variation between physical and technical performances during out-of-conference (OC) games and in-conference (IC) games. They found no statistically significant differences between game types but suggested “the chronically congested match fixture of collegiate soccer and the subsequent fatigue incurred by the players as the season progressed could potentially explain some of the differences observed between OC and IC game” (p. 3367). This points to an important gap within the literature as no studies to date have examined the impact of the NCAA’s Friday - Sunday scheduling versus Thursday - Sunday scheduling on the technical performance of collegiate level female players.

Therefore, the aim of the current investigation was to explore the possible differences in match technical performance of Division I female players when they have less than 48 hours between games or more than 48 hours between games. Specifically, it was hypothesized: (1) There will be a significantly greater decrease in the passing accuracy (P%) of Division I female soccer players between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games, (2) There will be a significantly greater decrease in the percentage of shots on goal (SOG %) taken by Division I female soccer players between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games and (3) There will be a significantly greater decrease in time of ball possession (Po%) held by Division I female soccer players between the first and second match of the week when playing with less than 48 hours between games as opposed to when they have greater than 48 hours between games.

Study Design

Division I female collegiate soccer players from a single southeastern university team were monitored throughout their 2018-2019 and 2019-2020 competitive seasons. Games were recorded on a single video camera by the equipment manager, as part of the team's general game-day procedures. Game data from 5 Thursday matches, 3 Friday Matches, and 8 Sunday matches were generated by Vidswap to determine the P%, Po%, and SOG% for each regulation game where at least one player played a full 90 minutes of regulation time. Data were then analysed to compare differences in the skill-related technical performance of the team between the first game of the week and the second game of the week with less than 48 hours between matches and greater than 48 hours between matches.

Participants

Match data were collected from 33 NCAA Division I women's soccer players at a southeastern university during the 2018-2019 and 2019-2020 competitive seasons. Game video was captured using a single camera as part of the team's general procedures. Retrospective video analysis was approved by the university review board (see Appendix A) and permission was granted by the team's head coach. Data were collected for all players playing in any one of the 16 matches included in the analyses, as we believed this best reflected the inherent nature of the women's collegiate game at the NCAA Division I level.

Procedures

Skill-related technical performance during match play was analysed for players from a single university playing at the NCAA Division I level. In order to ensure anonymity of the players, all data were anonymized prior to analyses. Overall, 7 home games and 9 away games across two seasons (2018-2019, n = 10; 2019-2020, n = 14) were used in the analyses. All three positions (fullbacks, midfielders, strikers) were included in analyses so long as the player in those roles played a full 90 minutes in each of the two games of the week.

The video analysis software Vidswap was used to collect game data on key event occurrences throughout the game including P%, Po%, and SOG%. For the purposes of this study, technical variables were defined in the Vidswap software program and coded internally by Vidswap.

Statistical Analysis

Data from the video analysis were uploaded into the statistical software SPSS (IBM SPSS v 27). Results are expressed as mean values ± standard deviation (mean ± *SD*), unless otherwise stated. To investigate the differences in technical performance, change variables were created by calculating the mean differences between the Friday - Sunday games and the Thursday - Sunday games. Prior to analyses, data were evaluated for normality using the kolmogorov-smirnov test with Lilliefors' correction.

Independent t-tests were used to compare the in match physical performance of players between the Friday - Sunday change variables and the Thursday - Sunday change variables. Statistical significance was set at $p < .05$.

Results

Summary statistics (*M* ± *SD*) for P%, Po%, and SOG% during matches by game night are presented in Table 1.

Table1.

Technical Demands by Game Night

Variable	TH	FR	> 48 hours	< 48 hours
P (%)	69.4± 9.8	63.3 ±3.7	65.0 ± 12.3	64.3 ±0.5
Po (%)	49.0 ± 3.2	47.3 ±4.7	49.4 ± 5.9	47.0 ±1.0
SOG (%)	44.6± 10.5	44.6 ±14.7	44.6± 23.8	50.6±10.9

Note. TH = Thursday; FR = Friday; P (%) = Pass Percentage; Po (%) = Possession percentage; SOG (%) = Shots on goal percentage.

