Running Performance and Sleep Patterns in Canadian Female University Soccer Players

By

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Abstract

This longitudinal, correlational study aimed to assess running performance and sleep patterns in female University Sports soccer players (N = 12; 19.44 $\pm$ 1.69 years) in matches played with less than 24 hours of recovery. Global Positioning System (GPSport) was used to assess running performance throughout games during the 2016 season. Pittsburgh Sleep Quality Index was to determine good and bad sleeper's, while the Core Consensus Sleep Diary was used to determine total sleep time (min), time in bed (min), sleep efficiency (%), sleep onset latency (min), wake after sleep onset (min), number of awakenings (#), and sleep quality. Overall, players had significantly ($p \leq .026$) reduced running performance from the first to the second game, while sleep variables were typically significantly decreased after the second match. Our study indicates that coaches can rotate players and sleep hygiene strategies should be implemented to help mitigate any negative effects of disturbed sleep.

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CHAPTER 1 – SCIENTIFIC FRAMEWORK

1.1 Introduction

Overreaching and overtraining can simply be defined as an imbalance between training or competition (or a combination of both) and recovery, leading to progressive chronic fatigue, underperformance, altered mood state and increased infections (Budgett, 1998; Kellmann, 2002; Kreider, Fry, & O'Toole, 2002; Meeusen et al., 2013). Development of overreaching is not solely from the physical stress imposed from training and competition, but also psychological stress factors perceived by the individual (i.e. balancing school, work and sleep) (Kennedy, Tamminen, & Holt, 2013). Under-recovery is the failure to fulfill current recovery demands and can be the result of a lack of quality sleep (Kellmann, 2002), extensively prolonged training sessions, and frequent stressful competitions (Budgett, 1998; Kellmann, 2002; Ritchie, Hopkins, Buchheit, Cordy, & Bartlett, 2015). Thus, an individual's optimal performance and health appears to require a balance between training, performance and nonperformance stressors, and the quantity and quality of recovery, including sleep. A majority of studies investigating overreaching have focused on individual endurance sports, while little research has focused on team sports, such as soccer (Meeusen et al., 2013). The accumulation of physical training and competitive matches may induce chronic fatigue and cause overreaching as the season progresses as indicated by a significant decrease in maximal oxygen uptake (VO_{2max}), plasma Immunoglobulin A, lymphocytes, monocytes, basophilocytes and mean cell hemoglobin concentration (Heisterberg et al., 2013).

Soccer is deemed as a physically demanding sport (Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005). Typically, professional male and female soccer players can cover distances ranging from 9-13 km throughout a match (Andersson, Randers, Heiner-Møller, Krustrup, &

Mohr, 2010; Bangsbo, Mohr, & Krustrup, 2006; Krustrup et al., 2005). At the university level, female soccer players have been reported to cover distances ranging from 8-11 km throughout a match of which, 1.1 km (15.6-20.0 km/hr) (Vescovi & Favero, 2014) and 1.6 km ($\geq$ 13 km/hr) (McCormack et al., 2014), is of high-intensity running (15.6-20.0 km/hr). In addition, game demands include accelerations, decelerations, changes of direction, jumping and kicking, all which have a considerable eccentric component and can result in muscle damage (Andersson et al., 2008; Nédélec et al., 2012; Varley & Aughey, 2013). Due to this high physical demand, fatigue has been reported to occur at three different time points throughout a match: after short-term intense periods in both halves; in the initial phase of the second half; and towards the end of the match (Mohr, Krustrup, & Bangsbo, 2005). As matches progress, the amount of high-intensity running performed decreases, possibly as a result of muscle damage, dehydration, glycogen depletion or any combination of these factors (Akenhead, Hayes, Thompson, & French, 2013; Krustrup et al., 2011). Post-match fatigue has been reported to be increased for up to 72 hours as indicated by reduced sprint performance, counter movement jump performance and maximal voluntary contraction strength of knee extensors and flexors (Andersson et al., 2008; Krustrup et al., 2011; Nédélec et al., 2012).

University Sports (U Sports), formerly known as Canadian Interuniversity Sports, requires female soccer teams to typically play two matches over the course of a weekend, with less than 24 hours of recovery between matches, over the course of a seven week regular season. With the lack of recovery between matches over a weekend and over the course of a season, players may be at risk of overtraining. Therefore, the purpose of this research study is to characterize the running performance and sleep patterns of Canadian university female soccer players before and after matches over the course of the competitive season.

1.2 Review of Literature

In recent years, soccer teams have made use of Global Positioning Systems (GPS) and accelerometers imbedded within these tracking devices, to provide an objective measure of external training load (Wehbe, Hartwig, & Duncan, 2014)**.** Global Positioning Systems units have been shown to be sufficiently reliable and accurate at quantifying running performance in various team sports for several years (Aughey, 2011; Coutts & Duffield, 2010; Cummins, Orr, O’Connor, & West , 2013; Ehrmann, Duncan, Sindhusake, Franzsen, & Greene, 2016; Varley, Fairweather, & Aughey, 2012).

Global Positioning Systems have been deemed valid and reliable for all variables of distance and speed in a variety of team sports (Hausler, Halaki, & Orr, 2016; Waldron, Worsfold, Twist, & Lamb, 2011). Global Positioning System variables that are most often reported in the literature are: total distance travelled, high speed running, sprinting distance, number of sprints performed, accelerations, decelerations and relative distance covered (total distance travelled per minute of match-play, $m \cdot min^{-1}$) (Hausler et al., 2016).

1.2.1.1 Running Performance of Female Soccer Players

The majority of the literature based on GPS running characteristics of athletes has come from professional male sports with scant amounts of literature pertaining to female athletes and university team sports, quite possibly due to the cost of GPS hardware and lack of personnel to interpret and summarize data (Datson et al., 2014). More recently, McCormack et al. (2015) and Vescovi and Favero (2014), are the only two known studies published on the physical demands of female university soccer players from the National Collegiate Athletic Association. Vescovi and Favero (2014) found that on average, female collegiate soccer players covered between 9.5 and 10.2 kilometers during a competitive match, while professional women reportedly covered over 10 kilometers per match (Andersson et al., 2010; Mohr, Krustrup, & Bangsbo, 2003). Vescovi and Favero (2014) reported that female soccer players covered between 315-577 meters of high intensity running (15.6-20 km/hr) and 61-248 meters of sprinting (> 20 km/hr) per match. McCormack et al. (2015) is the only study to my knowledge that compared the running performance of two matches separated by 42 hours in female university soccer players, with high-intensity running (HIR) rate (HIR/min) (≥ 3.61 m/s) significantly reduced from the first to the second match (games typically played on Friday then on Sunday) (McCormack et al., 2015).

1.2.1.2 Sprinting

Sprinting constitutes one of the more important activities observed in soccer matches. Sprinting is essential to win possession of the ball, move past a player, create space for team-mates, play the ball into space, deceive opponents, track runs of an opponent, as well as to create and minimize scoring opportunities (Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Di Salvo et al., 2010; Reilly, Bangsbo, & Franks, 2000; Varley & Aughey, 2013). Since soccer encompasses short distance sprints (<10 m) and given that the required distance to achieve maximal velocity from a standing or running start (~40 m vs ~29 m, respectively) is greater than 10 meters, the ability to accelerate may be a more valuable component to determine in soccer than sprint speed (Di Salvo et al., 2009; Di Salvo et al., 2010; Varley & Aughey, 2013).

1.2.1.3 Accelerations & Decelerations

Acceleration is a distinct quality and precursor to maximal speed running (Little & Williams, 2005; Lockie, Murphy, Knight, & de Jonge, 2011). Accelerating is more metabolically demanding and requires a greater neural activation to the working muscles compared to constant speed running (di Prampero et al., 2005; Mero & Komi, 1986; Mero & Komi, 1987; Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010). It would be likely that the exclusion of accelerations and decelerations in match analysis could result in an underestimation of high-intensity movements (Opar, Williams, & Shield, 2012; Varley & Aughey, 2013).

1.2.1.4 High-Intensity Running

Greater amounts of high-intensity running performed ($\geq$15 km/hr) in high level soccer players have been reported, with less successful teams exhibiting greater decrements in high-intensity running over the course of a match (Iaia, Rampinini, & Bangsbo, 2009; Krustrup, Zebis, Jensen, & Mohr, 2010). This suggests that the ability to perform high-intensity running throughout a match is crucial (Iaia et al., 2009)

1.2.1.5 Relative Distance ($m \cdot min^{-1}$)

Cummins et al. (2013) indicated that relative distance or total distance travelled per minute of competition game time ($m \cdot min^{-1}$) may provide a more accurate reflection of match intensity than total distance covered, as it takes into account the event time. Additionally, distance is a measure of volume, while relative distance is a measure of intensity and a player who can sustain a higher work-rate throughout a full match gains an advantage over equally skilled players (Reilly et al., 2000; Saltin, 1973).

In the available research literature, there is a lack of research on female soccer players especially at the university level. The available data indicates that there is impaired running performance in matches where more than two matches are played per week; however, no study has investigated the running performance using GPS of Canadian female university soccer players during the competitive season (McCormack et al., 2015). Within this population, teams typically play two matches within 24 hours (i.e. games typically being played over the weekend; Friday and Saturday afternoon or Saturday and Sunday afternoon) over the regular season, lasting approximately eight weeks (beginning in September and ending late October). Within this population, the amount of time allocated to training, matches, school, and work, means that athletes typically report difficulty finding time to sleep (Kennedy et al., 2013).

1.3 Sleep Overview

Sleep can be defined as a reversible behavioral state in which an individual is perceptually disengaged from and is unresponsive to the environment (Carskadon & Dement, 2011). Sleep is a complex physiological and behavioral state that has two primary states based on physiological parameters. These are rapid eye movement (REM) and non-rapid eye movement (NREM) sleep. Non-rapid eye movement sleep is divided into three stages, which are associated with a progressive increase in the depth of sleep (Carskadon & Dement, 2011). Rapid eye movement sleep is characterized by muscle atonia, bursts of REM and dreaming (Carskadon & Dement, 2011). Preceding the initiation of sleep, salivary melatonin levels, distal skin temperature and sleepiness increase, while decreases in both core body and proximal skin temperature occur (Kräuchi, Cajochen, Werth, & Wirz-Justice, 2000). Cardiovascular changes in the form of reduced heart rate and blood pressure occur, with their lowest levels occurring during

NREM sleep when compared to wakefulness (Somers, Dyken, Mark, & Abboud, 1993). While REM sleep periods demonstrate increased sympathetic nerve activity levels above what is recorded during wakefulness, reported heart rate and blood pressure values may be similar to values recorded during periods of wakefulness (Somers et al., 1993). Sleep is beneficial for maintaining hormonal, immunological and metabolic homeostasis. This is apparent when homeostasis is threatened during partial or complete sleep deprivation, but returns after recovery sleep periods. When sleep is disrupted, growth hormone (Van Cauter, Plat, & Copinschi, 1998; Spiegel et al., 2000), leptin (Spiegel et al., 2004), rate of glucose clearance and effectiveness (Spiegel, Leproult, & Van Cauter, 1999), natural killer cell number (Irwin et al., 1996; Walsh et al., 2011) and activity levels decrease (Irwin et al., 1994; Irwin et al., 1996; Walsh et al., 2011); at the same time ghrelin (Van Cauter, Spiegel, Tasali, & Leproult, 2008) and cortisol levels increase (Spiegel et al., 1999; Spiegel et al., 2004).

It has been hypothesized that sleep, and in particular NREM slow-wave sleep (SWS) or deep sleep, is important for recovery in athletes (Halson, 2014; Taylor, Rogers, & Driver, 1997). While there is minimal research specifically using athletes, evidence in support of this theory includes the synchrony of growth hormone release with SWS in humans, the suggestion that optimum conditions for anabolism prevail during sleep and studies showing the duration of SWS to be proportional to preceding wakefulness (Shapiro, Bortz, Mitchell, Bartel, & Jooste, 1981). In addition, when SWS is decreased by sleep deprivation, an increase in daytime sleepiness and a reduction in performance have been observed (Dijk, 2010). Performance in the form of psychomotor vigilance tasks (PVT) decrease over time when participants spend, typically, less than seven hours of time in bed (Dinges et al., 1997; Belenky et al., 2003; Van Dongen, Maislin, Mullington, & Dinges, 2003; Lim & Dinges, 2008). These performance decrements take the form of increased reaction times and the number of lapses committed (reaction times equal to or greater than 500 milliseconds), with a constant worsening trend as the sleep restriction period progresses while sleepiness values (i.e. Stanford Sleepiness Scale) plateau but remain elevated above baseline (Dinges et al., 1997; Belenky et al., 2003; Van Dongen et al., 2003). These findings demonstrate that neurobehavioral functions worsen in a dose response manner to sleep deprivation, while subjective ratings of sleepiness remain constant, suggesting that participants adapt to chronic sleep restriction (Van Dongen et al., 2003; Simpson et al., 2016). This sleep restriction impact may have a negative effect on training sessions and matches in soccer players.

