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An Objective Measure of Sleep in Division I College Soccer Players Compared to the General College Population

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AN OBJECTIVE MEASURE OF SLEEP IN DIVISION I COLLEGE SOCCER PLAYERS COMPARED TO THE GENERAL COLLEGE POPULATION

by

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(Under the Direction of Bridget Melton)

ABSTRACT

Introduction: Sleep is necessary for proper recovery from daily life for both college athletes and students.

Purpose: To objectively evaluate the sleep quality of college athletes across gender, comparing them to a normal college student population.

Methods: A convenience sample of 104 subjects (19.39 ± 1.28 years), 42 Division college athletes and 62 comparison college students completed one week of data collection using the ActiGraph GT3X device. Wear time, sleep time, and wake time were recorded by each participant. Independent variables were athlete status and gender. Dependent variables were Total Sleep Time (TST), Wake After Sleep Onset (WASO), Latency, and Efficiency as well as physical activity levels. Independent T-tests were used to compare variables of groups to normative data and between groups. Chi-square Tests of Independence were used to compare physical activity levels between groups. Pearson's Product Correlations were used to compare the relationship of sleep and physical activity levels for each group.

Results: One Sample Independent T-Tests showed all groups have significantly less TST and sleep efficiency ($p < 0.001$) than the recommended values of 8 hours a night and 85% efficiency.

Two Sample T-Tests showed male athletes had significant less TST than the comparison group ($p = .010$). Chi-square Tests of Independence showed no differences in physical activity levels. Pearson Product Correlations showed moderate relationships between physical activity and both latency ($r = .383$) and efficiency ($r = -.364$) for male athletes. For female athletes, there were moderate relationships between physical activity and TST ($r = -.402$), latency ($r = .557$), and efficiency ($r = -.417$).

Conclusion: Findings suggest that both the Division I college athlete and general college student populations suffer from poor sleep quality. This study was inconclusive as to if differences are present between the two groups. Additional research regarding factors of a Division I athlete lifestyle and their effect on sleep quality.

INDEX WORDS: Sleep quality, Actigraphy, Athletes

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CHAPTER 1

INTRODUCTION

The prevalence of sleep quality in scientific research has been steadily increasing over the past 30 years. The way sleep quality is measured has evolved during this time, with the typical variables of interest including total hours of sleep or sleep loss. There are several classifications for these variables, including sleep deprivation, sleep restriction, and insomnia. Sleep deprivation is typically defined as one night of sleep loss or a continuous bout of wakefulness lasting 24 hours (Drake et al., 2001). Sleep restriction, sometimes referred to as partial sleep deprivation, encompasses nights where the subject receives fewer than 6 hours of sleep during the night, either by delay in sleep onset, earlier wake times, or disturbed sleep by waking subjects after sleep onset (Cappuccio, D'Elia, Strazzullo, & Miller, 2010; Fullagar, Skorski, et al., 2015). Both classifications are typically used in research and the definitions can vary between researchers. Another way to define sleep loss is insomnia, which is a clinic diagnosis where the individual experiences at least one of the following: difficulty initiating sleep, difficulty maintaining sleep, waking up early, or chronic occurrences of non-restorative or poor quality sleep (Edinger et al., 2004).

Quality sleep can impact both mental and physical aspects of life. Mental health is intertwined with sleep for various disorders. The comorbidity of sleep quality and several diagnoses, including anxiety, depression, eating disorders, developmental disorders, borderline and anti-social disorders, attention-deficit/hyperactivity disorder, and schizophrenia (Baglioni et al., 2016; Staner, 2010). Sleep quality has also been linked to cognitive performance, decision making, and motor sequence learning (Appleman, Albouy, Doyon, Cronin-Golomb, & King, 2016; Belenky et al., 2003; Seeley, Smith, MacDonald, & Beninger, 2016). On the physical aspects of health, sleep restriction disturbs glucose metabolism and may be a risk factor for diabetes (Ayas et al., 2003; Spiegel, Leproult, & Van Cauter, 1999). Cardiovascular health is also at risk from short sleep and low sleep efficiency, showing indications of low vagal tone and increased risk of myocardial infarction and heart disease (Amagai et al., 2010; Castro-Diehl et al., 2016). It is clear that quality of sleep can impact health in different ways, and studies of physical performance expand upon these health concerns.

Human performance can be measured through tasks of both aerobic and anaerobic nature. Studies utilizing sleep deprivation in various athletes have found deficits in sustained aerobic exercises, such as less time to exhaustion, decreased minute ventilations, and decreased performance output (Azboy & Kaygisiz, 2009; Martin, 1981; Martin & Chen, 1984; Oliver, Costa, Laing, Bilzon, & Walsh, 2009). Sleep deprivation can also impact anaerobic performance, by decreasing sprint times, isokinetic power deficits, and decreased peak power on Wingate testing (Bulbulian, Heaney, Leake, Sucec, & Sjoholm, 1996; Skein, Duffield, Edge, Short, & Mundel, 2011; N. Souissi, Sesboüé, Gauthier, Larue, & Davenne, 2003). Although all of this related to sleep deprivation which may not be applicable to elite athletes, there is also research that supports sleep restriction as a source of performance decrements (Fullagar, Skorski, et al., 2015). Sub-maximal repetitions of bench press, leg press, deadlift, and bicep curls have been shown to be impacted by sleep loss and have greater deficits as a protocol progressed suggesting cumulative effects (Thomas Reilly & Piercy, 1994). Wingate testing is again affected by sleep, with sleep restriction leading to difficulty maintaining maximal work and decreased mean and peak power in students, footballers, and professional judo competitors (Abedelmalek et al., 2013; Mougin et al., 2001; D. N. Souissi et al., 2008; N. Souissi et al., 2013). It has been concluded that sleep restriction has a greater impact on repetitive sub-maximal strength, power, and sport specific skill performance over singular bouts of aerobic activity (Fullagar, Skorski, et al., 2015).

While it is apparent that poor sleep quality has negative effects on health and performance, different populations can be more susceptible to sleep related problems. The National Sleep Foundation recommends 7 to 9 hours of sleep a night in the young adult and adult populations, but on average adults age 18-91 only receive 6.9-7.1 hours a night (Hirshkowitz et al., 2015; National Sleep Foundation, 2015). In general, the American population experiences short sleep time. Broken down further, the college population, falling in the category of young adults, may have more prevalent sleep issues. The American College Health Association's (ACHA) National College Health Assessment (NCHA) from the fall of 2016 shows that almost 50% of college students report sleep difficulties to some extent, with 47.9% of those having issues with sleepiness a minimum of 4 days per week (ACHA-NCHA, 2016). Even though it is reported that these sleep problems impact academic performance, three-quarters of college students report they do not receive sufficient information from their institutions to remedy the problem (ACHA-NCHA, 2016; Gaultney, 2010). It is apparent the college population experiences a unique environment with demands of school, work, and social life that all interact and contribute to poor sleep quality (Lund, Reider, Whiting, & Prichard, 2010).

Yet another subset of the population is the collegiate athlete. The National Collegiate Athletic Association's (NCAA) study of Growth, Opportunities, Aspirations, and Learning of Students in college (GOALS) reported that Division I athletes on average spend 38.5 hours a week on sports participation, 34 hours a week on academics, 17.1 hours a week socializing, and only sleep 6.2 hours a night (Paskus & Bell, 2016). After completing this survey, the athletes were presented with topics they wished to have more information on and one of the top responses was maximizing athletic performance through proper sleep hygiene and increased sleep time (Paskus & Bell, 2016). This survey highlights a new area of sleep assessment in collegiate athletes not previously explored.

Early research assessing sleep in athletes suggested that athletes had superior sleep compared to non-athletic counterparts due to high levels of aerobic fitness (Demirel, 2016; Porter & Horne, 1981; Shapiro et al., 1984). Recently, the data suggests the opposite, and due to the various factors of the athlete lifestyle, athletes have poor sleep quality. Relationships exist between stressors of competition and poor sleep, including anxiety and excitement, with nervousness and thoughts of competition being the most common complaint (Erlacher, Ehrlenspiel, Adegbesan, & El-Din, 2011; Juliff, Halson, & Peiffer, 2015; Lastella, Roach, Halson, Martin, et al., 2015; Lastella, Lovell, & Sargent, 2014; Savis, 1994). In addition to competitions, the travel to and from athletic events can contribute to poor sleep by unfamiliar sleep environments, time zone changes, short and long travel schedules, and altitude exposure (Erlacher et al., 2011; P. Fowler, Duffield, & Vaile, 2015; Peter Fowler, Duffield, & Vaile, 2014; Lastella, Roach, Halson, Martin, et al., 2015; Lastella et al., 2014; McGuckin, Sinclair, Sealey, & Bowman, 2014; Pedlar et al., 2005; Jim Waterhouse, Reilly, Atkinson, & Edwards, 2007; Winter, Hammond, Green, Zhang, & Bliwise, 2009). The timing of training and competition can also impact sleep either with early or late schedules (Fullagar, Duffield, et al., 2015; Sargent, Halson, & Roach, 2014; Sinnerton & Reilly, 1992). Even the type of sport, team or individual, can change sleep patterns as the training patterns, time in season, and team culture influence the athletes and can limited the predictability of sleep disturbances by age (Fullagar, Duffield, et al., 2015; Juliff et al., 2015; Lastella, Roach, Halson, Martin, et al., 2015). The lifestyle of an athlete provides unique circumstances that can influence the populations' quality of sleep.