The average P%, Po%, and SOG% for each of the four game days (Thursday, Friday, > 48 hours, < 48 hours) were similar and not statistically significantly different ($p > .05$). There were also no statistically significant differences between any of the change variables. Possession was the only variable where the team had a lower mean percentage during the second game played < 48 hours later (47.0 ±1.0%) rather than during the first game played of the week (47.3 ±4.7), but by less than 1%. Possession percentage also showed the least amount of variation between Thursday games (49.0 ± 3.2%) and games played > 48 hours later (49.4 ± 5.9%). There was not a statistically significant differences (*t* (6) = 0.233, *p* = .831, 95% CI [-7.32 - 8.79]) in the percentage of possession between the < 48-hour change variable (0.3 ± 5.5%) and the > 48 hours change variable (-0.4 ± 3.9%). Similarly, there were also no statistically significant differences in the change variables for the teams Pass percentages, *t* (6) = -1.235, *p* = .263, 95% CI [-16.10, 5.30], or shots on goal percentage, *t* (6) = -0.359, *p* = .732, 95% CI [-56.31 - 41.9]. A summary of these results are presented in Table 2.

Table 2.

Technical Performance by Schedule Type

	< 48 hours	> 48 hours			
Variable	*M*(*SD*)	*M*(*SD*)	Mean Diff.	*t*	95% CI
P%	-1.0(3.4)	4.4(6.9)	-5.4	-1.2	[-16.1, 5.3]
Po%	0.3(5.5)	-0.4(3.9)	0.7	0.2	[-7.3, 8.7]
SOG%	-6.0(25.7)	1.2(28.3)	-7.2	-0.3	[-56.3, 41.9]

Note. P(%) = Pass percentage; Po (%) = Possession percentage; SOG (%) = Shots on goal percentage.

Discussion

The purpose of this study was to examine the effects of playing two matches per week, separated by different recovery periods (< 48 hours and > 48hours), on the physical performances of a Division I female soccer team. It was hypothesized there would be a statistically significant greater decrease in the technical performance of Division I female soccer players, as characterized by P%, Po%, and SOG%, during the second match of the week when consecutive games were played less than 48 hours apart as opposed to when players had greater than 48 hours between matches. All three hypotheses were rejected as there were no statistically significant differences between the P%, Po%, and SOG% in consecutive games played with different recovery periods.

The present study contributes to the limited body of research on this topic. To our knowledge, only Bozzini et al. (2020) has explored the technical performances of Division I female soccer players. This is also the only other study to specifically examine the effects of the two most common NCAA playing schedules for Division I women's soccer (Thursday - Sunday and Friday - Sunday) on team technical performance. Specifically, Bozzini et al. (2020) compared the technical performances of Division I female players, as characterized by the percentages of passing accuracy, successful dribbles, successful tackles, and successful challenges, between in-conference (IC) and out-of-conference (OC) games. They found similar but slightly higher passing percentage averages (OC = 75.8 ± 5.1% and IC = 73.5 ± 6.1%) then were observed in the present study (65.5 ± 2.7%). However, similar to the present study, Bozzini et al. (2020) found no statistically significant differences in the team's technical performances. Together, these results suggest that skill-related performance during match play is not impacted by playing successive matches within a short timeframe or congested schedule. These results are also in line with other findings from studies conducted on elite soccer players. For instance, Carling and Dupont (2011) concluded that a fatigue-related decline in the physical performance of professional soccer players was not accompanied by a decline in skill-related performance. Dellal et al. (2013) had similar results, suggesting that technical performance was unaffected during the prolonged and congested periods of professional team schedules.

Generally, direct comparisons between the collegiate level of play and the professional level are difficult and not recommended, as the substitution rules are distinctive. At the collegiate level, there are unlimited substitutions. This significantly decreases the number of players that play the full 90 minutes. In the present study, only five players met the criteria of playing 90 minutes in both games scheduled in a single week. An acknowledged limitation of this study was that variation in substitution patterns by different collegiate teams could greatly impact results. One explanation for the observed consistency in technical variables in the present study was that the coach had a deep enough bench to allow for more frequent substitution. This could have helped alleviate some of the possible impacts of fatigue on the technical performance variables assessed. It is also possible that the technical abilities between the starters and non-starters for this team are minimal, and thus the technical performance of the team is mostly unaffected by change in personnel. This might not be the case for all Division I collegiate teams as some may have a greater number of players playing the full 90 minutes and others may have greater technical differences between their starters and non-starters. Further investigation is necessary before drawing any final conclusions.

In conclusion, this study was the first to our knowledge to examine the effects of the NCAA scheduling in women's soccer on the technical performances of a Division I team. There were no significant differences in technical performance, as characterized by P%, Po%, or SOG% when players played a Friday - Sunday or a Thursday - Sunday schedule. Furthermore, there were no significant differences between first matches of the week and the second match of the week, regardless of whether it was played > 48 hours or < 48 hours later. While further research is necessary to explore additional factors that may have impacted technical performance levels of a Division I team such as sample size, number of substitutions made, quality of opposition, playing tactics, formation and playing position, the present study will broaden the current body of knowledge at the Division I female collegiate soccer level.