1.3.1.1 Sleep as a Part of Recovery

One of the most obvious methods for managing fatigue and enhancing recovery, from exercise, is adequate passive rest and obtaining sufficient sleep (Meeusen et al., 2013). Sleep is deemed as an important aspect of post-exercise recovery and when the balance between appropriate training stress and recovery is disrupted, a short-term overreaching state results (Hausswirth et al., 2014; Kellmann, 2002; Samuels, 2008). Sleep is an essential part of fatigue management, while persistent sleep loss can negatively affect the quality of a training session and general well-being (Halson, 2014). The primary need for sleep has been hypothesized as being neurally based rather than a requirement for restitution of other biological tissues (Horne & Pettitt, 1984; Meeusen et al., 2013). It is generally recommended that athletes should have at least one passive rest day each week, because the absence of a recovery day, especially during intensified training periods, is closely related to the onset of signs of overreaching and underrecovery (Kellmann, 2002). A passive rest day can also act as a ‘‘time-out’’ period for athletes and prevent them from becoming totally preoccupied with their sport and possibly encourage them to pursue a different (passive) interest (Bruin, Kuipers, Keizer, & Vander Vusse, 1994; Meeusen et al., 2013). Such distractions from the daily routine of training may alleviate boredom and reduce stress perception (Kellmann, 2002; Kennedy et al., 2013).

Polysomnography is deemed the "gold standard" in determining sleep quality and quantity (Ancoli-Israel et al., 2003). Polysomnography uses multiple methods simultaneously and continuously records physiological changes that occur in various organ systems (Jafari & Mohsenin, 2010). These methods include: electroencephalography (recording of surface electrical activity of the brain), electro-oculography (records eye movements), electromyography (records muscle activity, submental and/or leg), air flow measurements and cardiac monitoring (Jafari & Mohsenin, 2010). Due to the cost, expertise and invasiveness that are required to document sleep in this manner, it is not practical for studies within team sports. The Pittsburgh Sleep Quality Index (PSQI) has been deemed as an effective instrument to assess the global quantity and quality of sleep as well as persistent sleep disturbances of participants (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI assesses seven areas: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications and daytime dysfunction. All 19 self-rated questions are weighted equally on a scale of 0-3. The seven component scores are then summed to yield a global PSQI score, which ranges from 0-21, with a higher score indicates a poorer sleep quality. Scores ≥ 5 indicate that an individual is having severe difficulties in at least two areas or moderate difficulties in more than three areas.

Sleep diaries are considered the gold standard for indicating the subjective sleep quality of participants and have been validated against objective measures of actigraphy (Carney et al., 2012; Kölling, Endler, Ferrauti, Meyer, & Kellmann, 2016a). Although sleep diaries are considered a basic tool, no standardized sleep diary exists that can be routinely included in sleep research (Carney et al, 2012). The Core Consensus Sleep Diary (CSD) was developed by the CSD workgroup in 2005 and represents the most critical parameters to be included in a sleep diary. The core CSD contains nine items: (1) the time of getting into bed; (2) the time at which the individual attempted to fall asleep; (3) sleep onset latency (SOL); (4) number of awakenings; (5) duration of awakenings (WASO); (6) time of final awakening; (7) final rise time; (8) perceived sleep quality (rated via Likert scale); and (9) an additional space for open-ended comments from the respondent (Carney et al., 2012).

1.3.1.2 Sleep in the General and Athletic Populations

As reported by Ferrara and De Gennaro (2001), the amount of subjective sleep reported in 1959 decreased from 8 to 9 hours per night (Kripke, Simons, Garfinkel, & Hammond, 1979) to 7 to 8 hours (Bliwise, King, Harris, & Haskell, 1992) of sleep attained in the mid 1980's. In a study conducted by the National Sleep Foundation in 2013, adults (age 23-60) slept on average 6 hours and 51 minutes on workdays and 7 hours and 37 minutes on non-workdays (National Sleep Foundation: 2013 Sleep in America Poll-Exercise and Sleep, 2013). Participants indicated that a mean of 7 hours and 17 minutes of sleep is needed to function at their best during the day, an amount which is in accordance with the recommended 7 to 9 hours (Ferrara & De Gennaro, 2001; Hirshkowitz et al., 2015; Watson et al., 2015). University students have been reported to acquire a median sleep duration of approximately 6.5 hours per night (Buboltz, Brown, & Soper, 2001; Hicks, Fernandez, & Pellegrini, 2001) and student-athletes may be at a greater risk of attaining even less sleep (Kennedy et al., 2013).

While it is recommended that athletes attain 9 to 10 hours of sleep per night, and current recommendations for healthy adults is 7 to 9 hours, recent evidence has indicated that athletes acquire far less sleep than what is recommended (Bompa & Haff, 2009; Ferrara & De Gennaro, 2001; Hirshkowitz et al., 2015; Watson et al., 2015). Athletes from a variety of sports including: basketball, soccer, rugby, netball, triathletes, Australian Rules Football, swimming, road cycling, Olympic athletes - canoeing, speed skating, running and diving have reported, via actigraphy and sleep diaries, a mean sleep duration ranging from 5:51 (hours:min) to 8:07 (hours:min) per night with the majority of means reporting less than 7 hours per night. Studies have reported quantities of 400.7 min (SD; ± 61.8) (Mah, Mah, Kezirian, & Dement, 2011), 7:13 hours:min (SD; ± 0.39 min) (Robey et al., 2014), 414 mins (SD; ± 64 mins) (Dennis, Dawson, Heasman, Rogalski, & Robey, 2016), 7:04 hours:min (SD; ± 1:01) (Shearer, Jones, Kilduff, & Cook, 2015), 8:11 hours:min (SD; ± 0:27) (Romyn, Robey, Dimmock, Halson, & Peeling, 2016), 6:43 hours:min (SD; ± 0:47) (Hausswirth et al., 2014), 6:30 hours:min (SD; ± 1:18) (Sargent, Lastella, Halson, & Roach, 2014), 6:56 hours:min (SD; ± 0:44) (Leeder, Glaister, Pizzoferro, Dawson, & Pedlar, 2012), 8:44 hours:min (SD; ± 0:40) (Fullagar et al., 2016a), 6:38 hours:min (SD; ± 1:01) (Fullagar, Skorski, Duffield, & Meyer, 2016b), 8:46 hours:min (SD; ± 1:03) (O'Donnell, Bird, Jacobson, & Driller, 2018).

Shearer et al. (2015) is the only known study reporting the sleep quality of athletes after competition. Twenty-eight male rugby union players were monitored using actigraphy over a five night period. For clarity, these data were recorded on: S1 (reference night sleep), S2 (pregame), S3 (post-game), S4 (post-game +1), and S5 (postgame +2). Post-game (S3) mean time asleep was significantly less than the reference night sleep (S1) (6:02 vs 7:04 hours:min; ($p <$ .05). Fullagar et al. (2016a) studied the subjective sleep and recovery responses of elite male soccer players across training days and both day and night matches over a 21 day period. The authors reported that sleep duration was significantly ($p >$ .05) unchanged between training days (8:44 hours:min; SD $\pm$ 0:40) and day matches (8:20 hours:min; SD $\pm$ 0:41), with only sleep duration being significantly impaired after night matches 5:43 ± 1:36 when compared to training days and day matches. Similar results were reported after night matches in amateur male soccer players where sleep duration was significantly ($p <$ .05) different from baseline (night match, 4:30 hours:min; SD $\pm$ 0:27, baseline, 6:38 hours:min; SD $\pm$ 1:01) (Fullagar et al., 2016b). O'Donnell et al. (2018) observed the sleep patterns of 10 elite female netball athletes. This study reported that mean total sleep time following a match (6:03 hours:min; SD $\pm$ 1:51) was significantly lower ($p <$ .05) than control values (8:46 hours:min; SD $\pm$ 1:03). This study used only a single testing day for control, training, and match days, which likely impacted their results. These results indicate that athletes are attaining less sleep, especially after night matches, than what is recommended for a regular night's sleep and this may have a negative effect on subsequent athletic performance.

1.3.1.3 Sleep Loss and Exercise Performance

It is unlikely that athletes experience total sleep deprivation before competition and rather are more likely to experience a state of partial sleep deprivation (Reilly & Edwards, 2007). Recent evidence indicates that depriving participants of sleep at the end compared to the beginning of the evening (i.e. approximately 3 hours at the beginning vs. the end of the evening) typically has a greater negative impact on athletic performance (Souissi et al., 2008) and reaction time (Jarraya, Jarraya, Chtourou, Souissi, & Chamari et al., 2013), possibly due to increased fatigue caused by staying awake for a longer period of time (Souissi et al., 2008). Jarraya et al. (2013) reported that spatial and constant attention is much more affected by sleep deprivation in the beginning of the night than at the end. The authors indicated that the discrepancies between physical and cognitive exercises could be due to the nature of the tasks. Performance decrements have been reported in Judokas (HajSalem, Chtourou, Aloui, Hammouda, & Souissi, 2013; Souissi et al., 2013), Taekwondo (Mejri et al., 2016), cyclists (Mougin et al., 1991) and in physically active young adults (Souissi et al., 2008) who have been partially sleep deprived later in the evening compared to a reference sleep night (HajSalem et al., 2013; Mejri et al., 2016; Mougin et al., 1991; Souissi et al., 2008; Souissi et al., 2013). Skein, Duffield, Edge, Short, and Mundel (2011) reported that in 10 male team sport athletes, muscle glycogen levels were significantly lower after 30 hours of continuous sleep deprivation compared to controls after a 30 minute graded exercise run and 50 minute intermittent-sprint exercise protocol, including a 15 meter maximal sprint every minute. Although this is an extreme circumstance, the authors indicated that this method for sleep deprivation was used to simulate a night of minimal sleep due to extended travel commitments. This study shed some light on the matter of impaired sleep and glycogen synthesis and if sleep is inadequate, ensuing performance may be decreased. With no study examining the effects of partial sleep deprivation on female university soccer players and the likelihood of this cohort having disturbed sleep prior and post match days, it is plausible that female university soccer players could potentially have running performance decrements in the second match played over the weekend which may be compounded by poor or inadequate amounts of sleep.

1.3.1.4 Causes of Poor Sleep Prior to Competition

Nédélec, Halson, Abaidia, Ahmaidi, and Dupont (2015) indicated multiple potential stressors that could influence sleep quantity and quality in elite soccer players. Some of these stressors are: excitement and arousal as a consequence of competition, match outcome and related mood, playing away (e.g. first night effect during the first night in a hotel, travel) and the use of electronic media devices before sleep (Nédélec et al., 2015). A majority of athletes from various sports (i.e. swimming, cycling, soccer, and rugby) have reported impaired sleep the night prior to competitions, with the most common reasons for a poor sleep being problems falling asleep (Erlacher, Ehrlenspiel, Adegbesan, & Galal El-Din, 2011; Juliff, Halson, & Peiffer , 2015; Lastella, Lovell, & Sargent, 2014), waking up throughout the night (Erlacher et al., 2011; Juliff et al., 2015), thoughts about competition (Erlacher et al., 2011; Juliff et al., 2015; Lastella et al., 2014), unfamiliar surroundings (Erlacher et al., 2011; Juliff et al., 2015; Lastella et al., 2014) and noises in the room or outside (Erlacher et al., 2011; Juliff et al., 2015; Lastella et al., 2014).

Valenza, Rodenstein, and Fernández-de-las-Peñas (2011) indicated that pain and muscle discomfort had negative implications on sleep quality in rehabilitation patients, while mice who were subjected to injections of acidified saline (increased mechanical sensitivity) demonstrated increased fragmentation while overall sleep duration did not change (Sutton & Opp, 2014). Hausswirth et al. (2014) reported that overreached triathletes reported disturbed sleep patterns, measured via actigraphy, possibly due to mild muscle fatigue or soreness. Fatouros et al. (2010) and Mohr et al. (2015) indicated that delayed onset muscle soreness was still evident in soccer players 48 hours post-match and this may account for modifications in sleep quantity or quality. Nédélec et al. (2015) indicated that muscle soreness and pain could possibly be a reason behind a poorer sleep quantity and quality in soccer players. Chiu et al., (2005) reported that poor sleep quality (indicated by the sleep problem scale; higher scores indicate poorer sleep) was associated with low pain thresholds (determined by a Fischer Pressure Algometer). Lower pain thresholds (thermal stimuli) were reported in sleepy individuals (Multiple Sleep Latency Test $\leq$ 5 min) (Chhangani et al., 2009), while sleep extension for four nights (10hr time in bed) resulted in reduced sleepiness and an increased pain threshold (thermal stimuli) (Roehrs, Harris, Randall, & Roth, 2012). Forced awakenings every hour for 20 minutes increased spontaneous pain compared to sleep restriction (delayed bed time) in healthy females (Smith, Edwards, McCann, & Haythornthwaite, 2007). Hausswirth et al. (2014) examined sleep quality by wrist actigraphy in 27 well trained triathletes that were placed in an overload training group or control group. The overload period lasted 3 weeks with a 30% increase in training load (volume) above normal and subsequently, performed a two-week taper period in which the training volume was reduced to 50% of their normal training load. The main finding pertaining to sleep during the overload period was a progressive decrease in sleep quality, most notably, sleep efficiency and immobile time. Sleep duration, sleep efficiency and immobile time all improved after the two week taper, indicating that a reduced training load at the expense of training volume improved sleep quality in triathletes.

The generally accepted function of sleep is that it serves to aid recovery for the body and mind from previous wakefulness and/or prepare the individual for the upcoming wake period (Halson, 2014; Leeder et al., 2012; Samuels, 2008). Poor sleep spanning across several days or weeks may potentially predispose athletes to injury and illness via higher chronic fatigue levels (Cohen, Doyle, Alper, Janicki-Deverts, & Turner, 2009; Hausswirth et al., 2014; Meeussen et al., 2013). Therefore, monitoring longitudinal sleep behavior may be an important potential and controllable mechanism of reducing the severity and occurrence of performance decrements, injuries and illnesses (Dennis et al., 2016; Luke et al., 2011; Milewski et al., 2014; Vgontzas et al., 2004).