For most of the aforementioned studies, quality of sleep was measured using subjective questionnaires, such as the Epworth Sleepiness Scale (ESS), Multiple Sleep Latency Test (MSLT), Medical Outcomes Study- Sleep Scale (MOS-SS), or the most widely used Pittsburgh Sleep Quality Index (PSQI) (Smith & Wegener, 2003). These tools are convenient and while some, such as the PSQI have been shown to be internally reliable and subject to test-retest validity, there are no significant correlations to objective sleep quality measures (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989; Grandner, Kripke, YOON, & Youngstedt, 2006; Monk et al., 1994). The gold standard of objective sleep measurements is polysomnography (PSG), which can measure several variables at once, including: brainwave activity, blood oxygen levels, heart rate, respiration rate, eye movements, and leg movements (Anch, Browman, Mitler, & Walsh, 1988; Marino et al., 2013). This provides an accurate and objective measure of sleep, but is not practical for large-scale studies as the laboratory setting can obtrusively alter sleep patterns and the high cost of equipment (Kanady, Drummond, & Mednick, 2011; Marino et al., 2013). Due to the flaws in the previously mentioned methods, another tool called actigraphy has emerged in the past 30 years. Actigraphy uses wearable accelerometers to calculate variables of sleep using body positions and movements (Marino et al., 2013). Several studies support actigraphy as a valid tool to distinguish sleep vs. wake compared to polyomnography (Acebo, 2005; Ancoli-Israel et al., 2003; Chesson Jr, Coleman, Lee-Chiong, & Pancer, 2007; de Souza et al., 2003; Kanady et al., 2011; Marino et al., 2013). Using the raw accelerometry data, the Sadeh algorithm is applied to discern several variables of sleep quality, namely total sleep time, sleep latency, sleep efficiency, and wake after sleep onset (Marino et al., 2013; Sadeh, Sharkey, & Carskadon, 1994). These variables can then be compared to normative data as well as between test subjects to assess sleep quality.

Sleep research in athletes has several pitfalls that highlight an interesting new area of study. First, most research of sleep in athletes has been done on the elite populations and not the collegiate athlete population. With the unique stress of being both a college student and an athlete, the collegiate athlete population seems more susceptible to poor quality of sleep, but no research has proven this. The only study to date on sleep in collegiate athletes was conducted on 11 male basketball players(Mah, Mah, Kezirian, & Dement, 2011). The study measured sleep quality by actigraphy and athletic performance before and after sleep extension to determine if performance would increase with increased total sleep time (Mah et al., 2011). The athletes' performance did improve, suggesting that the athletes did not get sufficient sleep prior to the intervention, but did not highlight all aspects of sleep quality and was only performed on 11 male athletes (Mah et al., 2011). Secondly, most studies of sleep in athletes rely on subjective measures of sleep. For the above study, an objective measure was used, but as part of an intervention study where athletic performance was the outcome measure. Leeder and colleagues studied sleep quality in elite athletes using actigraphy, and found sleep time of athletes comparable to their non-athletic counterparts, but had significantly lower quality of sleep (Leeder, Glaister, Pizzoferro, Dawson, & Pedlar, 2012). However, this study was performed while the athletes were not competing and did not assess direct effects of competition on sleep (Leeder et al., 2012). The aim of this study is to add to the depth of sleep research establish a novel and objective measure of sleep in collegiate athletes that can be used to better their health and performance in the future. The purpose of this study is to objectively evaluate the sleep quality of college athletes across gender, comparing them to a normal college student population.

CHAPTER 2

REVIEW OF LITERATURE

Sleep Quality and Related Health Issues

Sleep quality has become a hot topic in the field of medicine due to its various effects. Quality of sleep can be measured in a variety of different ways, including the total hours of sleep, sleep latency, number of times waking after sleep onset, and sleep efficiency. Typically, in sleep research the variable of interest is total hours of sleep or sleep loss. To understand the impact of sleep quality on both physical and mental health, the classifications of sleep loss such as sleep deprivation, sleep restriction, and insomnia must be defined. Sleep deprivation is typically defined as one night of sleep loss or a continuous bout of wakefulness lasting 24 hours (Drake et al., 2001). Sleep restriction, sometimes referred to as partial sleep deprivation, encompasses nights where the subject receives fewer than 6 hours of sleep during the night, either by delay in sleep onset, earlier wake times, or disturbed sleep by waking subjects after sleep onset (Cappuccio et al., 2010; Fullagar, Skorski, et al., 2015). Both classifications are typically used in research and the definitions can vary between researchers. Another way to define sleep loss is insomnia, which is a clinic diagnosis where the individual experiences at least one of the following: difficulty initiating sleep, difficulty maintaining sleep, waking up early, or chronic occurrences of non-restorative or poor quality sleep (Edinger et al., 2004). While those with insomnia may experience both sleep deprivation or sleep restriction, the individual has been diagnosed by a healthcare professional and can receive treatment.

By understanding how sleep quality is measured, its implications of physical and mental health can be investigated. For the general population, studies have shown links to several physical health concerns. Self-reported sleep restrictions has been shown disturbances in glucose metabolism which may be a risk factor for symptomatic diabetes (Ayas et al., 2003; Spiegel et al., 1999). An objective measure of short total sleep time, low efficiency, and insomnia shows associations with markers that would indicate low cardiac vagal tone, which can increase risk for cardiovascular events such as myocardial infarction and heart disease (Amagai et al., 2010; Castro-Diehl et al., 2016). Other studies still have shown sleep loss decreasing the production of immunological variables that prevent infection (Krueger, Majde, & Rector, 2011).

One specific physical health concern that has been recently associated with sleep quality is obesity. Multiple studies have shown links between sleep restriction and decreased appetite regulation that can lead to obesity (Spiegel, Tasali, Leproult, & Van Cauter, 2009; Spiegel, Tasali, Penev, & Van Cauter, 2004). There has also been a U-shaped association found between sleep duration and obesity, showing both short and long sleepers are at a higher risk (Buxton & Marcelli, 2010; Wu, Gong, Zou, Li, & Zhang, 2017). Research has also started to link poor overall sleep quality, and not just sleep duration, to obesity as well (Countryman et al., 2013; Wu et al., 2017). It is still unclear what underlying mechanisms relate poor sleep to obesity, if its related to thermoregulation, caloric intake, energy expenditure, or hormone regulation, but it is clear that poor sleep has become a marker for obesity risk (Wu et al., 2017).

In addition to physical health concerns, sleep quality can impact mental health and functioning. Several researchers have analyzed the comorbidity of sleep loss and mental illnesses such as anxiety, depression, eating disorders, developmental disorders, borderline and anti-social personality disorders, attention-deficit/hyperactivity disorder, and schizophrenia (Baglioni et al., 2016; Staner, 2010). Van Dongen and colleagues suggested that 8 hours of sleep a night can prevent neurobehavioral deficits that may not stem from a mental illness (Van Dongen, Maislin, Mullington, & Dinges, 2003). Objective sleep measurements have shown impairments on other aspects of mental functioning such as cognitive performance, decision making, and motor sequence learning (Appleman et al., 2016; Belenky et al., 2003; Seeley et al., 2016). One study suggests that 24 hours of sustained wakefulness can decrease psychomotor performance equivalent to a blood alcohol content of 0.10% (Dawson & Reid, 1997). The correlations between sleep quality and both mental and physical health leads to questions regarding sleep's impact on performance.

Sleep and Performance

The previous section deliberated general health concerns associated with sleep but did not discuss how sleep might impact physical performance. Research has begun to determine the different effects of sleep deprivation, sleep restriction, and additionally, sleep extension on tasks of aerobic and anaerobic performance. Sustained aerobic exercise compared to on maximal effort exercise has been shown to be affected more by sleep deprivation (Blumert et al., 2007; Thomas Reilly & Edwards, 2007). This has been supported by several tests of exercise performance. Azboy and Kaygisiz found that after one night of sleep deprivation male volleyball players experienced less time to exhaustion, and both male runners and volleyball players had decreased minute ventilations during incremental ergometer exercise (Azboy & Kaygisiz, 2009). Martin also found that 36 hours of sleep deprivation decreased time to exhaustion by 11% when using treadmill walking at 80% VO_2max, and a few years later found a 20% decreased time to exhaustion after 50 hours of sleep deprivation (Martin, 1981; Martin & Chen, 1984). Oliver et. al had subjects complete 30 minutes of self-paced treadmill running following 24 hours of sleep deprivation and found a decrease in distance covered when compared to non-sleep deprived measures(Oliver et al., 2009). Sleep deprivation can also impact anaerobic measures of performance (Oliver et al., 2009). After 30 hours of sleep deprivation, Skein et. al found slower sprint times in male team-sport athletes (Skein et al., 2011). Bulbulian et. al also found deficits after 30 hours in the form of isokinetic power (Bulbulian et al., 1996). After 36 hours, decreased peak power on Wingate testing was seen in 13 healthy college-aged males (N. Souissi et al., 2003). Fullager et. al proposes the data is still unclear due to small sample sizes and that it may not be applicable to elite athletes who rarely experience complete sleep deprivation, although are susceptible to sleep restriction (Fullagar, Skorski, et al., 2015).

There have also been performance deficits found related to sleep restriction, with more emphasis on psychological aspects of performance. Psychomotor function deficits were found in both males and females after one night of restricted sleep, while gross motor performance was unaffected (T. Reilly & Hales, 1988; Thomas Reilly & Deykin, 1983). With sleep restricted to 2.5 hours male and female swimmers also had no gross motor function changes, but increased tension, fatigue, confusion, and anger that could lead to potential shortcomings in competition (Beck & Clark, 1988; Dinges et al., 1997; Sinnerton & Reilly, 1992). Confusion has also been shown to increase prior to competition in elite Brazilian volleyball players after they self-reported poor sleep (Andrade, Bevilacqua, Coimbra, Pereira, & Brandt, 2016). Confusion has been linked to feelings of uncertainty, inability to control emotions, and unusual responses to anxiety (Beck & Clark, 1988). These mood changes can negatively impact decision making and execution of motor skills, influencing athletic performance (Dinges et al., 1997; Lastella et al., 2014). Consequently, changes in performance from sleep restriction are not solely mental. Poor performance on sub-maximal repetitions of bench press, leg press, deadlift, and bicep curls have been linked to sleep loss and had greater effects than singular maximal efforts and effects increased later in the protocol suggesting a cumulative effect (Thomas Reilly & Piercy, 1994). Similar to sleep deprivation, sleep restriction has also shown changes during Wingate testing, with issues maintaining maximal work as well as decreased mean and peak power in students, footballers, and professional judo competitors (Abedelmalek et al., 2013; Mougin et al., 2001; D. N. Souissi et al., 2008; N. Souissi et al., 2013). Fullager et. al concluded that sleep restriction does not impact singular bouts of aerobic activities, but rather repetitive sub-maximal strength, power, and sport specific skill performance (Fullagar, Skorski, et al., 2015).