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CHAPTER V: OVERALL DISCUSSION

The purpose of this dissertation was to examine the impact of the NCAA Women's Soccer game schedule on performance. Currently, teams generally play two games per week on a Thursday-Sunday or Friday-Sunday schedule. Two studies were conducted in this dissertation, the first examined the physical performance of players and the second examined technical performance of teams during both schedule types described above.

In the first study, the physical performances of players who had participated in the full 90 minutes of both games in a single week were evaluated. Physical performance was characterized as a player's TD, SD and HSRD accumulated during the 90 minutes of match play. Overall, the average SD and HSRD in the present study were similar to the averages observed in previous research, while players in the present study appeared to cover less TD overall. Most notably, there were no statistically significant differences among any of the physical performance variables between consecutive matches (Friday vs. Sunday and Thursday vs. Sunday). There were also no statistically significant differences between any of the physical performance variables when comparing the < 48 hours change variables and > 48 hours change variables.

In the second study, the technical performance of the team was evaluated based on all games where at least one player had played the full 90 minutes of both games in a single week. Technical performance was characterized as the teams P%, Po% and SOG% accumulated during the 90 minutes of match play. Overall, the average P% in the present study was similar to the limited averages available in previous research. Most importantly, there were no statistically significant differences among any of the technical performance variables between consecutive matches (Friday vs. Sunday and Thursday vs. Sunday). There were also no statistically significant differences between any of the technical performance variables when comparing the change variable for < 48 hours between matches and the change variable for > 48 hours between matches.

Together, the conclusion that can be drawn from both of these studies, suggests that overall, the NCAA typical game schedule does not negatively impact a players physical performance or a team's technical performance and therefore there is not an advantage to one scheduling type over the other. That being said, there may be some advantages to a Friday-Sunday schedule type that are specific to the collegiate population. Academically speaking, a Friday-Sunday schedule may allow players to miss fewer courses, especially when travelling to away games. However, further research is needed in order to better support these findings.

The present studies were only conducted at a single university and conclusions are based on a limited sample size. Future research is needed to better understand the physical and technical demands of women's division I soccer and a greater sample size of both teams and players are needed to better account for the many variations between programs. Future studies may look to include and account for the impacts of playing surface (turf vs. grass), quality of opponents, tactical formation, playing position, number of substitutions used, number of rest days, and playing condition (weather) as each of these may directly or indirectly impact the performances of players. Nevertheless, the present study will help broaden the currently limited body of knowledge on women's Division I collegiate soccer.

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APPENDIX

Appendix A: Institutional Review Board Approval Letter

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129
FWA: 00005331/IRB Regn.. 0003571

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN007 – EXEMPTION DETERMINATION NOTICE

Tuesday, May 04, 2021

Protocol Title	***An Examination of the Physical and Technical Game Performance of a Division I Women's Soccer Team Across Varying Rest Periods***
Protocol ID	**21-1170 4**
Principal Investigator	**Kelsie Roberts** (Student)
Faculty Advisor	Jennifer Caputo
Co-Investigators	Sandra Stevens and Colby Jubenville
Investigator Email(s)	*kn4ec@mtmail.mtsu.edu; jenn.caputo@mtsu.edu*
Department/Affiliation	Health and Human Performance

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXEMPT** review mechanism under 45 CFR 46.101(b)(2) within the research category ***(4) Study involving existing data*** *(analysis of performance data collected for non-research use).* A summary of the IRB action and other particulars of this protocol are shown below:

IRB Action	**EXEMPT from further IRB Review** Exempt from further continuing review but other oversight requirements apply		
Date of Expiration	**12/31/2022**	*Date of Approval:* **5/4/21**	*Recent Amendment:* NONE
Sample Size	FIFTY (50)		
Participant Pool	**Data collected from healthy famale adults (18 or older) who were NCAA Division 1 soccer players for MTSU**		
Exceptions	NONE		
Type of Interaction	☒ Non-interventional or Data Analysis ☐ Virtual/Remote/Online Interview/survey ☐ In person or physical– Mandatory COVID-19 Management (refer next page)		
Mandatory Restrictions	**1. All restrictions for exemption apply.** **2. The participants must be 18 years or older.** **3. Identifiable information including, names, addresses, voice/video data, must not be obtained.** **4. NOT approved for new data collection.**		
Approved IRB Templates	*IRB Templates:* NONE *Non-MTSU Templates:* NONE		
Research Inducement	NONE		
Comments	NONE		