With the available evidence, the likely implications for poor performance after partial sleep restriction indicates that female university soccer players may be at risk for insufficient quantity and or poorer quality of sleep prior to competition. To date, no study has reported the sleep patterns of female university soccer players pre- and post-match over the course of a competitive season and whether these patterns play a factor in possible running performance decrements already observed in this population.

1.4 Statement of the Problem

It is evident that soccer is a demanding game and that when played, one match per week allows for enough time to recover before the next. However, when playing two or more matches per week and with the possibility of an accumulation of partial sleep deprivation, there could be a lack of recovery and thus an increased chance for residual fatigue to manifest in reduced running performance. With an abundant amount of research reporting on fixture congestion (i.e. frequent matches are played over a short period of time) in professional male soccer players, research on female soccer players is considerably lacking in the literature. With only two studies reporting the running performance of female university soccer players over the course of a season, further research is warranted, especially in situations where matches are played on consecutive days. Sleep is regarded as a necessary physiological and important recovery modality by athletes, however, limited research is available that reports on the sleep patterns of university athletes, let alone, female athletes. It would be worthwhile indicating whether sleep quantity and quality are affected by frequent matches and training. Therefore, this research study will focus on female university soccer players and have a dual purpose. Firstly, the primary purpose of this research is to establish if there is a decrease in running performance variables as assessed by GPS from the first to second match in back-to-back games in female university soccer players. A secondary purpose is, to determine whether the sleep quantity and quality of this population decreases throughout the course of the weekend.

1.5 Hypotheses

1. The total distance, distance of high-intensity running (≥ 16 km/hr), relative speed, number of sprints, sprint distance, the number of accelerations and decelerations, specifically $\geq 3\ m \cdot s^{-2}$ and $\geq -3\ m \cdot s^{-2}$, respectively, performed will decrease during the second match compared to the first match when these matches are separated by less than 24 hours..

2. Bad sleepers, as indicated by the PSQI, will perform worse in higher intensity running (≥ 16 km/hr), sprint number, sprint distance and accelerations ≥ 3 m□s^{2} on the second compared to the first match, when compared to good sleepers.

3. Sleep characteristics will change over the course of the weekend from T1 to T2 (T1; Training 1, T2; Training 2). Sleep onset latency, number of wake episodes, wake episode duration will all increase after each match and progressively worsen until T2, while total sleep time, time in bed and sleep efficiency should decrease, with the lowest values seen on T2.

4. A positive relationship will be found between components of sleep characteristics (efficiency, total sleep time, time in bed) sleep quality and GPS running variables (high intensity running zones three through six, accelerations in zone three, sprint number and distance).

5. A negative relationship will be found between total length of awakenings and GPS running variables (high intensity running zones three through six, accelerations in zone three, sprint number and distance).

CHAPTER 2 – METHODS

2.1 Participants

Twelve U Sport level outfield female soccer players were recruited as study participants. The following characteristics were assessed in the soccer players at the beginning of the season, age, height (cm) and weight (kg), and how long they have been in university. Participants were tracked across seven weekends, on five of which matches were played with less than 24 hrs between them (i.e. Saturday and Sunday). On two different weekends, matches were played with greater than 24 hours between each other (i.e. Friday and Sunday; Thursday and Saturday) and were therefore omitted from the data set. Participants were instructed not to veer from their normal habits (i.e. diet, smoking, drinking alcohol, medication). Nutrition logs were not documented throughout this study. The study was approved by the Education and Nursing Research Ethics Board at the University of Manitoba (APPENDIX A). All participants (APPENDIX B) and the athletic director (APPENDIX C) provided written informed consent. All participation was voluntary and participants were made aware that they could discontinue from the study at anytime.

2.2 Global Positioning System

Thirty minutes prior to the commencement of warm-ups of training sessions and matches, Global Positioning System (GPS), which contains an accelerometer that captures movements at 100Hz (SPI HPU, 15 Hz, GPSport, Canberra, Australia), units were switched on by the investigator and placed outdoors in the docking station for participants to take their assigned unit. Participants were fitted with a GPS unit before the warm-up, in a tight fitting vest to reduce movement artifact (noise) for the entire training session and matches. At the end of matches, the participant returned the GPS unit and vest to the investigator. Data was then downloaded and split into different warm up components, first half, half-time and second half using the manufacturer's software and then exported to an Excel spreadsheet file. In accordance with McCormack et al. (2015), data for each match was averaged for the players who participated in a minimum of 45 minutes of that match. These 45 minutes did not have to be continuous; the players solely needed to have accumulated a minimum of 45 minutes of playing time to be included in the data set.

The speed zones used were categorized as low-intensity running (Distance Zone one) (0-11.9 km/hr), moderate intensity running (Distance Zone two) (12-15.9 km/hr), high-intensity running zone one (Distance Zone three) (16-17.9 km/hr), high-intensity zone two (Distance Zone four) (18-19.9 km/hr), high-intensity zone 3 (Distance Zone five) (20-22.9 km/hr) and high-intensity zone 4 (Distance Zone six) ($\geq$ 23 km/hr). The primary running variable measured from GPS units used in the data analysis were the number of sprints because this variable encompasses the most important activities observed in soccer matches (i.e. creating and stopping goal scoring opportunities) (Di Salvo et al., 2009; Di Salvo et al., 2010; Reilly et al., 2000; Varley & Aughey, 2013). The secondary running variables that were measured in this study included: total distance (meters), distance of high-intensity running (m), relative distance covered ($m \cdot min^{-1}$) (calculated as per the distance covered/ by the total time the participant was on the field), and the number of accelerations and decelerations. In this investigation, a sprint was defined as a running velocity equal to or greater than 23 km/hr and lasting longer than one second. All participants were deemed capable of attaining this sprint speed after analysis of 40 meter sprint times at the end of preseason. High-intensity running was defined as running at or greater than 16 km/hr (Distance Zone three and higher). A summation of high intensity running of all zones equal to or greater than 16 km/hr was used (calculated by summating high-intensity running zones three through six; at or greater than 16 km/hr) (Distance Zones three through six).

In accordance with Akenhead et al. (2013), acceleration and deceleration counts were analyzed using operationally defined thresholds of low acceleration (LA; Zone one; from 1 to 2 $m \cdot s^{-2}$), medium acceleration (MA; Zone two; from 2 to 3 $m \cdot s^{-2}$), high acceleration (HA; Zone three; $\geq$3 $m \cdot s^{-2}$), high deceleration (HD; Zone three; $\geq$ -3 $m \cdot s^{-2}$), medium deceleration (MD; Zone two; from -3 to -2 $m \cdot s^{-2}$), low deceleration (LD; Zone one; from -2 to -1 $m \cdot s^{-2}$). The number of accelerations from all zones were summed giving a calculation for total acceleration. The same method was applied to total decelerations.

2.3 Sleep

The Pittsburgh Sleep Quality Index (PSQI) is an effective instrument to assess the global quality and quantity of sleep and persistent sleep disturbances of a research participant (Buysse et al., 1989) (Appendix D). The PSQI assesses seven areas: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications and daytime dysfunction. The seven component scores are then summed to yield a global PSQI score, which ranges from 0-21, with a higher score indicating a poorer sleep quality. Scores $\geq$ 5 indicate that a subject is having severe difficulties in at least two areas or moderate difficulties in more than three areas. The PSQI was administered one month after the completion of the final match of the season. All PSQI data was acquired by the first week of December, 2016. The PSQI was used as a reference point to determine the global sleep quantity and quality over the past month as well as to determine whether participants were deemed “good” or “bad” sleepers. A bad sleeper was identified if the global PSQI score was $\geq$ 5 as per the instructions from Buysse et al. (1989). Periods of napping were not documented throughout this study, even though participants may have napped. Permission was granted from the author to use the PSQI (Appendix E). Mean global PSQI scores and various assessment components are available in Appendix F.

Participants were required to complete the Core Consensus Sleep Diary (Core CSD) in accordance with the instructions set out by Carney et al. (2012) (Appendix G). Permission was granted from the author to use the Core CSD (Appendix H). The core components necessary for a sleep diary that Carney et al. (2012) deemed critical are bedtime, sleep onset latency, number of wake episodes, wake episode duration, awakening time (getting out of bed) and total sleep time. These basic parameters were deemed satisfactory for distinguishing patients with primary insomnia from normal sleepers as well as comparisons with actigraphy (SenseWear Armband™) in athletes (Natale et al., 2015; Kölling et al., 2016a).

Participants were instructed to complete the Core CSD within one hour after waking on the morning prior to match day one (T1), morning of match day one (MD1), morning of match day two (MD2) and on the first day post-match (T2) (Appendix I). The morning prior to match day one (T1) was used as a baseline measure of sleep prior to each weekend's matches. Only Core CSD data from participants who competed in both matches over the course of the weekend (minimum of 45 accumulated minutes played in each match) were included in subsequent data analysis. The items used for subsequent analysis were: sleep onset latency, number of wake episodes, duration of wake episodes, sleep quality, total sleep time (TST), time in bed (TIB) and sleep efficiency.

In order to calculate Core CSD using a spreadsheet, time rotated around 12am (midnight). Midnight was considered zero and any time left of zero was considered negative, while any time after midnight was positive. For example, if a participant went to bed at 11:45 pm, the time entered in to the spreadsheet would be -15, if the participant went to bed at 1:10 am, the time entered would be 70. Using a custom spreadsheet, TST was calculated by subtracting the participants final awakening time from the time they tried to go to sleep, then subtracting the duration of sleep onset latency and total length of awakenings. Similarly, TIB was calculated by the time the participant got out of bed for the day from the time that they tried to fall asleep. Sleep efficiency was calculated by dividing TST by TIB, then multiplying this value by 100 to give a percentage. Time of completion of Core-CSD was at the end of the regular season, October 24th, 2016

2.4 Statistical Analysis

Participant flow

The potential total participant pool which was available for this study was 32. Since outfield players were the desired participants, four goalkeepers were excluded. Of the remaining 28 potential participants, eight individuals were excluded from the sample, having not played in any games throughout the season, leaving 20 viable participants. Of the remaining participants, 16 played in games while wearing GPS units, of those 16, three participants did not play in back-to-back matches, leaving 13 participants. One participant was excluded from the 13 viable participants due to not meeting the minimum of 45 minutes played in each match over the course of the weekend. The final sample size was N = 12 for GPS data. For sleep data, only one participant was excluded for subsequent data analysis due to not having any sleep diary data for matches, leaving the final number for sleep data analysis at $N = 11$.

Missing Data

Our study reported missing data of 35% based on participants' not meeting our inclusion criteria. Missing data was imputed using the kNN (Nearest Neighbor) method. The kNN method, missing values of cases with missing data (recipients) are replaced by values extracted from cases (donors) that are similar to the recipient (Beretta & Santaniello, 2016). The number of k neighbors was set to 3, as this number appears to preserve the original distribution of data (Beretta & Santaniello, 2016).

False Discovery Rate

A False Discovery Rate Adjustment (Hassard & Becker, 1986) was used to correct for multiple comparisons, was calculated as follows:

$0.05 * (t + 1) /2t$

where t is the number of tests conducted.

Data were compiled and presented as mean $\pm$ SD, unless otherwise stated, for all performance and sleep variables for each day assessed. Differences between the mean relative distance rate (total distance travelled divided by the total minutes played), high intensity running, number of sprints performed, number of accelerations and decelerations performed at different zones and minutes played during the first (G1; Game 1) and second matches (G2; Game 2) throughout the regular season were analyzed using a two factor time (G1 versus G2) by group (good versus bad sleepers) repeated measures ANOVA. A two factor time (T1, MD1, MD2, T2) by group (good versus bad sleepers) repeated measures ANOVA was calculated for sleep onset latency, wake episode duration, total sleep time, time in bed and sleep efficiency for T1, MD1, MD2 and T2. For nonparametric variables, the Friedman Test was used on the number of wake episodes and sleep quality on T1, MD1, MD2 and T2. The Pearson product-moment coefficient of correlation was used to determine whether a relationship existed between the total length of awakenings, sleep efficiency, total sleep time, time in bed and sleep quality from MD1, MD2 and T2 with GPS running variables. A post hoc power analysis was used to determine the required sample size (N) which indicated that a sample size of 170 participants was required. All statistical analyses were calculated using TIBCO STATISTICA version 13.3 (StatSoft, Tulsa, Oklahoma, USA) software, with significance set at $p \leq .05$.

CHAPTER 3: RESULTS

Table 1 indicates participant baseline demographic data. Briefly, 12 female U Sport soccer players from the University of Manitoba participated in this study (age 19.44 $\pm$ 1.69 years old, height 162.41 $\pm$ 4.56 cm, weight 60.38 $\pm$ 4.39 kg, years in university 2 $\pm$ 1.04) (Table 1).

Table 1

Anthropometric data of female U Sport soccer players

	Pooled (N = 12)	Good Sleepers (n = 5)	Bad Sleeper (n = 7)
Age (years)	19.44 $\pm$ 1.69	19.01 $\pm$ 0.99	20.94 $\pm$ 1.81*
Height (cm)	162.41 $\pm$ 4.56	163.71 $\pm$ 5.06	160.6 $\pm$ 3.44
Weight (kg)	60.38 $\pm$ 4.39	60.77 $\pm$ 5.12	59.84 $\pm$ 3.62
Years in University	2 $\pm$ 1.04	1.57 $\pm$ 0.79	2.60 $\pm$ 1.14

Note. * Significantly different from good sleepers, $p < .05$; all values are displayed as mean $\pm$ standard deviation

When analyzing the differences in GPS variables between good and bad sleepers by repeated measures ANOVA, only relative speed demonstrated a significant time by group interaction ($p < .05$; see Table 2). Post hoc analysis indicated that good sleepers ($n = 5$) had significantly higher mean relative speed in G1 (113.22 $\pm$ 3.32 $m \cdot min^{-1}$) compared to G2 (109.16 $\pm$ 4.33 $m \cdot min^{-1}$) (Figure 1). No statistically significant group effects were observed ($p > .05$); however, there were significant main time effects ($p \leq .026$) for all GPS performance variables except relative speed and deceleration in zone one ($p > .026$; see Table 2) where the significant GPS performance variables all decreased from G1 to G2. With $p \leq .05$, only decelerations zone one were not significant ($p = .071$) when G2 was compared to G1.