While most studies look at sleep loss, there is a small realm of research analyzing the effects of sleep extension and performance. The earlier development of this realm included studies adding naps to the study of partial sleep deprivation. When subjects were restricted to 4 hours of sleep, but provided a 20 minute nap around lunchtime there was an increase of cognitive motor, and sprint speed performance compare to those who did not receive a nap (J. Waterhouse, Atkinson, Edwards, & Reilly, 2007). Postolache et. al supported the notion that naps increase performance on cognitive tasks, such as learning skills, strategy, and tactics through chronobiology, or the study of human rhythms (Postolache et al., 2005). The newest aspect of sleep extension was performed by Mah et. al in 2011, by having collegiate basketball players increase their amount of sleep as much as possible (Mah et al., 2011). After the two weeks, their performance on basketball skill tasks were compared to baseline, showing increases in sprint speed and free throw accuracy as well as increased vigor and decreased fatigue (Mah et al., 2011). This research suggests that prior to the intervention the athletes were experiencing poor effects of sleep restriction. With various aspects of sleep defined and related to performance, it is important to understand how these present in specific populations.

Epidemiology

The National Sleep Foundation recommends 7 to 9 hours of sleep a night for both the young adult and adult populations (Hirshkowitz et al., 2015). With adults age 18-91 in the United States sleeps 7.1 hours a night on average, with duration dropping to 6.9 hours during the work week (National Sleep Foundation, 2015). In addition to sleep duration on the lower end of the recommended amount, approximately 10% of the population has been diagnosed with insomnia, with increased rates due to age and gender (Brown, 2005). There have also been increased mortality rates in adults in recent years with self-reported short sleep (<7 hours) and long sleep (>9 hours) across various studies (Cappuccio et al., 2010). For the general population sleep has become of increasing interest, but more specific populations may give light to varying effects of sleep.

According to the American College Health Association's (ACHA) National College Health Assessment (NCHA) from the fall of 2016, 49.8% of college students report experiencing sleep difficulties to some extent, with 63.7% experiencing enough sleep between 0-3 days a week and 47.9% have issues with sleepiness a minimum of 4 days per week (ACHA-NCHA, 2016). Of those students who report sleep difficulties, 44.7% report negative impact on academics either as a low exam grade, low course grade, incomplete or dropped class, or a significant disruption on thesis work (ACHA-NCHA, 2016). Short sleep in college students has also been correlated with a lower GPA (Gaultney, 2010). While there are relatively high occurrence of sleep issues in the college population, only 7.2% were diagnosed with some form of sleep disorder and only about half of those receive some form of treatment (ACHA-NCHA, 2016). This may be due to lack of information on how to handle sleep difficulties as only 25.7% of college students report that they received sufficient information from their institutions

(ACHA-NCHA, 2016). Research by Jennings also suggests that increased information from a college institution on health promotion and education on sleep quality may reduce negative outcomes of sleep difficulties (Jennings, 2014). It is apparent the college population is presented unique circumstances with the demands of school, work, and social life that all contribute to poor sleep quality (Lund et al., 2010).

There is another unique population that experiences all the sleep difficulties listed above and additionally, the demands of athletic participation. The National Collegiate Athletic Association (NCAA) study of Growth, Opportunities, Aspirations and Learning of Students in college (GOALS) reports that Division I athletes spent a median of 34 hours a week on academics in 2015, an increase of 2 hours from 2010 (Paskus & Bell, 2016). Another aspect of general college life, time spent socializing for DI athletes was approximately 17.1 hours a week in 2015, which had decreased 2.4 hours since 2010 (Paskus & Bell, 2016). These athletes also have a time commitment of 38.5 hours a week for their prospective sports participation, with an even higher median amount for sports such as FBS football, FCS football, baseball, and women’s softball (Paskus & Bell, 2016). In addition, two-thirds of DI athletes report they spend as much or more time on athletics out of season as in-season (Paskus & Bell, 2016). With close to 90 hours a week accounted for, it is logical that these athletes only report sleeping 6.2 hours a night, well below the recommended amount (Hirshkowitz et al., 2015; Paskus & Bell, 2016). After completion of the survey, the athletes were given a list of topics and asked which topics they wished they had more information on. One of the top responses included maximizing athletic performance through proper sleep hygiene and increased sleep amount (Paskus & Bell, 2016). While all of these statistics come from a self-reported survey of college athletes, it presents a new area of sleep assessment not previously explored.

Sleep Measurement Instrumentation

Currently, polysomnography (PSG) is the gold standard of sleep measurements. PSG uses various measurements to classify sleep stage and quantify sleep quality, including: surface electrodes to measure brainwave activity, blood oxygen levels, heart rate, respiration rate, eye movements, and leg movements (Anch et al., 1988; Marino et al., 2013). This provides an objective measure of sleep quality, but is not useful for large-scale studies and tends to obtrusively alter regular sleep patterns with the laboratory setting (Marino et al., 2013). PSG also lacks practicality due to the high cost of equipment and the training required to perform testing (Kanady et al., 2011). While PSG is not often used for these reasons, it does provide a standard to compare other possible measurements to determine their worth in sleep research.

One of those tools is a self-report sleep scale, of which many variations exist. Examples include the Epworth Sleepiness Scale (ESS), Multiple Sleep Latency Test (MSLT), Medical Outcomes Study- Sleep Scale (MOS-SS), or the most widely used Pittsburgh Sleep Quality Index (PSQI) (Smith & Wegener, 2003). Typically, these scales include several items the subject can answer independently using a Likert scale or frequency scale (e.g., most days, less than half, few days, none) to describe variables of sleep quality, including total sleep time, number of times woken after sleep onset, and subjective feelings of sleep quality (Smith & Wegener, 2003). These tools are easy to administer, and while the PSQI has been shown to be internally reliable and subject to test-retest validity, there is low to no significant positive correlations between objective sleep quality measures (Backhaus et al., 2002; Buysse et al., 1989; Grandner et al., 2006; Monk et al., 1994). In addition, most of these tools lack normative data for the healthy population (Smith & Wegener, 2003). Most studies that utilize sleep scales use populations diagnosed with a sleep disorder and use this tool to assess prevalence of symptoms and impact on quality of life (De Weerd et al., 2004). Studies that utilize the ESS and MSLT use the measure of daytime sleepiness to determine quality of sleep, but sleepiness is a result of poor sleep quality not a direct measure as many other variables can impact daytime sleepiness (Johns, 2000).

Another tool called actigraphy has been investigated heavily in the past 30 years. Actigraphy use wearable accelerometers to calculate variables of sleep (total sleep time, wake after sleep onset, latency, and efficiency) using body positions and movements (Marino et al., 2013). Several studies support actigraphy as a valid tool to distinguish sleep vs. wake compared to polysomnography (Acebo, 2005; Ancoli-Israel et al., 2003; Chesson Jr et al., 2007; de Souza et al., 2003; Kanady et al., 2011; Marino et al., 2013). It has also been validated in the adolescent and younger adult populations (Blood, Sack, Percy, & Pen, 1997; Cole, Kripke, Gruen, Mullaney, & Gillin, 1992; de Souza et al., 2003; Jean-Louis et al., 1996, 1997; Johnson et al., 2007; Monk, Buysse, & Rose, 1999; Paquet, Kawinska, & Carrier, 2007; Sadeh, 2015). In a validation of 77 younger and older adults that were both healthy and diagnosed insomnia patients, actigraphy was found to have high accuracy of 86%, sensitivity above 90% for each participant, and high participant-specific accuracy above 80% (Marino et al., 2013). The specificity was highly variable, showing that it was difficult to determine repeated waking patterns in those diagnosed with insomnia (Marino et al., 2013; Tryon, 2004). These discrepancies may be due to the nature of actigraphy measurements, which use immobility as an indicator of sleep while PSG uses changes in brain wave activity patterns (Tryon, 2004). This is an issue for those populations with increased wakefulness throughout the night with limited movements and can also cause overestimates of total sleep time and underestimate wake time (Ancoli-Israel et al., 2003; Marino et al., 2013; Tryon, 2004). These variables are calculated using either threshold or regression algorithms, and different protocols have been used throughout the literature (Paquet et al., 2007). A standardization of these analysis parameters may help decrease these errors (Cole et al., 1992; Jean-Louis, Kripke, Cole, Assmus, & Langer, 2001).

One of the models of wrist actigraphs that has been validated as the best model for sleep data is the ActiGraph GT3X-BT (ActiGraph Corp LLC, Pensacola, FL), showing significant equivalence to PSG using Bland-Altman plots compared to commercially available activity monitors (Rosenberger, Buman, Haskell, McConnell, & Carstensen, 2016). The GT3X-BT also utilizes two standardized algorithms based on age. The Cole-Kripke algorithm was developed for commercially available actigraphs from the work of Mullaney et. al and Webster et. al, who developed a manual scoring technique and algorithm for experimental actigraph models, respectively (Mullaney, Kripke, & Messin, 1979; Webster, Kripke, Messin, Mullaney, & Wyborney, 1982). Due to the population of the study, the Cole-Kripke algorithm is generally applied to populations aged 35-65 years of age (Cole et al., 1992). The Sadeh algorithm was developed from a similar study utilizing subjects 10-25 years of age and is applied by the GT3X-BT to this population (Sadeh et al., 1994). Originally, these algorithms were both developed using the Motionlogger Actigraph (Ambulatory Monitoring, Inc., Ardsley, NY), which the Actigraph Corp used to scale and adapt the algorithms to allow the GT3X-BT to produce matching data. The Sadeh algorithm was utilized in the previously mentioned study by Rosenberger et. al (Rosenberger et al., 2016).

Sleep Research in Athletes

Early research analyzing sleep in athletes suggested that athletes had superior sleep quality compared to non-athletic counterparts and was attributed to high levels of aerobic fitness

(Demirel, 2016; Porter & Horne, 1981; Shapiro et al., 1984). More recent research suggests the opposite; athletes have poor sleep quality due to various factors of the lifestyle. Some researchers found relationships between poor sleep and the stressors before and during competition including anxiety and excitement, with nervousness and thoughts of competition being the most common complaint regardless of sport or gender (Erlacher et al., 2011; Juliff et al., 2015; Lastella, Roach, Halson, Martin, et al., 2015; Lastella et al., 2014; Savis, 1994). In addition to competitions, the travel to and from athletic events can contribute to poor sleep by unfamiliar sleep environments, time zone changes, short and long travel schedules, and altitude exposure (Erlacher et al., 2011; P. Fowler et al., 2015; Peter Fowler et al., 2014; Lastella, Roach, Halson, Martin, et al., 2015; Lastella et al., 2014; McGuckin et al., 2014; Pedlar et al., 2005; J. Waterhouse et al., 2007; Winter et al., 2009). The timing of training and competition can also impact sleep either with early or late schedules, with 52.3% of elite athletes reporting subjective sleep disturbances after late training or games (Fullagar, Duffield, et al., 2015; Juliff et al., 2015; Sargent et al., 2014; Sinnerton & Reilly, 1992). Even the type of sport, team or individual, can change sleep patterns as the training patterns, time in season, and team culture influence the athletes and can limited the predictability of sleep disturbances by age (Fullagar, Duffield, et al., 2015; Juliff et al., 2015; Lastella, Roach, Halson, & Sargent, 2015). By these studies, it is apparent that the lifestyle of an athlete provides unique circumstances that influence sleep quality.

Above, the physical and mental performance detriments from poor sleep were shown, and here it is shown that athletes are exposed to unique scenarios that increase their likelihood to experience poor sleep, but there is a lack of evidence showing the level of poor sleep in athletes. Most of the above studies relate aspects of athletic life to poor sleep using self-reported sleep measurements. This may provide insight into how the athlete perceives their sleep quality, but disconnect has been found between perceived sleep and objective measures of sleep quality (Backhaus et al., 2002; Buysse et al., 1989; Grandner et al., 2006; Monk et al., 1994). There is limited research describing sleep quality in athletes objectively, and of those there are wide variations in the populations, multiple methods, and generally small sample sizes. One of the earliest was of 7 elite female swimmers and it compared sleep patterns over 6 months of training using PSG measures (Taylor, Rogers, & Driver, 1997). Two nights of data were collected for each swimmer at the timepoints of training onset, peak training, and taper, each approximately 3 months apart (Taylor et al., 1997). The study found no significant changes between training onset and peak training, and only significant decreases in slow wave sleep amount and decreased movements from both onset to taper and peak to taper (Taylor et al., 1997). This supports theories of sleep stating slow wave sleep is key to physical recovery, as it decreases as training volume decreases (Schmidt, 2014). The study suggests that there is not much change based on training volume, although there were no baseline measures of sleep established prior to the start of training. Also, there may be bias from data collection taking place in the laboratory setting and for only 2 nights at each time point. Though the results were few, it does provide a framework for further research analyzing changes in sleep due to training volume.

Most of the other objective sleep research in athletes has taken place in the past 7 years, starting in 2011(Mah et al., 2011). Baseline and intervention sleep extension data was collected for 11 Division I male collegiate basketball players using both actigraphy and a self-report sleep diary (Mah et al., 2011). Athletic performance was also tested using sprint tests and free throw accuracy at both timepoints. It was determined that at baseline the athletes slept on average 6.6 hours a night and self-reported 7.8 hours, and after they were instructed to extend sleep to 10 hours a night they averaged 8.45 hours while reporting 10.4 hours (Mah et al., 2011). This sleep extension of almost 2 hours showed improvements in athletic performance as well as perceived fatigue and vigor (Mah et al., 2011). Currently, this is the only study to assess sleep patterns in collegiate athletes and the researchers suggest further research utilize variables of sleep quality that give more insight than total sleep time alone (Mah et al., 2011).

Several studies have utilized elite athletes on the national and Olympic stages. A study of both team and individual sport athletes in Australia used both actigraphy and sleep diaries over 7 days of typical training to determine that, on average, athletes sleep 6.8 hours a night and individual sport athletes have significantly less sleep and less efficiency than their team sport counterparts (Lastella, Roach, Halson, & Sargent, 2015). In 2012, Leeder et. al established that while not competing Olympic athletes have a comparable amount of sleep to their non-athletic age and gender matched controls, but have significantly lower sleep quality (Leeder et al., 2012). Considerable individual variation was seen amongst the athletes, but differences in sport type may have contributed to the differences (Leeder et al., 2012). Another study of elite swimmers aimed to find differences due to training levels over 12 training and 2 rest days, focusing on the trend of early morning training sessions (Sargent et al., 2014). A lower sleep time and decreased sleep efficiency was found on training days compared to rest days, as well as increased time to fall asleep (Sargent et al., 2014). Although, for both conditions sleep time, efficiency, and latency were below the normal and recommended amounts (Sargent et al., 2014). Sargent et. al suggests there is no rationale for early morning training and it may restrict sleep (Sargent et al., 2014). This is an interesting concept for elite athletes that may be able to change training schedules, but for other populations of athletes it is impossible to change.

One such population would be the adolescent age group that not only has sport commitments, but scholarly as well. In a recent study, Suppiah et. al tracked sleep in 29 male elite secondary school athletes in Singapore for 7 days to track changes in sleep quality between weekdays and weekends (Suppiah, Chee Yong Low, & Chia, 2016). Using actigraphy and sleep diaries, the researchers found the youth on average maintained 5.5 hours of sleep on weeknights and delayed bedtime and waketime on the weekends (Suppiah et al., 2016). Psychomotor tasks were also used to determine possible sleep debt effects, which were evident by superior performance on the days following sleep extension on the weekends and a deterioration of performance as the week progressed through Friday (Suppiah et al., 2016). This research suggests that the scheduling pressure being both student and athlete lead to a "social jet-lag", or this cycle of sleep debt and sleep extension (Suppiah et al., 2016).

Purpose

It is evident by the above research that sleep research in athletes is on the rise, but various holes in the literature leave much to be desired. Fullagar et. al suggests that the next step is determining where in athletics sleep is an issue using long-term observational studies (Fullagar, Duffield, et al., 2015). Performance is obviously an area impacted by sleep with coaches and athletes agreeing that it is a critical aspect of optimal performance, but as seen above there are few studies that establish the quality of sleep in athletes in order to determine how to effectively intervene, alter recovery protocols, and adjust training time to maximize sleep and improve performance (Fullagar, Duffield, et al., 2015; Fullagar, Skorski, et al., 2015; Halson, 2008; Lastella, Roach, Halson, & Sargent, 2015; Mah et al., 2011; Venter, 2014).

In addition to lacking objective data on athletes, there is much variation in the population. Studies seem to focus on elite athletes, but the age and type of athlete are rarely brought into account. One group that has limited sleep data is the collegiate athlete population, with data for only 11 male basketball players (Mah et al., 2011). As highlighted above, the collegiate athlete populations adds increased stressors that impact sleep quality on top of those all athletes encounter, with large time commitments to their sport, school, and social life (Paskus & Bell, 2016). This environment is prime for breeding poor quality of sleep, and may potentially be worse than the sleep patterns already elicited by the college population (ACHA-NCHA, 2016). All of the research gives way for further research analyzing the effects of college life, variations in sleep throughout a semester, collegiate sports participation, and training volume, which have all been shown to impact sleep (ACHA-NCHA, 2016; Gaultney, 2010; Jennings, 2014; Lack, 1986; Paskus & Bell, 2016; Robey et al., 2014; Sargent et al., 2014; Taylor et al., 1997). The aim of this study is to establish a novel and objective measure of sleep in collegiate athletes that can be used to better their health and performance in the future. The purpose of this study is to objectively evaluate the sleep quality of college athletes across gender, comparing them to a normal college student population.

CHAPTER 3

METHODS

Study Design

A cross-sectional study design of Division I soccer athletes and collegiate non-athlete comparison group were used to assess quality of sleep. Data was collected at various timepoints throughout one semester for one-week intervals for both collegiate athletes and gender matched collegiate students. The Actigraph GT3X+ activity monitor (ActiGraph Corp, LLC Pensacola, FL) was utilized to track both sleep and physical activity level. It had original been intended that each group would be assessed at two timepoints however only the male athlete group was able to complete both data collections. Effects were examined by comparing objective measures of sleep quality between the four groups (male athletes, female athletes, male controls, female controls). The relationships between physical activity levels and sleep quality was also assessed since sleep and physical activity are known synergistic health behaviors.

Participants

A convenience sample of male and female collegiate soccer players and gender matched healthy collegiate students (18-25 years old) were recruited through the soccer program coaches and undergraduate courses in the School of Health Sciences and Kinesiology at a single Division I university in the Southeastern United States. An informed consent and demographics questionnaire was completed prior to testing. The demographics questionnaire was used to determine inclusion/exclusion criteria of the participants.

Inclusion and exclusion criteria were based on characteristics that may confound the sleep patterns or make controls dissimilar to athletes. These were used to ensure the controls were healthy collegiate students held to the same academic standards as the Division I collegiate athlete without the time commitment of organized sport. ("Division I Progress Toward Degree Requirements," 2015, "Graduation Requirements for Georgia Southern University," n.d.) The inclusion/exclusion criteria were as follows:

Inclusion Criteria

1. Age 18-25 years
2. Willing and able to provide informed consent

Athletes (Additional Inclusion Criteria):

3. Participate in Division I university sport program

Exclusion Criteria

1. BMI $\geq$ 30.0
2. GPA < 2.0
3. Course enrollment at part-time
4. Current diagnosis of sleep disorder (Chesson Jr et al., 2007; Hedner et al., 2004; Kenneth L. Lichstein et al., 2006)
5. Current medication for sleep manipulation
6. Current diagnosis of depression or anxiety (Staner, 2010)
7. PHQ-2 score $\geq$ 2 (Kroenke, Spitzer, & Williams, 2003)
8. Limited physical activity due to injury

Non-Athletes (Additional Exclusion Criteria):

9. Participation in a club sport

Instrumentation

Demographics questionnaire. This questionnaire includes questions about the participants' age and gender that will be used when assigning ActiGraph wrist monitors. Questions about mental health and anti-psychotics were included to determine if a participant would be excluded from the study. The Personal Health Questionnaire-2 (PHQ-2) is a screening tool used to identify possible depressive disorders (Kroenke et al., 2003). It was also included in the questionnaire due to its brevity and validity to exclude participants with possible depressive disorders that might confound sleep data (Kroenke et al., 2003).