Table 2

Comparison of mean global positioning system (GPS) running variables from Game 1 (G1) to Game 2 (G2) in Good and Bad sleepers within female U Sport soccer players

Variables	G1	G2	*P*-Value		
			Time	Group	Time X Group
Duration (min)					
Good	84.82 ± 7.43	82.51 ± 9.81	.009*	.701	.094
Bad	89.49 ± 4.98	81.03 ± 5.17			
Relative speed ($m \cdot min^{-1}$)					
Good	113.22 ± 3.32	109.16 ± 4.33	.040	.460	.015*
Bad	107.81 ± 11.23	108.25 ± 9.25			
Total Distance (m)					
Good	9576.15 ± 625.32	9019.49 ± 729.16	.000*	.847	.198
Bad	9641.41 ± 716.74	8778.82 ± 1081.18			
Distance Zone one (m)					
Good	6736.92 ± 534.75	6554.67 ± 726.39	.004*	.665	.082
Bad	6807.24 ± 290.85	6221.08 ± 356.8			
Distance Zone two (m)					
Good	1902.50 ± 124.61	1679.86 ± 107.65	.000*	.534	.404
Bad	1775.54 ± 390.19	1605.21 ± 422.45			
Distance Zone three (m)					
Good	448.63 ± 38.35	381.19 ± 36.96	.000*	.707	.212
Bad	459.76 ± 151.32	417.35 ± 169.73			
Distance Zone four (m)					
Good	263.06 ± 28.00	214.27 ± 34.81	.000*	.442	.133
Bad	287.22 ± 100.15	258.54 ± 119.42			

Table 2 continued

Variables	G1	G2	*P*-Value		
			Time	Group	Time X Group
Distance Zone five (m)					
Good	174.32 + 32.31	147.03 + 27.08	.002*	.258	.239
Bad	212.05 + 88.62	197.80 + 98.63			
Distance Zone six (m)					
Good	50.73 + 11.23	42.46 + 5.91	.003*	.178	.131
Bad	99.59 + 84.89	78.83 + 73.64			
Distance Zone three through six (m)					
Good	936.73 + 101.27	784.95 + 96.94	.000*	.365	.160
Bad	1058.62 + 374.94	952.53 + 415.87			
Sprint Count (#)					
Good	5.61 + 1.39	3.98 + 0.33	.000*	.198	.811
Bad	8.05 + 4.71	6.28 + 4.38			
Sprint Distance (m)					
Good	257.63 + 67.03	199.40 + 17.18	.004*	.217	.741
Bad	357.45 + 203.81	309.09 + 216.64			
Accelerations Zone one (#)					
Good	340.50 + 34.35	330.75 + 35.86	.010*	.592	.139
Bad	341.41 + 17.79	311.51 + 23.65			
Accelerations Zone two (#)					
Good	93.53 + 12.86	86.54 + 10.38	.000*	.640	.668
Bad	97.32 + 9.75	89.04 + 12.16			
Accelerations Zone three (#)					
Good	22.57 + 6.72	19.66 + 4.04	.003*	.272	.629
Bad	26.45 + 5.74	22.64 + 3.77			

Table 2 continued

Variables	G1	G2	*P*-Value		
			Time	Group	Time X Group
Total Accelerations (#)					
Good	456.61 ± 47.82	436.95 ± 39.63	.002*	.909	.173
Bad	465.19 ± 28.59	423.19 ± 38.32			
Decelerations Zone one (#)					
Good	276.90 ± 33.43	273.73 ± 29.46	.071	.689	.171
Bad	279.37 ± 20.31	258.97 ± 18.83			
Decelerations Zone two (#)					
Good	92.33 ± 12.30	85.66 ± 9.13	.001*	.814	.835
Bad	90.71 ± 15.76	83.37 ± 19.89			
Decelerations Zone three (#)					
Good	37.10 ± 9.70	31.80 ± 6.75	.000*	.363	.321
Bad	44.03 ± 14.21	35.83 ± 9.95			
Total Decelerations (#)					
Good	406.33 ± 45.03	391.19 ± 35.70	.003*	.906	.161
Bad	414.11 ± 27.48	378.17 ± 44.02			

Note. All values are displayed as mean ± standard deviation. G1 = Game 1; G2 = Game 2.

[a] Good sleepers $n = 5$.

[b] Bad sleepers $n = 7$.

* Indicates significantly different $p \leq .026$

Figure 1. Results of Repeated Measures Analysis of Variance to represent the time by group effect for relative speed

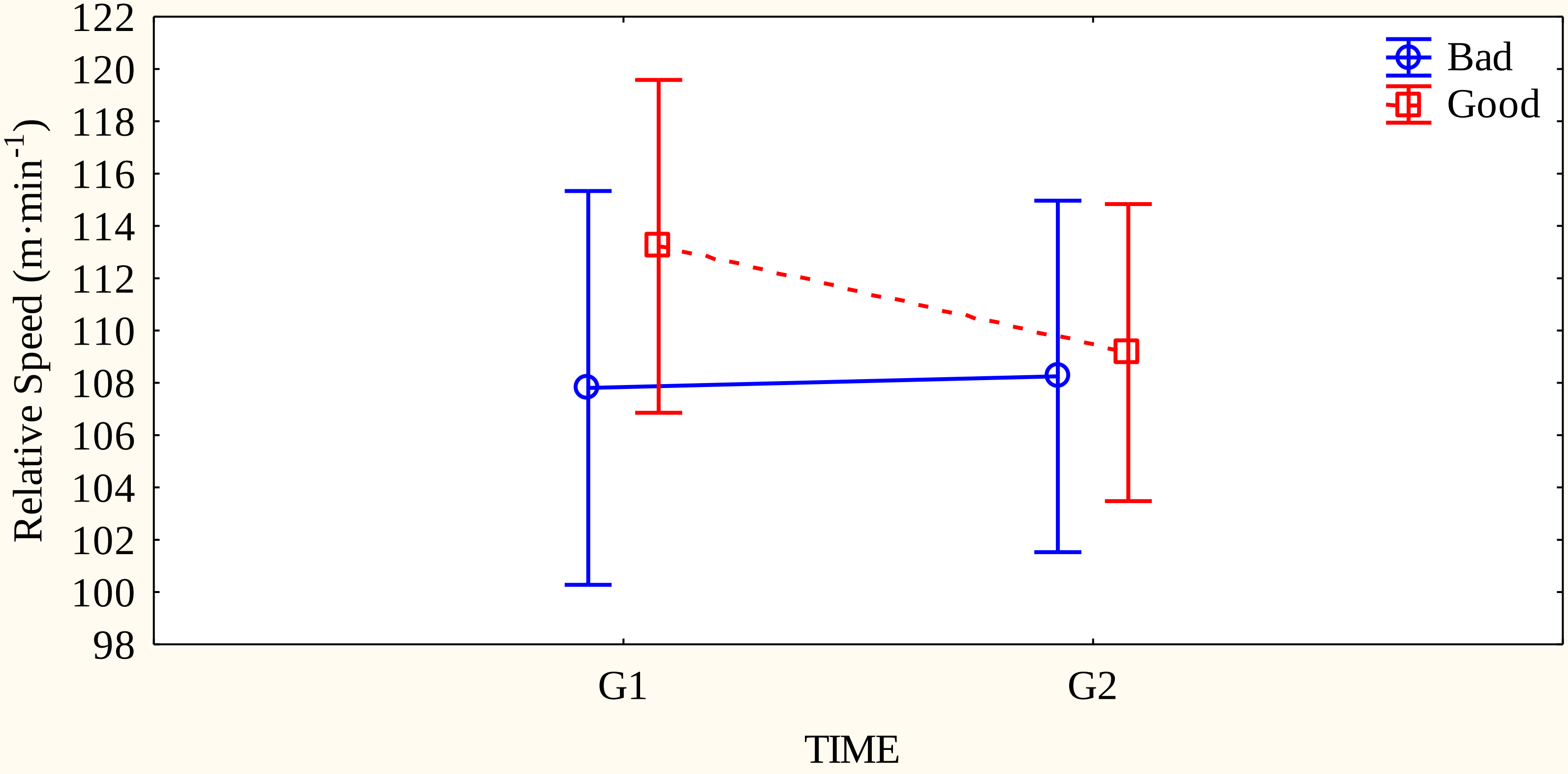

Figure 1. Graph displaying the time by group interaction between relative speed (derived from global positioning system) and good and bad sleepers (based on the Pittsburgh Sleep Quality Index). Vertical bars denote 0.95 confidence intervals. G1 = Game 1; G2 = Game 2.

Using repeated measures ANOVA, the sleep patterns from T1, MD1, MD2 and T2 were analyzed and results are indicated in Table 3. Significant main effects for time were noted for WASO ($p < .001$), sleep efficiency ($p < .001$), total sleep time ($p < .001$), and time in bed ($p = .008$). Post hoc analysis indicated that WASO on T1 (2.19 ± 1.90 min) and MD1 (6.58 ± 4.85 min) were significantly lower when compared to MD2 (13.52 ± 11.59 min). Sleep efficiency post hoc analysis indicated that T2 (87.71 ± 7.69%) was significantly lower than T1 (93.33 ± 3.97%), MD1 (92.33 ± 4.99 %) and MD2 (90.91 ± 5.70 %). Further post hoc analysis of total sleep time indicated a significant less amount of sleep time observed for T2 (417.06 ± 57.22 min) compared to T1 (453.07 ± 44.03 min), MD1 (466.87 ± 39.70 min) and MD2 (460.19 ± 45.32 min). Post hoc analysis of time in bed demonstrated a significant decrease for T2 (475.33 ± 46.36 min) compared to MD1 (503.91 ± 30.82 min) and MD2 (504.45 ± 30.91 min), but not T1 (484.03 ± 33.45 min). No significant effects were observed for sleep onset latency ($p > .05$). A group effect ($p = .05$) was observed for total sleep time where good sleepers (472.08 min) slept longer than bad sleepers (421.95 min). No time by group interactions were noted for any of the sleep variables ($p > .05$).

Using the Friedman test for nonparametric variables, no significant effects were observed for the number of awakenings and sleep quality ($p > .05$); see Table 4.

Table 3

Good and Bad sleeper mean Core sleep diary data of female U Sport soccer players over the course of a weekend

Variables	T1	MD1	MD2	T2	*P*-Value		
					Time	Group	Time X Group
SOL (min)							
Good	9.96 ± 3.67	8.22 ± 2.15	9.32 ± 3.64	10.61 ± 5.18	.256	.224	.992
Bad	15.15 ± 8.31	13.41 ± 8.76	14.64 ± 10.63	16.52 ± 12.56			
WASO (min)							
Good	1.40 ± 0.94	5.26 ± 2.17	11.09 ± 6.01	5.34 ± 4.72	.000*	.347	.881
Bad	3.13 ± 2.42	8.16 ± 6.86	16.43 ± 16.46	9.67 ± 11.18			
SE (%)							
Good	95.24 ± 2.34	94.60 ± 1.89	93.03 ± 2.75	89.85 ± 3.64	.000$	.164	.985
Bad	91.03 ± 4.54	89.61 ± 6.38	88.36 ± 7.55	85.13 ± 10.78			
TST (min)							
Good	475.09 ± 33.97	485.37 ± 26.92	481.94 ± 36.09	445.93 ± 40.22	.000#	.050¥	.628
Bad	426.65 ± 42.47	444.67 ± 43.65	434.09 ± 44.10	382.41 ± 58.42			
TIB (min)							
Good	497.28 ± 26.71	511.13 ± 19.96	516.36 ± 29.77	497.78 ± 46.68	.008€	.097	.395
Bad	468.13 ± 36.41	495.24 ± 41.29	490.17 ± 28.53	448.40 ± 31.41			

Note. All values are displayed as mean ± standard deviation. $p \leq .05$. TST = Total Sleep Time; TIB = Time in Bed; WASO = Wake After Sleep Onset; SOL = Sleep Onset Latency; SE = Sleep Efficiency; T1 = Training 1; MD1 = Match Day 1; MD2 = Match Day 2; T2 = Training 2.

[a] Good sleepers $n = 5$. [b] Bad sleepers $n = 6$.

[*] Indicates MD2 is significantly different to T1 and MD1 $p \leq .05$

Table 3 continued

$ Indicates T2 is significantly different to all other time points $p \leq .05$

# Indicates T2 is significantly different to all other time points $p \leq .05$

¥ Indicates a significant difference between Good and Bad sleepers $p \leq .05$

€ Indicates T2 is significantly different to MD1 and MD2 $p \leq .05$

Table 4

Mean nonparametric data of Good and Bad sleeper Core sleep diary data of female U Sport soccer players over the course of a weekend

Variables	T1	MD1	MD2	T2
Number of Awakenings (#)				
Good	1.31 ± 0.80	1.37 ± 0.54	1.68 ± 0.72	1.28 ± 0.76
Bad	1.44 ± 1.15	1.79 ± 1.61	2.24 ± 1.60	2.04 ± 1.36
Sleep Quality (1-5 scale)				
Good	3.62 ± 0.21	3.62 ± 0.20	3.41 ± 0.36	3.39 ± 0.37
Bad	3.23 ± 0.27	3.17 ± 0.29	2.93 ± 0.51	2.93 ± 0.32

Note. All values are displayed as mean ± standard deviation. $p \leq .050$. T1 = Training 1; MD1 = Match Day 1; MD2 = Match Day 2; T2 = Training 2.