ActiGraph GT3X+ activity monitor. The ActiGraph GT3X+ activity monitor (ActiGraph Corp, LLC Pensacola, FL) uses a 3-axis microelectromechanical system (MEMS) accelerometer to gather acceleration data of the desired extremity. The data were sampled using a 12-bit analog to digital converter at a rate of 30 Hz and stored on the device as raw, unfiltered data. This data was then uploaded to a computer using the accompanying ActiLife software (ActiGraph Corp, LLC Pensacola, FL).(ActiGraph Corp, 2016) Using this software, the Sadeh algorithm was applied to produce several variables describing sleep quality (Sadeh et al., 1994). The ActiGraph has been validated as a reliable and objective measure of sleep quality compared to polysomnography (Acebo, 2005; Ancoli-Israel et al., 2003; de Souza et al., 2003; Dj, Df, & S, 1980; Jean-Louis et al., 1996, 2001; Johnson et al., 2007; Kushida et al., 2001; Marino et al., 2013; Slater et al., 2015; Tonetti, Pasquini, Fabbri, Belluzzi, & Natale, 2008).

Procedures

Research procedures were approved by the University's Institutional Review Board prior to any testing. Participants were recruited from the men and women's soccer teams and undergraduate kinesiology classes.

Informational Sessions. There were several informational sessions conducted over a 2-week period. The informational sessions for the men and women soccer athletes were conducted after practice for their convenience. For the comparison group, two one-hour nights sessions and one after class session was held to meet the needs of the student volunteers. During the informational session – the study's aim and purpose was described, along with details of the informed consent. After any participant questions, the volunteers were given the questionnaire and primary research double check the survey for inclusion and exclusion criteria. Responses to the PHQ-2 were evaluated to see if a referral to the campus counseling center was warranted. No participants were required a referral. If they student was eligible they completed the anthropometric measures as describe above. Then the participants were asked to download the Remind Application to assistant with adherence to the measurement protocols.

Instructions for Actigraphy. The last part of the information session included receiving the actigraphy device and specific instructions. Participants were asked to not alter their daily activities or sleep patterns. Data was collected from each participant for a one-week timepoint, with the exception of the male athlete group who participated in two separate one-week timepoints based on training volume. For the data collection period, the participants wore the ActiGraph device on their non-dominant wrist at all times, except with swimming, showering, or any athletic participation in which it was prohibited (i.e., collegiate Division I soccer games). The participants recorded when the device was not worn for 20 minutes or more in the activity log, which provided information to exclude false sedentary behavior data. The participants also recorded the time they went to bed and time they woke up on the activity log. Other than wearing the device and tracking wear time the participants were instructed to not change their typical daily behaviors. The device captured both physical activity levels and sleep patterns during the testing period. Reminders were sent via the Remind application throughout the week to encourage adherence and proper data collection. All information was anonymous. At the end of the week the device was returned with the activity log.

Activity log. The activity log was used to determine what time the participant went to bed and when the participant awoke. It was also a record of when the participant removed the ActiGraph device for more than twenty minutes. This information was used to divide the accelerometer data into wake and rest time periods as well as remove false time periods of inactivity due to the participant not wearing the device.

Remind Application. The Remind Application (Remind HQ, San Francisco, CA) can be downloaded onto any smartphone device. This communication platform was used to promote adherence to the protocol of the study. Each participant enrolled in a class controlled by the researcher. The researcher used the platform to send daily reminders to the participants to where the Actigraph device and log their activity. The participants could also use this platform to contact the researcher in case there were issues with the devices. If the participant did not have a smartphone or did not wish to download the Remind application, they still enrolled and opted to receive text message updates.

Data Analysis

Raw physical activity and sleep accelerometry data was sampled at 30 Hz using the ActiGraph GT3X+ wrist activity monitor. This raw accelerometry data was downloaded as an AGD file and processed using the ActiLife software. The data was divided into wake and sleep periods using the reported times in the activity log. For physical activity, the ActiGraph proprietary algorithm was applied to determine movements for each of the three axes and quantified as activity counts. The activity counts were totaled per hour of wear-time. The vector magnitudes of the 3-directional activity counts were used to quantify physical activity. Trends in the vector magnitude values for all participants were used to categorize physical activity into four levels: low, moderate, high, and very high. The proportion of time each participant spent in each of these categories was calculated. The average daily vector activity count was also used to quantify physical activity of each participant.

For sleep, the Sadeh algorithm was applied through the ActiLife software to identify periods of sleep and wake during the reported sleep period (Sadeh et al., 1994). This algorithm determined variables of sleep, including total sleep time (TST; total minutes of recorded sleep during sleep period), sleep latency (i.e., number of minutes to fall asleep), wake after sleep onset (WASO; i.e., minutes of wake after initial sleep onset), and sleep efficiency (i.e., ratio of TST to total sleep period, expressed as a percent).

Statistical Analysis

Independent Sample T-Tests were used to establish differences between the measures of sleep between the groups. Comparisons were made between the male athletes and non-athletes, female athletes and non-athletes, male and female athletes, and male and female non-athletes. Significant differences were determined using an alpha level of .05. Two-tailed T-Tests were used since physical activity has been shown to increase sleep quality even though the population subjectively reports poor sleep quality. No previous literature was found comparing athletes to non-athletes on objective sleep measurements. Independent Sample T-Tests were also used to establish differences in Average Daily Activity Counts (ADAC) for both males and females between the athlete and non-athlete groups. No previous literature was found using ADAC to compare activity levels of participants. An alpha level of .05 was used to determine significance.

Chi-square Tests of Independence were also used to establish differences between groups on physical activity levels. The frequencies of participants' activity level throughout a day were compared between male athletes and non-athletes and female athletes and non-athletes. Significance was determined at an alpha level of .05. Though these activity levels were determined using trends among the sample, the proportions were similar to physical activity intensity levels used in the ActiLife software. These intensity classifications were not valid for the Actigraph when worn on the wrist.

Pearson's Product Correlations were also used to analyze the relationships between physical activity levels and sleep quality measurements. Comparisons were made between ADAC and TST, WASO, latency, and efficiency for all groups as well as the entire sample. Correlations were considered to have a strong relationship when correlation coefficients were greater than .70, moderate relationships when the correlation coefficients were between .50-.70, and weak relationships when the coefficient was less than .50.

CHAPTER 4

RESULTS

A total of 133 subjects (19.39 years old ± 1.28) met the inclusion/exclusion criteria and agreed to participate in this study. Three subjects were lost due to failure to complete the testing protocol. Seven subjects were removed from analysis due to instrumentation error of the Actigraph devices. Nineteen subjects were also removed from analysis due to insufficient data of number of days worn. A total of 104 subjects was used for the final analysis. Of these, 42 were Division I athletes (24 male, 18 female) and 62 controls who were full time college students and non-athletes (23 male, 49 female). The male athlete group was the only group able to be tested for a second timepoint and at this second testing three additional subjects were lost, one due to instrumentation error and two due to insufficient data. See Consort diagram for attrition in Figure 1.

For the sleep data, a one-sample t-test comparing total sleep time (TST) and sleep efficiency for each group to the recommended amount of 8 hours and 85%, respectively, showed significant differences for all groups, with an alpha level of .05. These values can be found in Table 1. Additionally, an independent-samples t-test used to compared sleep measures between groups showed significant differences between TST for the male controls (M= 386.722, SD= 56.984) and the male athletes second timepoint (M= 344.362, SD= 49.094) conditions (t(44)= -2.701, p =.010), with the male athletes having less TST. An independent-samples t-test also showed significance between TST of the male athletes second timepoint (M= 344.362, SD= 49.094) and the female athlete (M= 379.754, SD= 47.241) conditions (t(38)= -2.290, p= .028), with the males having less TST than the females. No other comparisons showed significant differences between the groups, however, it should be noted that the general trend showed athletes got less TST and the male athletes had greater variability in sleep latency than any other group. All independent-sample t-test results for sleep variables can be found in Tables 3-8.

Physical activity data presented as average daily activity counts for each participant were compared using an independent-samples t-test and it was found that male athletes for both the first (M=161047.933, SD=39263.077) and second timepoint (M=138409.735, SD=42318.870) had significantly more activity counts (t(352)=-7.782, p=.000; t(322)=-2.149, p=.032) than the male controls (M=128740.628, SD=38624.096). However, there were no differences between the female athletes and female controls, as can be seen in Table 8. Additionally, a chi-square test of independence was conducted to determine if there were significant differences in the frequencies of varying levels of activity counts between groups. Tables 10-12 outlines these results, showing that there were no significant differences at an alpha level of 0.05.

Results of the Pearson Product Correlations show significance only in the Female Athlete group with the relationship of Average Daily Activity Counts (ADAC) and Latency. When the relationships were compared for the entire sample, significance was found between ADAC and Total Sleep Time (TST), Latency, and Efficiency. While significant, these correlations are all weak, except for the Female Athlete group which has a moderate correlation (R = .557). Table 13 shows the correlations for all groups as well as correlations for the entire sample and significance is indicated at an alpha level of .05.

Figure 1. Consort Diagram of Participant Enrollment

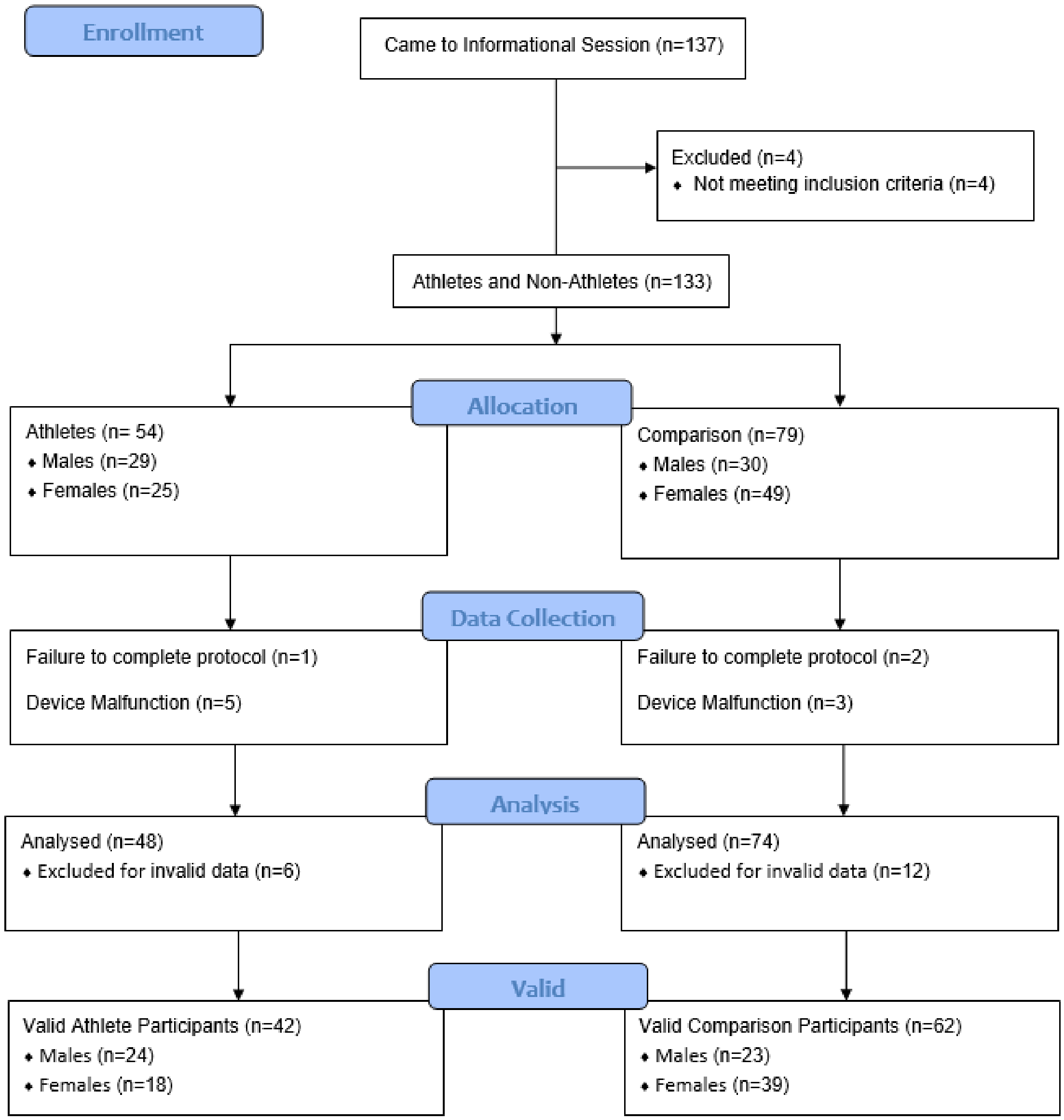

Table 1

Average Total Sleep Time Compared to Recommended 8 Hours

	TST (hours)	*t*	*p*
Male Non-Athletes	6.45 ± .95	12.63	<.001
Male Athletes Timepoint 1	6.06 ± .77	12.343	<.001
Male Athletes Timepoint 2	5.74 ± .82	7.825	<.001
Female Non-Athletes	6.63 ± .76	11.257	<.001
Female Athletes	6.33 ± .79	8.969	<.001

Note. TST = Total Sleep Time, Mean ± SD.

Table 2

Average Sleep Efficiency Compared to Recommended 85% Efficiency

	Efficiency (%)	*t*	*p*
Male Non-Athletes	80.83 ± 7.15	2.797	.011
Male Athletes Timepoint 1	78.37 ± 6.65	4.884	<.001
Male Athletes Timepoint 2	77.28 ± 7.82	4.524	<.001
Female Non-Athletes	80.38 ± 5.74	5.027	<.001
Female Athletes	80.07 ± 5.02	4.167	<.001

Note. Mean ± SD.

Table 3

Sleep Measure Means for Male Athletes at Timepoint 1 and Male Non-Athletes

	Group			
	Athletes	Non-Athletes	*T*	*p*
Latency (minutes)	21.05 ± 20.35	14.87 ± 7.75	1.369	.178
Efficiency (%)	78.37 ± 6.65	80.83 ± 7.15	-1.246	.219
TST (hours)	6.06 ± .77	6.45 ± .95	-1.582	.120
WASO (minutes)	78.37 ± 22.98	78.89 ± 35.50	-.062	.951

Note. TST = Total Sleep Time, WASO = Wake After Sleep Onset, Mean ± SD.

Table 4

Sleep Measure Means for Male Athletes at Timepoint 2 and Male Non-Athletes

	Group			
	Athletes	Non-Athletes	*T*	*p*
Latency (minutes)	23.65 ± 20.82	14.87 ± 7.75	1.895	.069
Efficiency (%)	77.28 ± 7.82	80.83 ± 7.15	-1.604	.116
TST (hours)	5.74 ± .82	6.45 ± .95	-2.701	.010
WASO (minutes)	79.93 ± 26.14	78.89 ± 35.50	.113	.911

Note. TST = Total Sleep Time, WASO = Wake After Sleep Onset, Mean ± SD.

Table 5

Sleep Measure Means for Female Athletes and Female Non-Athletes

	Group			
	Athletes	Non-Athletes	*T*	*p*
Latency (minutes)	14.09 ± 7.40	18.30 ± 12.00	-1.613	.113
Efficiency (%)	80.07 ± 5.02	80.38 ± 5.74	-.191	.849
TST (hours)	6.33 ± .79	6.63 ± .76	-1.342	.185
WASO (minutes)	79.51 ± 21.42	79.56 ± 29.66	-.007	.994

Note. TST = Total Sleep Time, WASO = Wake After Sleep Onset, Mean ± SD.

Table 6

Sleep Measure Means for Male Athletes at Timepoint 1 and Female Athletes

	Group			
	Males	Females	*T*	*p*
Latency (minutes)	21.05 ± 20.35	14.09 ± 7.40	1.349	.185
Efficiency (%)	78.37 ± 6.65	80.07 ± 5.02	-.899	.374
TST (hours)	6.06 ± .77	6.33 ± .79	-1.126	.267
WASO (minutes)	78.37 ± 22.98	79.51 ± 21.42	-.165	.870

Note. TST = Total Sleep Time, WASO = Wake After Sleep Onset, Mean ± SD.

Table 7

Sleep Measure Means for Male Athletes at Timepoint 2 and Female Athletes

	Group			
	Males	Females	*T*	*p*
Latency (minutes)	23.65 ± 20.82	14.09 ± 7.40	2.036	.051
Efficiency (%)	77.28 ± 7.82	80.07 ± 5.02	-1.369	.179
TST (hours)	5.74 ± .82	6.33 ± .79	-2.290	.028
WASO (minutes)	79.93 ± 26.14	79.51 ± 21.42	.053	.958

Note. TST = Total Sleep Time, WASO = Wake After Sleep Onset, Mean ± SD.

Table 8

Sleep Measure Means for Male Non-Athletes and Female Non-Athletes

	Group			
	Males	Females	*T*	*p*
Latency (minutes)	14.87 ± 7.75	18.30 ± 12.00	-1.374	.175
Efficiency (%)	80.83 ± 7.15	80.38 ± 5.74	.275	.784
TST (hours)	6.45 ± .95	6.63 ± .76	-.835	.407
WASO (minutes)	78.89 ± 35.50	79.56 ± 29.66	-.081	.936

Note. TST = Total Sleep Time, WASO = Wake After Sleep Onset, Mean ± SD.

Table 9

Average Daily Activity Count Means for All Groups

	Group			
	Athletes	Non-Athletes	*t*	*p*
Males (Timepoint 1)	161047.93 ± 39263.08	128740.63 ± 38624.10	-7.782	<.001
Males (Timepoint 2)	138409.74 ± 42318.87	128740.63 ± 38624.10	-2.149	.032
Females	148789.75 ± 49877.44	151152.27 ± 44432.38	.474	.636

Table 10

Distribution of Activity Count Levels of Male Athletes at Timepoint 1 and Male Non-Athletes

Activity Count	Group			
Level	Athletes	Non-Athletes	χ^2	*p*
Low	37%	42%	.16	.997
Moderate	40%	42%	.02	.999
High	16%	15%	.02	.999
Very High	7%	1%	2.25	.690

Note. $\chi^2 = 4.8975$, $p = .179459$.

Table 11

Distribution of Activity Count Levels of Male Athletes at Timepoint 2 and Male Non-Athletes

Activity Count	Group			
Level	Athletes	Non-Athletes	χ^2	*p*
Low	43%	42%	.01	.999
Moderate	39%	42%	.06	.999
High	14%	15%	.02	.999
Very High	4%	1%	.90	.925

Note. $\chi^2 = 1.9574$, $p = .581304$.

Table 12

Distribution of Activity Count Levels of Female Athletes and Female Non-Athletes

Activity Count Level	Group		χ^2	*p*
	Athletes	Non-Athletes		
Low	37%	32%	.18	.996
Moderate	41%	41%	.00	1
High	18%	25%	.57	.966
Very High	4%	2%	.33	.988

Note. χ^2 = 2.1685, *p* = .538175.

Table 13

Correlations for Average Daily Activity Count and Sleep Measures

	TST	Latency	Efficiency	WASO	*n*
Male Non-Athletes	-.286	.029	-.339	.269	23
Male Athletes Timepoint 1	-.238	.383	-.364	.200	26
Male Athletes Timepoint 2	-.249	-.043	-.062	.023	23
Female Non-Athletes	-.175	.172	-.121	.038	39
Female Athletes	-.402	.557*	-.417	.194	17
All Participants	-.206*	.177*	-.218*	.113	128

Note. TST = Total Sleep Time, WASO = Wake After Sleep Onset, * = $p \leq .05$.

CHAPTER 5

DISCUSSION

The purpose of this study was to establish the sleep quality of in-season collegiate Division athletes compared to their non-athlete college counterparts. Subjectively, it has been shown that the collegiate population suffers from poor sleep quality due to various demands of school, work and social commitments (ACHA-NCHA, 2016; Lund et al., 2010). Data presented by the NCAA suggests that collegiate athletes also suffer from poor sleep quality due to their time commitments (Paskus & Bell, 2016). The goal was to establish if the time commitments of collegiate athletes had a greater impact on sleep quality than the non-athlete college population. It was also a goal of this study to determine if physical activity levels, which was expected to be different for the two populations, had any relationship to quality of sleep.