[a] Good sleepers $n = 5$. [b] Bad sleepers $n = 6$.

The correlation coefficients of sleep variables with GPS running variables are shown in Table 5. The following variables were correlated at the $p < .05$ level: Total sleep time on T1 was negatively correlated with G1 distance zone five ($r = -.65$), deceleration zone two ($r = -.64$), deceleration zone three ($r = -.67$), and total decelerations ($r = -.65$). Total sleep time on T1 was negatively correlated with G2 distance zone four ($r = -.62$), distance zone five ($r = -.63$), distance zones three through six ($r = -.60$), and deceleration zone three ($r = -.74$). No correlations were present between total sleep time on MD1 and G1. Total sleep time on MD1 was negatively correlated with G2 distance zone four ($r = -.63$), and deceleration zone three (*r* = -.68). Total sleep time on MD2 was negatively correlated with G1 deceleration zone two (*r* = -.73). Total sleep time on MD2 was negatively correlated with G2 distance zone three (*r* = -.61), distance zone four (*r* = -.69), distance zone five (*r* = -.61), distance zones three through six (*r* = -.60), deceleration zone two (*r* = -.60), and deceleration zone three (*r* = -.71). No correlations were observed for total sleep time between T2 and G1 and G2.

Time in bed on T1 was negatively correlated with G1 distance zone four (*r* = -.66), distance zone five (*r* = -.79), distance zone six (*r* = -.68), distance zones three through six (*r* = -.75), sprint count (*r* = -.67), sprint distance (*r* = -.67), deceleration zone two (*r* = -.71), deceleration zone three (*r* = -.78) and total deceleration (*r* = -.74). Time in bed on T1 was negatively correlated with G2 distance zone three (*r* = -.62), distance zone four (*r* = -.70), distance zone five (*r* = -.74), distance zone six (*r* = -.62), distance zones three through six (*r* = -.74), sprint count (*r* = -.62), sprint distance (*r* = -.69), acceleration zone three (*r* = -.62), deceleration zone two (*r* = -.62), deceleration zone three (*r* = -.80) and total deceleration (*r* = -.62).

Time in bed on MD1 was negatively correlated with G1 relative speed (*r* = -.64), distance zone two (*r* = -.62), distance zone three (*r* = -.83), distance zone four (*r* = -.80), distance zone five (*r* = -.71), distance zones three through six (*r* = -.76), deceleration zone two (*r* = -.75), and deceleration zone three (*r* = -.77). Time in bed on MD1 was negatively correlated with G2 relative speed (*r* = -.85), distance zone two (*r* = -.73), distance zone three (*r* = -.87), distance zone four (*r* = -.85), distance zone five (*r* = -.78), distance zones three through six (*r* = -.80), deceleration zone two (*r* = -.79), and deceleration zone three (*r* = -.83).

Time in bed on MD2 was negatively correlated with G1 total distance (*r* = -.75), distance zone three (*r* = -.70), distance zone three through six (*r* = -.64), acceleration zone two (*r* = -.69), acceleration zone three (*r* = -.78), total accelerations (*r* = -.65), deceleration zone two (*r* = -.78), deceleration zone three (*r* = -.72), and total decelerations (*r* = -.77). Time in bed on MD2 was negatively correlated with G2 distance zone three (r = -.61), distance zone four (*r* = -.67), distance zones three through six (*r* = -.62), acceleration zone two (*r* = -.77), acceleration zone three (*r* = -.61), total accelerations (*r* = -.61), deceleration zone two (*r* = -.72), deceleration zone three (*r* = -.70), and total decelerations (*r* = -.65).

Time in bed on T2 was negatively correlated with G1 duration (*r* = -.71), acceleration zone one (*r* = -.61), total accelerations (*r* = -.67), and total decelerations (*r* = -.79). No statistically significant relationships were observed for T2 with G2.

Sleep quality on T1 was negatively correlated with G1 acceleration zone three (*r* = -.69). Sleep quality on MD1 was positively correlated with G2 distance zone one (*r* = .65), and acceleration zone one (*r* = .63). Sleep quality on MD2 was negatively correlated with G2 distance zone four (*r* = -.64).

Length of awakenings on MD2 was positively correlated with G1 distance zone three (*r* = .77), distance zone four (*r* = .77), distance zone five (*r* = .69), distance zones three through six (*r* = .68), and deceleration zone two (*r* = .82). Length of awakenings on MD2 was positively correlated with G2 relative speed (*r* = .63), distance zone three (*r* = .82), distance zone four (*r* = .84), distance zone five(*r* = .72), distance zones three through six (*r* = .73), deceleration zone two (*r* = .75), and deceleration zone three (*r* = .74).

Length of awakenings on T2 was positively correlated with G1 deceleration zone two (*r* = .68). Length of awakenings on T2 was positively correlated with G2 distance zone three (*r* = .65), distance zone four (*r* = .71), distance zone five (*r* = .65), distance zones three through six (*r* = .63), and deceleration zone three (*r* = .69). No statistically significant correlations were observed for length of awakenings for T1 and MD1with G1 and G2.

No statistically significant relationships existed between sleep efficiency and GPS running variables for any time point, therefore sleep efficiency data is omitted from Table 5.

Table 5

Summary of Pearson product-moment coefficient of correlation between sleep variables and Game 1 (G1) and Game 2 (G2) global positioning system (GPS) running variables

		TST				TIB			
		T1	MD1	MD2	T2	T1	MD1	MD2	T2
Duration (min)	G1	-.43	.08	-.28	-.46	-.39	.30	-.38	-.71*
	G2	-.18	.35	-.08	-.05	-.36	.15	-.35	-.40
Relative speed ($m \cdot min^{-1}$)	G1	.14	-.13	-.09	.35	-.01	-.64*	-.23	.36
	G2	-.09	-.47	-.34	.09	-.14	-.85$	-.36	.19
Total Distance (m)	G1	-.39	-.06	-.46	-.18	-.52	-.37	-.75*	-.49
	G2	-.24	.06	-.29	.00	-.46	-.37	-.57	-.28
Distance Zone one (m)	G1	-.16	.26	-.14	-.14	-.16	.27	-.37	-.46
	G2	.03	.43	.02	.15	-.13	.16	-.28	-.19
Distance Zone two (m)	G1	-.14	-.14	-.35	.10	-.28	-.63*	-.60	-.05
	G2	-.23	-.21	-.35	.05	-.42	-.73*	-.58	-.09
Distance Zone three (m)	G1	-.43	-.45	-.59	-.19	-.55	-.84$	-.70*	-.25
	G2	-.51	-.57	-.61*	-.29	-.62*	-.87$	-.61*	-.25
Distance Zone four (m)	G1	-.52	-.51	-.58	-.30	-.66*	-.81*	-.60	-.29
	G2	-.62*	-.63*	-.70*	-.41	-.70*	-.85$	-.67*	-.38
Distance Zone five (m)	G1	-.65*	-.51	-.59	-.43	-.79*	-.71	-.59	-.45
	G2	-.63*	-.59	-.61*	-.41	-.74*	-.78	-.57	-.40
Distance Zone six (m)	G1	-.49	-.12	-.17	-.30	-.68*	-.22	-.29	-.51
	G2	-.39	.03	-.05	-.18	-.62*	-.13	-.24	-.45
Zone three through six (m)	G1	-.58	-.46	-.57	-.33	-.75*	-.77*	-.64*	-.40
	G2	-.60*	-.55	-.60*	-.37	-.74*	-.80*	-.62*	-.38

Table 5 continued

		TST				TIB			
		T1	MD1	MD2	T2	T1	MD1	MD2	T2
Sprint Count (#)	G1	-.46	-.11	-.19	-.27	-.67*	-.25	-.30	-.46
	G2	-.38	.01	-.08	-.17	-.61*	-.16	-.26	-.43
Sprint Distance (m)	G1	-.46	-.15	-.23	-.27	-.69*	-.31	-.32	-.43
	G2	-.47	-.13	-.19	-.24	-.69*	-.31	-.33	-.45
Accelerations Zone one (#)	G1	-.33	.21	-.22	-.27	-.38	.20	-.47	-.61*
	G2	-.04	.37	-.06	.10	-.23	.05	-.40	-.25
Accelerations Zone two (#)	G1	-.42	-.14	-.40	-.24	-.47	-.33	-.69*	-.52
	G2	-.49	-.29	-.53	-.26	-.57	-.57	-.77*	-.48
Accelerations Zone three (#)	G1	-.54	-.36	-.53	-.34	-.60	-.56	-.78*	-.58
	G2	-.53	-.24	-.36	-.32	-.62*	-.40	-.61*	-.58
Total Accelerations (#)	G1	-.44	.06	-.35	-.31	-.50	-.04	-.65*	-.67*
	G2	-.23	.20	-.24	-.02	-.41	-.16	-.61*	-.40
Decelerations Zone one (#)	G1	-.30	.26	-.17	-.30	-.34	.36	-.37	-.60
	G2	-.12	.34	-.06	.02	-.34	.05	-.36	-.31
Decelerations Zone two (#)	G1	-.64*	-.53	-.73*	-.44	-.71*	-.76*	-.78*	-.47
	G2	-.50	-.43	-.60*	-.26	-.62*	-.79*	-.72*	-.32
Decelerations Zone three (#)	G1	-.67*	-.54	-.60	-.43	-.78*	-.78*	-.72*	-.54
	G2	-.74*	-.68*	-.71*	-.53	-.80*	-.83*	-.70*	-.50
Total Decelerations (#)	G1	-.65*	-.13	-.56	-.51	-.74*	-.21	-.77*	-.79*
	G2	-.41	-.06	-.40	-.18	-.62*	-.41	-.65*	-.43

Note. $p < .050$. TST = Total Sleep Time; TIB = Time in Bed; WASO = Wake After Sleep Onset; T1 = Training 1; MD1 = Match Day 1; MD2 = Match Day 2; T2 = Training 2; $n = 11$.

* indicates $p \leq .05$, $ indicates $p \leq .001$

Table 5 continued

		Sleep Quality				WASO			
		T1	MD1	MD2	T2	T1	MD1	MD2	T2
Duration (min)	G1	-.29	.21	-.03	-.23	.45	-.28	-.14	.08
	G2	.17	.53	.14	.26	-.24	-.45	-.01	.02
Relative speed (m·min^{-1})	G1	.07	.05	-.27	.14	-.59	.18	.48	.18
	G2	-.25	-.23	-.54	-.22	-.34	.42	.63*	.38
Total Distance (m)	G1	-.30	.32	-.35	-.14	-.13	-.15	.38	.32
	G2	.01	.39	-.18	.13	-.45	-.19	.38	.26
Distance Zone one (m)	G1	-.21	.41	-.02	-.09	.27	-.37	-.16	-.02
	G2	.20	.65*	.15	.31	-.26	-.46	-.03	-.07
Distance Zone two (m)	G1	-.15	.23	-.39	.01	-.41	.03	.55	.30
	G2	-.12	.06	-.37	.03	-.56	.06	.56	.33
Distance Zone three (m)	G1	-.31	-.01	-.56	-.22	-.32	.27	.77*	.53
	G2	-.29	-.17	-.59	-.29	-.28	.44	.82*	.65*
Distance Zone four (m)	G1	-.24	-.12	-.49	-.20	-.34	.34	.77*	.58
	G2	-.36	-.20	-.64*	-.40	-.18	.45	.84$	.71*
Distance Zone five (m)	G1	-.25	-.19	-.43	-.22	-.29	.29	.69*	.58
	G2	-.30	-.34	-.55	-.35	-.23	.41	.72*	.65*
Distance Zone six (m)	G1	-.04	-.30	-.02	-.01	-.35	-.14	.02	.18
	G2	.03	-.24	.11	.14	-.43	-.27	-.10	.04
Zone three through six (m)	G1	-.26	-.15	-.46	-.19	-.37	.23	.68*	.54
	G2	-.29	-.25	-.53	-.29	-.29	.36	.73*	.63*

Table 5 continued

		Sleep Quality				WASO			
		T1	MD1	MD2	T2	T1	MD1	MD2	T2
Sprint Count (#)	G1	.01	-.25	-.01	.07	-.42	-.14	.11	.15
	G2	.04	-.28	.04	.12	-.45	-.21	-.04	.08
Sprint Distance (m)	G1	.03	-.24	-.07	.05	-.44	-.07	.20	.22
	G2	-.02	-.29	-.06	.03	-.44	-.09	.12	.23
Accelerations Zone one (#)	G1	-.19	.48	.02	-.06	.19	-.40	-.08	.07
	G2	.15	.63*	.10	.33	-.33	-.47	.05	-.05
Accelerations Zone two (#)	G1	-.51	.04	-.34	-.26	.06	-.14	.14	.23
	G2	-.48	.04	-.47	-.29	-.06	.02	.42	.41
Accelerations Zone three (#)	G1	-.69*	-.23	-.51	-.43	.04	-.01	.28	.30
	G2	-.52	-.26	-.27	-.25	-.07	-.13	.08	.18
Total Accelerations (#)	G1	-.39	.32	-.16	-.18	.16	-.33	.03	.16
	G2	-.06	.51	-.07	.17	-.30	-.40	.17	.09
Decelerations Zone one (#)	G1	-.14	.42	.13	.05	.24	-.44	-.14	-.09
	G2	.19	.54	.17	.36	-.38	-.48	.06	-.08
Decelerations Zone two (#)	G1	-.42	.08	-.59	-.37	-.06	.33	.82*	.68*
	G2	-.31	.09	-.50	-.20	-.28	.23	.75*	.55
Decelerations Zone three (#)	G1	-.53	-.28	-.51	-.38	-.18	.19	.52	.51
	G2	-.53	-.26	-.59	-.45	-.05	.43	.74*	.69*
Total Decelerations (#)	G1	-.41	.28	-.25	-.20	.11	-.19	.31	.31
	G2	-.09	.35	-.18	.09	-.37	-.16	.45	.27

Note. $p < .05$. TST = Total Sleep Time; TIB = Time in Bed; WASO = Wake After Sleep Onset; T1 = Training 1; MD1 = Match Day 1; MD2 = Match Day 2; T2 = Training 2; G1 = Game 1; G2 = Game 2; $n = 11$.

* indicates $p \leq .05$, $^{\$}$ indicates p $\leq$ .001

CHAPTER 4: DISCUSSION

This is the first study, to our knowledge, that demonstrates that running and sleep patterns over the course of a season, in Canadian U Sport female university soccer players, are altered over weekends. In accordance with our first hypothesis, running performance was significantly reduced from G1 to G2 while sleep progressively worsened from T1 to T2 over the course of the weekends. Surprisingly, our second hypothesis was not supported in which bad sleepers did not perform worse than good sleepers for any of the running variables. Unexpectedly, for relative speed, good sleepers performed better on G1 compared G2, while bad sleepers' relative speed remained unchanged from G1 to G2. Our third hypothesis was partially supported in which total sleep time, time in bed and sleep efficiency all decreased from T1 to T2. The highest duration of awakenings was not observed on T2 but on MD2, while sleep onset latency and the number of awakenings did not significantly change throughout the course of the weekend. Strangely, a poor nights' sleep appears to increase high intensity running distance the next day.

Global Positioning System

Overall, our findings for total distance covered and relative speed from the first match (G1) were similar to values reported in National Collegiate Athletic Association female soccer players by Vescovi and Favero (2014). As for the amount of high intensity running performed in G1, our values are similar to the distances reported by elite female national players (930 $\pm$ 348 m; Mean $\pm$ SD), reported by Trewin, Meylan, Varley, and Cronin (2018). Finally, our data for the number of sprints performed (6.63 $\pm$ 3.27, Mean $\pm$ SD) were similar to those reported by McCormack et al. (2015) (4.31 $\pm$ 3.51; Mean $\pm$ SD). It is difficult to make any comparisons for sprint distance due to the variation in what speed threshold is used to define a sprint and whether sprint distance is reported in studies. Similarly, it is difficult to make any comparisons for accelerations and decelerations since studies use different speed zones and may indicate acceleration and deceleration distance, not frequency.

Our findings of reduced running performance derived from GPS in female U Sport soccer players are somewhat in accordance with McCormack et al. (2015). McCormack et al. (2015) demonstrated that high intensity running (HIR)/min was reduced significantly between two games performed on a Friday and Sunday (i.e. two days apart). Although we did not calculate HIR/min, HIR did significantly decrease from G1 to G2. Our findings indicate that duration and the number of sprints were significantly lower from G1 to G2 but not relative speed, which is in discordance with the results of McCormack et al. (2015), who indicated that relative speed, duration and sprint number were not significantly different from Friday to Sunday matches. The discrepancy between our findings and those of McCormack et al. (2015) possibly lie with the length of recovery between games (24 hrs vs 48 hrs) and discrepancies between GPS running speed zones for HIR. McCormack et al. (2015) deemed HIR equal to or greater than 3.61 m/s (13 km/hr) while our study was set to equal or greater than 16 km/hr. The only finding from our study that was in accordance with McCormack et al. (2015) was that relative speed was not significantly different for the entire participant sample between either time points.

As for the significant time by group effect observed for relative speed, in which good sleepers' relative speed significantly decreased from G1 to G2, while bad sleepers did not significantly change (Figure 1), it should be noted, that good sleepers mean relative speed at both time points was higher compared to bad sleepers. It is plausible that good sleepers were better rested for G1 and thus performed better than bad sleepers, based on relative speed. As for the significant decrease from G1 to G2 for good sleepers, it is possible that they may have not paced themselves properly during G1, in order to maintain a similar relative intensity for G2. Between good and bad sleepers, an uneven distribution of attacking players (i.e. attacking midfielders and fullbacks) was reported in good sleepers (data not shown), thus possibly increasing the relative speed observed in our results, since Di Salvo et al. (2009) indicated that running distance is playing position specific. Finally, the number of first year players allotted between groups was uneven, with good and bad sleepers having four and one first year players, respectively (data not shown). With good sleepers having a greater number of first year players, it is possible that they may not have been technically or tactically proficient for this standard of competition, thus likely increasing the possibility of making an error, culminating in an increase in running distance.

A number of possible mechanisms exist to explain the decrease in running performance from G1 to G2. Firstly, fluid loss of 2.0 % of body weight after playing soccer matches has been reported in both highly trained females and males (Krustrup et al., 2006; Andersson et al., 2008; Mohr et al., 2010; Krustrup et al., 2011). Shirreffs, Taylor, Leiper, & Maughan (1996) indicated that it takes ~6 hours to rehydrate and the main factors determining post-exercise rehydration status were the fluid volume consumed (which should be $\geq$ 150 % of sweat loss) and composition of the fluid consumed where the sodium concentration should be 61 mmol/L. Thus, dehydration likely plays a limited role in fatigue in a subsequent match. More likely, rehydration plays a more critical role in glycogen resynthesis in which a loss of intracellular fluid volume decreases the rate of glycogen and protein synthesis, while high-cell volume appears to have the opposite effect (Waller, Heigenhauser, Geor, Spriet, & Lindinger, 2009; Keller, Szinnai, Bilz, & Berneis, 2003).

Secondly, the amount of high-intensity running performed decreases throughout a match, possibly as a result of glycogen depletion (Mohr, Krustrup & Bangsbo, 2005; Krustrup et al., 2006; Bangsbo, Mohr & Krustrup, 2006; Krustrup et al., 2010; Krustrup et al., 2011). Many studies have supported this and indicated that muscle glycogen stores were significantly reduced post-match and did not completely recover to baseline levels within 48 to 72 hours irrespective of the level of play (Jacobs, Westlin, Karlsson, Rasmusson, & Houghton, 1982; Krustrup et al., 2011). Asp, Daugaard, Kristiansen, Kiens, and Richter (1998) reported that in seven male participants, previously eccentrically damaged muscles had lower muscle glycogen content compared to rested controls. The authors attributed damaging eccentric exercise to impaired glycogen synthesis, thus lowering glycogen storage. These investigations indicate the possible difficulty in replenishing glycogen stores after soccer matches if the next match is played within 24 hours. Without full recovery after a high level match, depleted muscle glycogen stores may impede sprinting and high-intensity running performance in matches played within 72 hours (Fatouros et al., 2010; Mohr et al., 2015).

Thirdly, during a soccer match, intense activities such as sprinting, accelerating, decelerating, changing directions, kicking and jumping, which encompass high force eccentric contractions, may culminate in skeletal muscle damage (Opar et al., 2012; Nédélec et al., 2012). Muscle damage is credited to mechanical disruption of the muscle fiber, including cell membrane (sarcolemma) damage, and disruptions of the myofibrillar banding patterns (Clarkson, Nosaka, & Braun, 1992; Raastad et al., 2009). The damaging effects of eccentric muscle actions are characterized by a temporary decrease in muscle function, and increase in intracellular proteins in blood as well as increased muscle soreness that can affect subsequent exercise capacity (Howatson & Van Someren, 2008; Nédélec et al., 2012; Krustrup et al., 2011; Mohr et al., 2015). Our results are the first, to our knowledge, that report a significant decrease in GPS running performance when matches are played with less than 24 hours of recovery.

Sleep

Our results indicate that total sleep time (TST), time in bed (TIB) and sleep efficiency (SE) progressively worsened from T1 to T2, while MD2 wake after sleep onset (WASO) was significantly higher compared to T1 and MD1 but not T2. No significant effects were observed for sleep onset latency (SOL), number of awakenings, and sleep quality.

In general, TST for T1 was within the recommended 7 to 9 hours of sleep per night (Ferrara & De Gennaro, 2001; Hirshkowitz et al., 2015; Watson et al., 2015), but well below the 9 to 10 hours recommended by Bompa and Haff (2009). Our data for SE, WASO and SOL are well below the cutoffs of < 85 %, > 30 min, and > 30 min, respectively (Schutte-Rodin, Broch, Buysse, Dorsey, & Sateia, 2008). As for sleep quality, our data are similar to what was reported by the National Sleep Foundation (2013) of which a majority of participants (76 %) indicated as having very good/fairly good sleep quality (based on a 4-point Likert-scale; ranging from very bad to very good). In comparison with the sample of students from Buboltz et al. (2001), mean weekday sleep time was 6:55 (hours:min), while our participants mean TST for T1 was 453 min (7:33; hours:min). This indicates that our sample was acquiring ~37 minutes more sleep than the student sample from Buboltz et al. (2001)

With the lowest TST values observed on T2, similar results have been demonstrated in male rugby (Shearer et al., 2015) and female netball players (O'Donnell et al., 2018) in which TST was significantly lower after matches compared to baseline. Unlike Shearer et al. (2015) and O'Donnell et al. (2018), our data indicate no significant change between MD1 and MD2, but significantly decreased after G2 (T2 sleep), possibly indicating an accumulation of physiological and non-physiological factors that may be at play. The decrease of TST on T2 may be a result of increased pain and muscle soreness accumulated over the course of the weekend, since muscle soreness can persist for up to 72 hours post-match (Krustrup et al., 2011). With school or the participants' regular weekly schedule recommencing on T2, regular wake times may have played a factor in reduced TST. Late night travel (arrival time ranged from 1-3 am on two separate occasions) and also the fear of travelling on planes/buses besides poor travelling conditions (i.e. turbulence and late night/poor driving conditions) may have increased participants' alertness. A group effect existed for TST, in which bad sleepers had significantly lower mean sleep times compared to good sleepers (~50 min). To our knowledge, this is the only data available to demonstrate a significant group effect between good and bad sleepers in an athletic population. It should be noted that neither good nor bad sleepers' mean TST was lower than 7 hours from T1 to T2.

Our data indicated that time in bed (TIB) for T2 was significantly lower compared to MD1 and MD2 but not T1. As indicated in the literature, values for TIB after a match are mixed, with mean data ranging from 293 min (Fullagar et al., 2016b), 472 min (O'Donnell et al., 2018), 476 min (Shearer et al., 2015) 531 min (Fullagar et al., 2016a). Our data for T2 is similar to the values reported by Shearer et al. (2015) and O'Donnell et al. (2018), but only after the second match was played. It should be noted that the previously cited studies only reported on sleep after one match, while our study adds to the current literature by reporting that TIB is unchanged after one match but is significantly decreased after the second match of the weekend. The possible reason for this finding is that both T1 and T2 have awakening times that are on weekday mornings (i.e. school days) and thus participants have a schedule to maintain by going to class or work, thus possibly explaining why there was no significant difference between these two time points. Our results demonstrate that our participants acquired more TIB over the weekend, which is in accordance with Buboltz et al. (2001), who indicated that university students reported achieving more time spent in bed over the weekend than during the weekday.

Consistent with our findings with TST and TIB, sleep efficiency (SE) significantly decreased over the course of the weekend with the lowest value observed on T2. This indicates that our participants spent less time asleep while in bed even though SE on T2 was still above the recommended cut off of 85 % (Reed & Sacco, 2016). Data on SE within athletic populations is mixed. Our data is somewhat in accordance with Fullagar et al. (2016b) and Shearer et al. (2015), in which SE did not change significantly after the first match, but our data is the first to indicate that after G2 (T2 sleep), SE was significantly reduced. However, O'Donnell et al. (2018) reported a significant decrease in SE in female netball players after a match. Unlike previous studies, our study compared back-to-back matches, which makes any direct comparisons difficult.

With our data demonstrating a significant increase for WASO on MD2 compared to T1 and MD1, pain accumulated from G1 may have played a part in these findings by increasing the length of awakenings. However, our findings are inconsistent with previous studies in which WASO did not significantly change after matches (Fullagar et al., 2016a; Fullagar et al., 2016b; Shearer et al., 2015). It should be noted that our mean values for WASO on MD2 were similar to Fullagar et al. (2016a) but dissimilar to those of Shearer et al. (2015) who reported mean WASO lengths of greater than one hour in male rugby players. Nédélec et al. (2015) and Hausswirth et al. (2014) both indicated that muscle soreness and pain could possibly be a reason behind a poorer sleep quantity and quality in soccer players and overreached triathletes, respectively.

Based on our findings, MD2 was not significantly different from T2, thus it is possible that the first match of each weekend may have a greater impact on muscle soreness, and subsequently WASO on MD2, and any possible soreness accumulated from G2 may reach a plateau, having little significant implications on WASO for T2.