This study is one of the first to objectively measure sleep quality in the collegiate athlete and non-athlete populations. By comparing average total sleep time (TST) to the 8 hours recommended by the National Sleep Foundation, it can be seen that all groups in this study are on average significantly below this recommendation ($p < .001$) (Hirshkowitz et al., 2015). This supports previous literature only outlining subjective measures of sleep quality in the college population, both athletes and non-athletes (ACHA-NCHA, 2016; Jennings, 2014; Lund et al., 2010). Subjective sleep data specific to college athletes shows they report an average TST of 6.2 hours a night, which aligns with the mean TST for the athletes in this study (Males: 6.06, 5.74; Females: 6.33) (Paskus & Bell, 2016). The only other study that objectively analyzes sleep in college athletes shows an average TST of 6.6 hours, which is again supported by the above data (Mah et al., 2011). In addition to TST, sleep efficiency < 85% is often used in the literature to establish poor sleep quality (Edinger et al., 2004; K. L. Lichstein, Durrence, Taylor, Bush, &

Riedel, 2003; Schutte-Rodin, Broch, Buysse, Dorsey, & Sateia, 2008). Again, both athletes and non-athletes are significantly less efficient than what is recommended, supporting the previous literature.

Direct comparison of sleep measures between groups showed minimal significance, with less total sleep time for male athletes than male comparisons and less total sleep time for male athletes compared to female athletes. Both of these apply to the week of male athlete data that was collected during a low volume practice week. The relationship between sleep and activity level will be discussed further below. It should be noted that data collection took place in the middle of the academic semester, aligning with the time of midterm exams. This timing could contribute to poor sleep quality seen across all participants. As for the difference based on sex, previous objective sleep research has shown that males have more fragmented and less efficient sleep (Berg et al., 2009; Roehrs, Kapke, Roth, & Breslau, 2006). It can also be seen that females spend more total time asleep than males (Fukuda et al., 1999; Hume, Van, & Watson, 1998; Kobayashi et al., 1998; Lauderdale et al., 2006; Redline et al., 2004; Reyner & Horne, 1995). However, this sex difference only existed in one of the three group comparisons based on sex. One factor that was not accounted for in this study was the time of day the athletes' practiced. For this sample, the male athletes practiced in the morning and the female athletes practiced in the afternoon due to shared facilities. The differences in schedule may serve as a confounding variable for sex differences found in this study. Future research should account for this factor to determine if sex differences in athletes do exist and may be able to highlight if greater sex differences exist between athletes compared to non-athletes.

It was hypothesized the collegiate athlete participants would be more physically active and at a higher level of physical activity than the non-athlete controls. While no previous research was found showing this comparison, the hypothesis was rooted in the knowledge that the general college population is not participating in the recommended level of physical activity (Calfas, Sallis, Lovato, & Campbell, 1994; Keating, Guan, Piñero, & Bridges, 2005; Leslie et al., 1999). The data collections periods for the athletes were originally supposed to take place over two weeks, one being high practice volume and the other low practice volume. Due to changes in the teams' schedules, this was only achieved for the men's soccer team. The hypothesis held true for both weeks of male athlete average daily activity counts compared to non-athletes, but not to the female comparison. There were also no differences for variations in activity level regardless of sex. There is currently no consensus on whether sex differences for physical activity exist in the college population. Some claim that no differences are present, while others claim males participate in more vigorous activity (Behrens & Dinger, 2003; Calfas et al., 1994; Huang et al., 2003; Leslie et al., 1999; Leslie, Fotheringham, Owen, & Veitch, 2000; Pinto & Marcus, 1995; Stock, Wille, & Krämer, 2001). One study has found that as students' progress through college their physical activity levels change, with males increasing and females decreasing (Buckworth & Nigg, 2004).

While the relationships between physical activity level and sleep measures were weak, the overall trend of decreased sleep quality as physical activity level increases is interesting to note. It is widely accepted that physical activity, both acute and regular, can positively influence sleep quality, although these effects are typically small. Acute exercise has been shown to increase total sleep time and decrease both sleep onset latency and wake after sleep onset (Kredlow, Capolzzoli, Hearon, Calkins, & Otto, 2015; Kubitz, Landers, Petruzzello, & Han, 1996; Youngstedt, O'Connor, & Dishman, 1997). Similar results have been found among studies of regular physical activity, although in both cases the studies lack robustness and call for further research (Kalak et al., 2012; Kredlow et al., 2015; Youngstedt, 2005). It should be noted that these studies are of different age groups, both sexes, and varying baseline physical activity levels. A recent meta-analysis showed age significantly moderated sleep latency for older individuals, but had no impact on any other sleep outcomes (Kredlow et al., 2015). As for sex, females had decreased benefit from acute exercise regarding wake after sleep onset (Kredlow et al., 2015). There was no pattern relative to baseline physical activity level (Kredlow et al., 2015). With the trend of increased physical activity decreasing sleep quality found in this study not aligning with previous research, there is potential for future research to determine if other aspects of the identity of a collegiate athlete outweigh the positive benefits of physical activity on sleep quality. These aspects might include academic commitments, required tutoring hours, practice and competition schedules, mandatory team functions, and psychological stress of being a student athlete.

This study had several limitations. First, since our population included healthy college age subjects and athletes, it may not be generalizable to the wider population. Sample size was limited by number of ActiGraph devices and may not detect significant differences between groups. The athlete participants were unable to wear the devices during games due to NCAA rules, which removes important physical activity data. Other limitations may include equipment malfunction, experimental mortality, and participant adherence. Experimental mortality impacted the ability of the researcher to determine changes over time as only one group was able to participate two times. Participant adherence may have affected the accuracy of the data. However, as this was self-reported, there may have been some inherent reporting bias.

Conclusion

The purpose of this study was to objectively measure sleep quality in the collegiate athlete and non-athlete populations as well as determine if relationships between physical activity and sleep quality exist for the populations. This study objectively established poor sleep quality in terms of TST and efficiency for both populations, supporting previous research that had been predominantly subjective of sleep quality in the college athlete and non-athlete populations. Both populations have poor sleep quality, yet it is still unclear if differences exist between the two groups. It is also unclear if physical activity is related to quality of sleep in this study, but the negative trends present contradict the positive relationships found in previous research. Further research in the population that controls for influence of schoolwork and variations in training intensity with a larger sample size could highlight if these negative trends are truly related to physical activity and if a significant relationship is present.

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APPENDIX

Research Compliance Combined Cover Page

Georgia Southern University

Application for Research Approval

Investigator Information:

Name of Principal Investigator: Natalie Brown	Phone: (734)735-7720	**For Office Use Only:**
Email: nb03704@georgiasouthern.edu (Note: Georgia Southern email addresses will be used for all correspondance.)	Department Name and PO Box: Health and Kinesiology PO Box 8076	**Protocol ID**
☐ Faculty ☐ Doctoral ☐ Specialist ☒ Masters ☐ Undergraduate ☐ Other:		
Name(s) of Co-Investigators: Bridget Melton	Phone: 912) 478-1973	
Email addresses: bmelton@georgiasouthern.edu	Department Name and PO Box: Health and Kinesiology PO Box 8076	

☒Faculty; ☐Doctoral; ☐Specialist; ☐Masters ☐ Undergraduate ☐ Other:
(If multiple: identify by initial letter behind name. E.g., F for faculty)

Personnel and/or Institutions Outside of Georgia Southern University involved in this research (Attach training certification):

Project Information: (Note: funded project titles MUST match grant title)

Title: An Objective Measure of Sleep in Division I College Athletes Throughout a Season Compared to the General College Population

Brief (less than 50 words) Project Summary: Using actigraphy to determine the sleep patterns and sleep quality of collegiate athletes in Division I athletics compared to the general college population.

Compliance Information:

Please indicate which of the following will be used in your research: (application may be submitted simultaneously)

☒ Human Subjects (Complete *Section A: Human Subjects* below)
☐ Care and Use of Vertebrate Animals (Complete *Section B: Care and Use of Vertebrate Animals* below)
☐ Biohazards (Complete *Section C: Biohazards* below)

☐ Yes ☒ No Do you or any investigator on this project have a financial interest in the subjects, study outcome, or project sponsor. (A disclosed conflict of interest will not preclude approval. An undisclosed conflict of interest will result in disciplinary action.).

Desired Start Date: August 2017 Anticipated renewals ☐ year 2 ☐ year 3	**Check one:** ☒ **New submission** ☐ **Resubmission #**

Funding Source: ☐ Federal ☐ State ☐ Private ☐ Internal GSU ☒ Self-funded/non- funded
Funding Agency/Department: Grant Number:

Section A: Human Subjects ☐ Not Applicable

Number of Subjects (Maximum) 100

Please indicate if the following are included in the study (Check all that apply):
☐ Survey delivered by email to .georgiasouthern.edu addresses
☐ Human Subjects Incentives
☐ Deception
☐ At Risk Populations (prisoners, children, pregnant women, etc)
☐ Video or Audio Tapes
☐ Medical Procedures, including exercise, administering drugs/dietary supplements, and other procedures, or ingestion of any substance

Section B: Care and Use of Vertebrate Animals ☐ Not Applicable

Purpose of use/care of animals:	*Please indicate if the following are included in the study:*

Research
Teaching
  Demo only
  Student participation in faculty work
  Class Project
Exhibition
Display
	Physical intervention with vertebrate animals
	Housing of vertebrate animals
	Euthanasia of vertebrate animals
	Use of sedation, analgesia, or anesthesia
	Surgery
	Farm animals for biomedical research (e.g., diseases, organs, etc.)
	Farm animals for agricultural research (e.g., food/fiber production, etc.)
	Observation of vertebrate animals in their natural setting

Section C: Biological Research ☐ Not Applicable ☐ Submitted Separately	
Biosafety Level: ☐ Exempt ☐ BSL 1 ☐ BSL 2 ☐ BSL 3	*Please indicate if the following are included in the study:* ☐ Use of rDNA ☐ Non native/invasive plant species ☐ Last EHS lab safety inspection date: ☐ Last IBC biosafety lab inspection date:

Signature of Applicant(s)(PI, CoPI): Natalie Brown	Date: 8/15/17
If student project, please complete research advisor's information below (note that advisor signature must be received before application will be reviewed.) **If faculty project, please complete department chair's information below.**	
By signing this cover page I acknowledge that I have reviewed and approved this protocol for scientific merit, rational and significance. I further acknowledge that I approve the ethical basis for the study.	
Department Chair or Research Advisor's Name (Print or Type): Bridget Melton	
Signature of Committee Chair/Research Advisor (if student)/Department Chair(if faculty): BMelton	Date: 8/15/17

Please submit this protocol to IRB@georgiasouthern.edu in a single email; scanned signatures and official Adobe electronic signatures are accepted. Applications may also be submitted via mail to the Georgia Southern University Office of Research Integrity, P.O. Box 8005.