Our findings demonstrated no significant effects for the number of awakenings for any time point which is consistent with results found in male soccer players (Fullagar et al., 2016a; Fullagar et al., 2016b). Specifically, it may be that there was a higher propensity for sleep after matches due to prolonged wakefulness, resulting in fewer awakenings throughout the night (Fullagar et al., 2016b). The potential for forgetting whether an awakening actually occurred and not being recorded is plausible. Also, the possibility for and accumulation of micro-arousals and fragmentations could have occurred without the participants' knowledge and may have impacted our results (Halasz, 1998; Halasz, Terzano, Parrino, & Bódizs, 2004). There is also the possibility that back-to-back matches may have little impact on the number of awakenings in this particular sample.

Our data is the first of its kind to demonstrate no significant time effects for sleep onset latency (SOL) after consecutive soccer matches played, which is in accordance with findings in male rugby union athletes (Shearer et al., 2015) and professional male soccer players after a match (Fullagar et al., 2016a; Fullagar et al., 2016b). However, the results observed by O'Donnell et al. (2018) in female netball players are different to ours in that they reported a significant increase in SOL after a match (67.0 $\pm$ 51.9 min; Mean $\pm$ SD) compared to baseline (27.5 $\pm$ 34.7 min; Mean $\pm$ SD). Shearer et al. (2015) examined objective sleep patterns of professional male rugby union players, prior and post-match-play, to assess the influence of competition. Shearer et al. (2015) indicated that SOL remained statistically unchanged (38 $\pm$ 34 min; Mean ± SD) post-match compared to baseline (34 ± 40 min; Mean ± SD). Similarly, Fullagar et al. (2016a) examined subjective sleep and recovery responses of elite male soccer players across training days, day and night matches. Sleep onset latency remained statistically unchanged after day matches (22 ± 13 min; Mean ± SD) when compared to training days (16 ± 7 min; Mean ± SD). Finally, Fullagar et al. (2016b) examined objective sleep of amateur male soccer players following a late-night soccer match. Once again, SOL was statistically unchanged after a late night match (8.8 ± 7.1 min; Mean ± SD) compared to baseline (15.2 ± 14.8 min; Mean ± SD). In accordance with the previous three studies, we found no significant changes to SOL after both MD2 and T2.

Our findings are supported by questionnaires conducted by Erlacher et al. (2011), in that team sport athletes appear to demonstrate less sleep problems prior to competition compared to athletes in individual sports. Pre-sleep cognitive activity (i.e. anxiety) has been associated with reports of longer SOL in nonclinical samples (Nicassio, Mendlowitz, Fussell, & Petras, 1985; Zoccola, Dickerson, & Lam, 2009). Erlacher et al. (2011) indicated that team sport athletes (versus individual sport athletes) appeared to demonstrate less anxiety before sleep, possibly because results and performance were not solely dependent on one individual. Another plausible explanation for our findings is that the reoccurring nature of matches may lend itself to better pre-sleep routines before competitions and thus reduce SOL (Erlacher et al., 2011). However, it should be noted that both Shearer et al. (2015) and Fullagar et al. (2016b) both used actigraphy to measure sleep variables, while Fullagar et al. (2016a) used sleep diaries. Although discrepancies exist between the two methods, based on our results, back-to-back matches have no significant effect on SOL within this sample.

According to our results, sleep quality did not change significantly throughout our study, which is consistent with the results obtained by Fullagar et al. (2016a, 2016b), in which sleep restfulness (sleep quality) was unchanged after soccer matches in males. Based on our results, it is plausible that sleep quality may not be impacted significantly by soccer matches over the course of the weekend. It is also possible that our participants' do not actually know what a good night's sleep feels like (even if SE and TST were above the minimum threshold and sleep quality was good overall) and therefore cannot differentiate between a good and bad night's sleep, therefore they may have become accustomed to suboptimal sleep quality (Simpson et al., 2016).

GPS versus Sleep Relationships

Total Sleep Time (TST)

To our understanding, our study of the relationship between games and the sleep quantity and quality attained before and after female U Sport soccer games is the first of its kind. Our results indicate that a negative correlation exists between TST attained on MD2 and the amount of HIT running performed in zone three, four, five, summed zones three through six, decelerations zones two and three on G2, thus, as TST decreased an increase in HIT running and decelerations were performed. This increased HIT running distance may be due to an increased number of errors conducted by our participants during match play, thus increasing the distance performed at HIT. A plausible explanation for this finding could be that studies using psychomotor vigilance tasks reported performance decrements in the form of increased reaction times and the number of lapses committed in participants spending less than seven hours of TIB (Dinges et al., 1997; Belenky et al., 2003; Van Dongen et al., 2003; Lim & Dinges, 2008). While our participants' mean TST for MD2 was similar to TST for the 8 hr TIB baseline values reported by Van Dongen et al. (2003) in which the number of lapses (tested via psychomotor vigilance tasks) were at their lowest, unlike our study, previous studies prohibited vigorous exercise to be performed by participants (Van Dongen et al., 2003) or their participants' were not athletes (Dinges et al., 1997; Belenky et al., 2003; Van Dongen et al., 2003) so these results are not directly applicable to the current study.

Time in Bed (TIB)

Similar to TST, a significant negative correlation existed between TIB and all running variables excluding running distance zone one and acceleration zone one. When we ran a Pearson product-moment coefficient of correlation *post hoc* analysis between TST and TIB, for matching T1, MD1, MD2 and T2, *r*-values were equal to 0.93, 0.76, 0.82 and .82, respectively ($p \leq .05$). These results indicate an excellent relationship between these two variables, thus any of the previously plausible explanations for TST and GPS running performance could be applied for TIB.

Sleep Quality

Our data suggests that there is a weak relationship between subjective sleep quality and GPS running distance. Only sleep quality on MD2 demonstrated a strong relationship with running distance zone four on G2, with no other significant relationships. A possible explanation of this finding is that a five point Likert scale for sleep quality may not be sensitive enough to differentiate among the various levels for sleep quality. A possible reason for our findings are supported by studies from Erlacher et al. (2011) and Juliff et al. (2015), in which athletes' did not believe that poor or disturbed sleep had any influence on performance. Based on our findings, sleep quality may not be affected to a large degree by soccer matches and vice versa. It cannot go without being stated that the menstrual cycle phase can change the sleep quality in healthy young women, thus, possibly impacting our findings as this was not controlled for in this study (Baker & Driver, 2004).

Wake After Sleep Onset (WASO)

The general findings for WASO indicate that a positive correlation exists with running distance zones three, four, five the summed zones three through six, and decelerations zone two and three. As WASO increased, an increase in running performance variables was noted. A possible explanation for this relationship is that delayed onset muscle soreness (DOMS) developed from G1, may have caused sleep disturbances, by increasing WASO and developing a state of partial sleep disruption during MD2 sleep, possibly having negative implications on neurobehavioral functions for G2 (i.e. increased reaction times and the number of lapses committed). This possible negative neurobehavioral state may then have increased the amount of HIT running performed, in order to compensate for increased errors committed on G2 by increasing the participants' mental fatigue. Our results are supported by Coutinho et al. (2017), who reported that mental fatigue negatively influenced male soccer players' tactical behavior during small-sided games. Kölling et al. (2016b) is the only study to our knowledge that reported that eccentrically based strength training for one week had no significant effect on objective measures of sleep in an athletic sample. It should be noted that this study only spanned one week and that a soccer match requires higher energy expenditure, while strength training causes more localized muscle damage (Kölling et al., 2016b). It appears that a cycle of muscle soreness and increased WASO occurs, since a positive correlation was observed for G2 and T2. We cannot confirm that this cycle does not perpetuate throughout the course of the week, with training, leading up to each weekend, as we did not incorporate that data into this study.

Strengths and Limitations of the Study

One strength of this study was that in-season longitudinal data was collected and simulated games were not used as a means to collect data, as this could possibly have changed some of the natural responses observed in in-season matches. Another strength of this study was the simultaneous use of both the CORE consensus sleep diary and GPS over the course of this study. A further strength of this study was that we used the PSQI to determine whether participants were classified as good or bad sleepers, which is rarely done in studies concerning the athletic population.

Since our study was conducted in a field setting, there are some limitations to this study. Although we used sleep diaries daily over the course of the season, this tool can be imprecise when compared to polysomnography, deemed the gold standard for sleep monitoring, and actigraphy (Kawada, 2008). Subjective measurements of sleep can also be influenced by mood, memory impairment and personality characteristics (Jackowska, Dockray, Hendrickx, & Steptoe 2011). It should be noted that the continuous use of actigraphy would have been far too invasive and impractical as well as having major logistical hurdles to overcome in order to be used for an entire season. Future research should incorporate the use of actigraphy alongside the sleep diaries when monitoring athletes. More importantly, future research should investigate coping strategies and education programs to indicate what possible added benefit these strategies would have on this particular population. A limitation of this study was that diet and the sleep environment were not monitored nor controlled for. Furthermore, a low sample size (N = 12), post hoc power analysis indicated an inadequate sample size, likely impacted the significance of our results. A limitation of our study was the possible effect of the menstrual cycle phases on running performance and subjective sleep (Baker & Driver, 2004). It is highly unlikely that we would have been able to control for this factor, making certain that testing did not occur during the menses cycle of each participant.

Another limitation of this study was that data was only collected over 10 games that were separated by less than 24 hours of recovery for one season. Although the low sample size and limited amount of game data was used for our study, this is a common occurrence within an athletic population let alone within a female population. Future studies should try and increase the number of viable participants (i.e. more participants from various teams) or increase the length of time in which data is collected or a combination of both. In order to increase the power of future studies, data should be collected over the course of five years, or greater, in order to increase the number of participants and weekends used with full data sets incorporated into the final analysis. From a soccer specific focus, this study did not incorporate video analysis to observe technical and tactical performance of our participants' (i.e. how many misplaced passes were performed or whether players were out of position) and therefore we cannot determine whether any of relationships observed between GPS and sleep were due to technical and tactical errors. Similar to previous studies, no performance data was collected on opponents, therefore, we cannot determine whether our participants' were outperformed during matches.

CHAPTER 5 - CONCLUSION

Results from our study indicate that female U Sport soccer players have reduced running performance and a worsening of subjective sleep duration and disturbances throughout the weekend when matches are played during the regular season. Our findings on determining a relationship between GPS running and sleep variables are preliminary and thus warrant further research in a more controlled environment. Future studies should concentrate on sleep hygiene strategies and their effects on exercise performance and vice versa within this population as little can be done to change the length of time at which games can be played. Practitioners may benefit from this data by rotating players between halves and matches in order to reduce the decline in running distance in the second match.

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APPENDICES

APPENDIX A - Ethics Approval Certificate

University of Manitoba | Research Ethics and Compliance

Human Ethics
208-194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2
Phone +204-474-7122
Email: humanethics@umanitoba.ca

PROTOCOL APPROVAL

TO: **David Turczyn** **(Advisor: Stephen Cornish)**
Principal Investigator

FROM: **Zana Lutfiyya, Chair**
Education/Nursing Research Ethics Board (ENREB) [redacted]

Re: **Protocol #E2017:023 (HS20602)**
"Determination of Running Performance and Sleep Patterns in Canadian Female University Soccer Players"

Effective: March 22, 2017 **Expiry:** March 22, 2018

Education/Nursing Research Ethics Board (ENREB) has reviewed and approved the above research. ENREB is constituted and operates in accordance with the current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans*.

This approval is subject to the following conditions:

1. Approval is granted only for the research and purposes described in the application.
2. Any modification to the research must be submitted to ENREB for approval before implementation.
3. Any deviations to the research or adverse events must be submitted to ENREB as soon as possible.
4. This approval is valid for one year only and a Renewal Request must be submitted and approved by the above expiry date.
5. A Study Closure form must be submitted to ENREB when the research is complete or terminated.
6. The University of Manitoba may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba *Ethics of Research Involving Humans*.

Funded Protocols:

- **Please mail/e-mail a copy of this Approval, identifying the related UM Project Number, to the Research Grants Officer in ORS.**

APPENDIX B – Participant Consent Form

102 Frank Kennedy Centre
Winnipeg, Manitoba
Canada R3T 2N2

UNIVERSITY OF MANITOBA | Faculty of Kinesiology and Recreation Management

INFORMED CONSENT FORM:

Title of Study: Determination of Running Performance and Sleep Patterns in Canadian Female University Soccer Players

PRINICIPAL INVESTIGATOR:

David Turczyn
Master of Science Candidate of Kinesiology & Recreation Management
Health, Leisure, & Human Performance Research Institute
University of Manitoba
[redacted]

OTHER INVESTIGATORS:

Dr. Stephen Cornish
Faculty of Kinesiology & Recreation Management
Health, Leisure, & Human Performance Research Institute
University of Manitoba
[redacted]

Dr. Phillip Gardiner
Faculty of Kinesiology & Recreation Management
Health, Leisure, & Human Performance Research Institute
University of Manitoba
[redacted]

Dr. Diana McMillan
Rady Faculty of Health Sciences
College of Nursing
University of Manitoba
[redacted]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

SOURCE OF SUPPORT: NONE

PURPOSE:

You are being asked to participate in a research trial investigating whether the effects of running performance, indicated by global positioning system, and sleep, questionnaire and diaries, are changed over the course of a weekend throughout a competitive season at the University Sport level.

DESCRIPTION:

It is expected that a total of 10 participants will be recruited to participate in this study. As a part of your regular training, participants were tracked using Global Positioning System (GPS) and sleep questionnaires across the 2016 competitive season. Participants were asked to complete the Core Consensus Sleep Diary (Core-CSD) daily for the duration of the season as a part of your regular performance and sleep monitoring. The Core-CSD is a detailed sleep log, indicating both sleep quality and quantity. The Pittsburgh Sleep Quality Index (PSQI) questionnaire was administered as a reference measure to determine the global sleep quality and quantity over the past month as well to determine whether participants were deemed “good” or “bad” sleepers. We are asking you to provide written informed consent to using the already collected data (as explained above) throughout the 2016 University of Manitoba woman’s soccer season for secondary data analysis and interpretation.

RISKS AND BENEFITS:

There is minimal risk associated to the activity that you will perform as this is a secondary data analysis. Participation in this experiment may not directly lead to any health benefits.

COSTS AND PAYMENTS:

There are no fees or charges to participate in this study. Participants will not receive any remuneration.

DEBRIEFING:

Feedback will be provided to participants after the completion of the study so they are aware of the results of the testing they completed (this includes running performance, sleep questionnaire and diaries). This will be done by the principal investigator (Mr. David Turczyn) who is performing the data analysis. Participants will be asked if they wish to receive copies of their data results and these will be sent out to them if they so desire (either by mail or email). A brief summary of the study results will be sent to those participants who so desire in aggregate form. This will be done at the end of the study once the data have been analyzed. Also, if more information on the study is desired by study participants then they will be able to contact the principal investigator of the study, David Turczyn.

VOLUNTARY CONSENT:

Participation in this study is strictly on a voluntary basis, and you can withdraw from the study at any time during the study or by contacting the principal investigator in person or email. If you do not wish to participate in the study, you are free to withdraw from the research study at any time without consequence and we thank you for your consideration. You can withdraw from the study by telling the primary investigator in person or through e-mail.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

CONFIDENTIALITY:

Your information will be kept confidential. Once you begin the study your name, information, and results will be referred to by a code number. All files containing identifying information will be stored in a locked cabinet separate from data with your, non-identifiable, code number. Your files with non-identifiable information will only be accessible by David Turczyn and Dr. Stephen Cornish and will be destroyed by Dr. Stephen Cornish seven years after the completion of the study (approximately August 2024). All papers containing personal information will be shredded by a confidential shredding process. All electronic files will be deleted. David Turczyn will only access the consent forms if audited by Education and Nursing Research Ethics Board or when it is time to destroy the consent forms.

It is anticipated that the results of this research will be presented within the primary investigators master's thesis, at a scientific conference in the proceedings as an abstract and in scientific publication journal article. No personally identifiable information will be used to present the data in these formats.

A copy of this consent form has been given to you to keep for your records and reference.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw

from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education and Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122 or humanethics@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Participant's Name (printed): ____

Participant's Signature: ______________________________ Date: ________________

Researcher and/or Delegate's Signature: ___________________ Date: ________________

All individuals who participate in this study are eligible to receive information on the outcomes of the study, via a one page synopsis of the key findings of the research as well as your personal data. If you would like to receive information on the results of this study please state your mailing address and email address below:

Address:____

City: ____

Postal code: ____

Email: ____

APPENDIX C – Athletic Director Consent Form

102 Frank Kennedy Centre
Winnipeg, Manitoba
Canada R3T 2N2

UNIVERSITY OF MANITOBA | Faculty of Kinesiology and Recreation Management

Consent Form

Title: Determination of Running Performance and Sleep Patterns in Canadian Female University Soccer Players

Names of Researchers: David Turczyn (Primary investigator), Faculty of Kinesiology and Recreation Management, University of Manitoba, phone [redacted], email: [redacted]

Stephen Cornish, Ph.D. (Assistant Professor – Thesis Advisor), Faculty of Kinesiology and Recreation Management, University of Manitoba, phone: [redacted], email: [redacted]

You are being asked permission to allow the University of Manitoba women's soccer team's athletes to be recruited for a research project. The purpose of this study is to investigate whether the effects of running performance, indicated by global positioning system, and sleep, questionnaire and diaries, are changed over the course of a weekend throughout a competitive season at the University Sport level. As this will be conducted as a secondary analysis, minimal risk is associated with it.

A total of 10 participants are expected to participate in this trial.

Confidentiality: Precautions will be taken to protect participant anonymity during the study. All files containing identifying information will be stored in a locked cabinet separate from data with a unique code number in room [redacted] at the University of Manitoba. Files with non-identifiable information will only be accessible by David Turczyn and Dr. Stephen Cornish. Participants names or other identifying traits will not be attached to any information, mentioned in any study report, nor be made available to anyone except the research team. David Turczyn will only access the consent forms if audited by Education and Nursing Research Ethics Board or when it is time to destroy the consent forms (approximately August 2024).

It is anticipated that the results of this research will be presented at a scientific conference in the proceedings as an abstract and in scientific publication journal article. No personally identifiable information will be used to present the data in these formats. Likewise, should you, as the Director of Athletics and Recreation, wish to see the results of the study, all results will be presented as averages to maintain participant anonymity after the study is done.

If you have questions concerning the study you can contact David Turczyn at [redacted] or at [redacted]

If you have any questions about your rights, or concerns about the study, please direct questions regarding your rights to the Human Ethics Coordinator at the Office of Research Ethics and Compliance at the University of Manitoba (Phone: [redacted] or Email: [redacted]).

Please read the following before signing this consent form:

- I have read or have had this read to me and understood the consent form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the result will only be used for scientific objectives.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I have been told that I will receive a dated and signed copy of this form.

Director of Athletics and Recreation Signature: ____

Date: ______________________

Primary Investigator Signature: ____

Date: ______________________

APPENDIX D - Pittsburgh Sleep Quality Index

Subject's Initials ______________ ID#________________ Date______________ Time_____ AM / PM

PITTSBURGH SLEEP QUALITY INDEX

INSTRUCTIONS:
The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?

   USUAL BED TIME __________

2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?

   NUMBER OF MINUTES __________

3. During the past month, when have you usually gotten up in the morning?

   USUAL GETTING UP TIME __________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

   HOURS OF SLEEP PER NIGHT __________

For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you . . .

a) Cannot get to sleep within 30 minutes

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

b) Wake up in the middle of the night or early morning

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

c) Have to get up to use the bathroom

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

d) Cannot breathe comfortably

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

e) Cough or snore loudly

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

f) Feel too cold

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

g) Feel too hot

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

h) Had bad dreams

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

i) Have pain

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

j) Other reason(s), please describe____

____

How often during the past month have you had trouble sleeping because of this?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

6. During the past month, how would you rate your sleep quality overall?

Very good ____________

Fairly good ____________

Fairly bad ____________

Very bad ____________

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all	___________
Only a very slight problem	___________
Somewhat of a problem	___________
A very big problem	___________

10. Do you have a bed partner or room mate?

No bed partner or room mate	___________
Partner/room mate in other room	___________
Partner in same room, but not same bed	___________
Partner in same bed	___________

If you have a room mate or bed partner, ask him/her how often in the past month you have had . . .

a) Loud snoring

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

b) Long pauses between breaths while asleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

c) Legs twitching or jerking while you sleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

d) Episodes of disorientation or confusion during sleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

e) Other restlessness while you sleep; please describe________________________________

____

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

APPENDIX E - Pittsburgh Sleep Quality Index Permission

Gasiorowski, Mary <GasiorowskiMJ@upmc.edu>

Fri 7/29/2016, 8:17 AM

David Turczyn

Action Items

Sent on behalf of Dr. Buysse

Dear David,

You have my permission to use the PSQI for your research study. You can find the instrument, scoring instructions, the original article, links to available translations, and other useful information at www.sleep.pitt.edu under the Research/Instruments tab. Please ensure that the PSQI is accurately reproduced in any electronic version (including copyright information). We request that you do cite the 1989 paper in any publications that result.

Note that Question 10 is not used in scoring the PSQI. This question is for informational purposes only, and may be omitted during data collection per requirements of the particular study.

This copyright in this form is owned by the University of Pittsburgh and may be reprinted without charge only for non-commercial research and educational purposes. You may not make changes or modifications of this form without prior written permission from the University of Pittsburgh. If you would like to use this instrument for commercial purposes or for commercially sponsored research, please contact the Office of Technology Management at the University of Pittsburgh at 412-648-2206 for licensing information.

Good luck with your research.

Sincerely,

Daniel J. Buysse, M.D.
Professor of Psychiatry and Clinical and Translational Science
University of Pittsburgh School of Medicine
E-1123 WPIC
3811 O'Hara St.
Pittsburgh, PA 15213
T: (412) 246-6413

F: (412) 246-5300
buyssedj@upmc.edu

From: Buysse, Daniel
Sent: Wednesday, July 27, 2016 5:39 PM
To: Gasiorowski, Mary
Subject: FW: PSQI- Permission Request

David Turczyn

|Wed 7/27/2016, 3:45 PM

Dr. D. J. Buysse,

I am writing to request permission to use the Pittsburgh Sleep Quality Index in my master's thesis entitled Determination of Running Performance and Sleep Patterns in Canadian Female University Soccer Players. Also, whether if it would be possible to create an electronic format of the PSQI on our website that we use for monitoring our athletes? The site that we are using is called Athlete Monitoring and is only accessible by our soccer players and coaches to use. I am the lead researcher on the project and will be conducting the study with my supervisor Dr. Stephen Cornish, Dr. Phillip Gardiner (committee member) and Dr. Diana McMillan (committee member).

The overall aim of the sleep component of this study is to better understand the relationship of sleep patterns and their impact on running performance during matches.

This tool (as you are aware) is found in the/ Journal of Psychiatric Research,/ 28(2), Buysse, D.J., Reynolds III, C.F., Monk, T.H., Berman, S.R., & Kupfer, D.J. The Pittsburgh Sleep Quality Index: A New Instrument for Psychiatric Practice and Research, 193-213 Copyright 1989.

We intend to publish and present the findings widely. We will of course acknowledge your work in any publications or presentations that include the sleep component within the analysis. I hope you will support the inclusion of your sleep tool in this exciting and innovative research project.

Regards,

David Turczyn

APPENDIX F - Global Pittsburgh Sleep Quality Index Scores

	Pooled	Good Sleepers	Bad Sleeper
	(N = 12)	(n = 5)	(n = 7)
Global PSQI Score	6.16 ± 3.49	2.80 ± 0.84	8.58 ± 2.37
Component 1: Subjective Sleep Quality	1.08 ± 1.00	0.20 ± 0.45	1.71 ± 0.76
Component 2: Sleep Latency	1.08 ± 1.00	0.80 ± 0.45	1.29 ± 1.25
Component 3: Sleep Duration	0.75 ± 0.75	0.20 ± 0.45	1.14 ± 0.69
Component 4: Habitual Sleep Efficiency	0.67 ± 0.89	0.20 ± 0.45	1.00 ± 1.00
Component 5: Sleep Disturbances	1.33 ± 0.65	1.00 ± 0.00	1.57 ± 0.79
Component 6: Use of Sleeping Medication	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Component 7: Daytime Dysfunction	1.25 ± 1.06	0.40 ± 0.55	1.86 ± 0.90

APPENDIX G - Core Consensus Sleep Diary

Consensus Sleep Diary-Core ID/Name:________________________________

	Sample							
Today's date	4/5/11							
1. What time did you get into bed?	10:15 p.m							
2. What time did you try to go to sleep?	11:30 p.m							
3. How long did it take you to fall asleep?	55 min.							
4. How many times did you wake up, not counting your final awakening?	3 times							
5. In total, how long did these awakenings last?	1 hour 10 min.							
6. What time was your final awakening?	6:35 a.m.							
7. What time did you get out of bed for the day?	7:20 a.m							
8. How would you rate the quality of your sleep?	☐ Very poor ☑ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good
9. Comments (if applicable)	I have a cold							

Figure 1 *(continued)*—Sleep Diary Instructions: Core

APPENDIX H - Core Consensus Sleep Diary Permission

Colleen Carney <ccarney@psych.ryerson.ca>

|6/2016, 10:33 AM

Yes to all, David. Sounds like an interesting study. Good luck!
Colleen

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: David Turczyn
Sent: Tuesday, July 26, 2016 11:19 AM
To: ccarney@ryerson.ca
Subject: CSD-Core request permission

David Turczyn

Tue 7/26/2016, 9:19 AM

ccarney@ryerson.ca

Sent Items

Dr. CE Carney,

I am writing to request permission to use the Consensus Sleep Diary-Core in my master's thesis entitled Determination of Running Performance and Sleep Patterns in Canadian Female University Soccer Players. Also, whether if it would be possible to create an electronic format of the sleep diary on our website that we use for monitoring our athletes? The site that we are using is called Athlete Monitoring and is only accessible by our soccer players and coaches to use. I am the lead researcher on the project and will be conducting the study with my supervisor Dr. Stephen Cornish, Dr. Phillip Gardiner (committee member) and Dr. Diana McMillan (committee member).

The overall aim of the sleep component of this study is to better understand the relationship of sleep patterns and their impact on running performance during matches.

This tool (as you are aware) is found in SLEEP, 35(2), Carney, C. E., Buysse, D. J., Ancoli-Israel, S., Edinger, J. D., Krystal, A. D., Lichstein, K. L., & Morin, C. M. (2012). The Consensus Sleep Diary: Standardizing Prospective Sleep Self-Monitoring, 287-302 Copyright 2012.

We intend to publish and present the findings widely. We will of course acknowledge your work in any publications or presentations that include the sleep component within the analysis. I hope you will support the inclusion of your sleep tool in this exciting and innovative research project.

Regards,

David Turczyn

APPENDIX I - Diagram Depicting Specific Days

Sleep →	Th→	Fri	Fri→	Sat		Sat→	Sun		Sun→	Mon
Time Point →		T1		MD1			MD2			T2
					↑			↑		
Matches →					G1			G2		