The application should contain all required documents specific to the committee to which you are applying. Questions or comments can be directed to (912)478-5465 or IRB@georgiasouthern.edu.

Georgia Southern Institutional Review Board Narrative Document

Personnel. The research team includes:

Natalie Brown, LAT, ATC – Graduate Assistant Athletic Trainer/Primary Investigator
Bridget Melton, Ed.D – Associate Professor of Kinesiology/Co-Investigator (CHAIR)
Chad Asplund, M.D. – Staff Physician/Medical Director Athletics Sports Medicine
Steve Patterson, Ed.D. – Clinical Instructor of Athletic Training
Kelly Sullivan, Ph.D. – Assistant Professor of Epidemiology

Bridget Melton is a professor within the College of Health and Human Science at Georgia Southern with previous research experience assessing sleep quality with the ActiGraph wrist activity model. She may assist with instrumentation and data extraction during the testing periods. Chad Asplund is an MD and the team doctor for Georgia Southern University Athletics. He is a member of the NCAA task force for sleep research. He has provided background knowledge of sleep in college athletes and his expertise will be utilized once the final results are determined. Steve Patterson is the program director for the undergraduate athletic training department within the College of Health and Human Sciences at Georgia Southern. He has expertise in the clinical applications in the field of athletic training and will be an important asset for determining future implications for the field of athletic training from this study. Kelly Sullivan is a professor within the College of Public Health. She has conducted research examining sleep in families with children. She has helped determine the appropriate statistical analysis for this project.

Purpose. The purpose of this study is to determine if differences in sleep patterns between Division I college athletes and non-athletes exist using an objective measure at different timepoints. My research questions include: Do NCAA Division I athletes have poor quality of sleep? Do NCAA Division I athletes have worse quality of sleep than their non-athlete counterparts? Does sleep quality change at different timepoints in the season? The null hypothesis would be that there are no effects of athlete status, timepoint, or group-by-time on sleep quality in NCAA Division I collegiate athletes compared to recreationally active college students who are not Division I athletes. Understanding sleep quality in collegiate athletes will lay groundwork for further research regarding the effects of sleep quality in the population.

Literature Review. The prevalence of sleep quality in scientific research has been steadily increasing over the past 30 years. The way sleep quality is measured has evolved during this time, with the typical variables of interest including total hours of sleep or sleep loss. There are several classifications for these variables, including sleep deprivation, sleep restriction, and insomnia. Sleep deprivation is typically defined as one night of sleep loss or a continuous bout of wakefulness lasting 24 hours.[1] Sleep restriction, sometimes referred to as partial sleep deprivation, encompasses nights where the subject receives fewer than 6 hours of sleep during the night,[2] either by delay in sleep onset, earlier wake times, or disturbed sleep by waking subjects after sleep onset.[3] Both classifications are typically used in research and the definitions can vary between researchers. Another way to define sleep loss is insomnia, which is a clinic diagnosis where the individual experiences at least one of the following: difficulty initiating sleep, difficulty maintaining sleep, waking up early, or chronic occurrences of non-restorative or poor quality sleep.[4]

Quality sleep can impact both mental and physical aspects of life. Mental health is intertwined with sleep for various disorders. The comorbidity of sleep quality and several diagnoses, including anxiety, depression, eating disorders, developmental disorders, borderline and anti-social disorders, attention-deficit/hyperactivity disorder, and schizophrenia.[5,6] Sleep quality has also been linked to cognitive performance,[7] decision making,[8] and motor sequence learning.[9] On the physical aspects of health, sleep restriction disturbs glucose metabolism[10] and may be a risk factor for diabetes.[11] Cardiovascular health is also at risk from short sleep and low sleep efficiency, showing indications of low vagal tone[12] and increased risk of myocardial infarction and heart disease.[13] It is clear that quality of sleep can impact health in different ways, and studies of physical performance expand upon these health concerns.

Human performance can be measured through tasks of both aerobic and anaerobic nature. Studies utilizing sleep deprivation in various athletes have found deficits in sustained aerobic exercises, such as less time to exhaustion,[14–16] decreased minute ventilations,[15,16] and decreased performance output.[17] Sleep deprivation can also impact anaerobic performance, by decreasing sprint times,[18] isokinetic power deficits,[19] and decreased peak power on Wingate testing.[20] Although all of this related to sleep deprivation which may not be applicable to elite athletes,[3] there is also research that supports sleep restriction as a source of performance decrements. Sub-maximal repetitions of bench press, leg press, deadlift, and bicep curls have been shown to be impacted by sleep loss and have greater deficits as a protocol progressed suggesting cumulative effects.[21] Wingate testing is again affected by sleep, with sleep restriction leading to difficulty maintaining maximal work[22] and decreased mean and peak power in students,[23] footballers,[24] and professional judo competitors.[25] It has been concluded that sleep restriction has a greater impact on repetitive sub-maximal strength, power, and sport specific skill performance over singular bouts of aerobic activity.[3]

While it is apparent that poor sleep quality has negative effects on health and performance, different populations can be more susceptible to sleep related problems. The National Sleep Foundation recommends 7 to 9 hours of sleep a night in the young adult and adult populations,[26] but on average adults age 18-91 only receive 6.9-7.1 hours a night.[27] In general, the American population experiences short sleep time. Broken down further, the college population, falling in the category of young adults, may have more prevalent sleep issues. The American College Health Association's (ACHA) National College Health Assessment (NCHA) from the fall of 2016 shows that almost 50% of college students report sleep difficulties to some extent, with 47.9% of those having issues with sleepiness a minimum of 4 days per week.[28] Even though it is reported that these sleep problems impact academic performance,[28,29] a three-quarters of college students report they do not receive sufficient information from their institutions to remedy the problem.[28] It is apparent the college population experiences a unique environment with demands of school, work, and social life that all interact and contribute to poor sleep quality.[30]

Yet another subset of the population is the collegiate athlete. The National Collegiate Athletic Association's (NCAA) study of Growth, Opportunities, Aspirations, and Learning of Students in college (GOALS) reported that Division I athletes on average spend 38.5 hours a week on sports participation, 34 hours a week on academics, 17.1 hours a week socializing, and only sleep 6.2 hours a night.[31] After completing this survey, the athletes were presented with topics they wished to have more information on and one of the top responses was maximizing athletic performance through proper sleep hygiene and increased sleep time.[31] This survey highlights a new area of sleep assessment in collegiate athletes not previously explored.

Early research assessing sleep in athletes suggested that athletes had superior sleep compared to non-athletic counterparts[32] due to high levels of aerobic fitness.[33,34] Recently, the data suggests the opposite, and due to the various factors of the athlete lifestyle, athletes have poor sleep quality. Relationships exist between stressors of competition and poor sleep, including anxiety and excitement,[35–38] with nervousness and thoughts of competition being the most common complaint.[39] In addition to competitions, the travel to and from athletic events can contribute to poor sleep by unfamiliar sleep environments,[35–37] time zone changes,[40] short and long travel schedules,[41–44] and altitude exposure.[45] The timing of training and competition can also impact sleep either with early[46,47] or late schedules.[48] Even the type of sport, team or individual, can change sleep patterns as the training patterns, time in season, and team culture influence the athletes and can limited the predictability of sleep disturbances by age.[37,39,48] The lifestyle of an athlete provides unique circumstances that can influence the populations' quality of sleep.

For most of the aforementioned studies, quality of sleep was measured using subjective questionnaires, such as the Epworth Sleepiness Scale (ESS), Multiple Sleep Latency Test (MSLT), Medical Outcomes Study- Sleep Scale (MOS-SS), or the most widely used Pittsburgh Sleep Quality Index (PSQI).[49] These tools are convenient and while some, such as the PSQI have been shown to be internally reliable and subject to test-retest validity, there are no significant correlations to objective sleep quality measures.[50–53] The gold standard of objective sleep measurements is polysomnography (PSG), which can measure several variables at once, including: brainwave activity, blood oxygen levels, heart rate, respiration rate, eye movements, and leg movements.[54,55] This provides an accurate and objective measure of sleep, but is not practical for large-scale studies as the laboratory setting can obtrusively alter sleep patterns and the high cost of equipment.[55,56] Due to the flaws in the previously mentioned methods, another tool called actigraphy has emerged in the past 30 years. Actigraphy uses wearable accelerometers to calculate variables of sleep using body positions and movements.[55] Several studies support actigraphy as a valid tool to distinguish sleep vs. wake compared to polyomnography.[55–60] Using the raw accelerometry data, the Sadeh[61] algorithm is applied to discern several variables of sleep quality, namely total sleep time, sleep latency, sleep efficiency, and wake after sleep onset.[55] These variables can then be compared to normative data as well as between test subjects to assess sleep quality.

Sleep research in athletes has several pitfalls that highlight an interesting new area of study. First, most research of sleep in athletes has been done on the elite populations and not the collegiate athlete population. With the unique stress of being both a college student and an athlete, the collegiate athlete population seems more susceptible to poor quality of sleep, but no research has proven this. The only student to date on sleep in collegiate athletes was conducted on 11 male basketball players by Mah et al.[62] The study measured sleep quality by actigraphy and athletic performance before and after sleep extension to determine if performance would increase with increased total sleep time.[62] The athletes' performance did improve, suggesting that the athletes did not get sufficient sleep prior to the intervention, but did not highlight all aspects of sleep quality and was only performed on 11 male athletes.[62] Secondly, most studies of sleep in athletes rely on subjective measures of sleep. For the above study, an objective measure was used, but as part of an intervention study were athletic performance was the outcome measure. Leeder et al. studied sleep quality in elite athletes using actigraphy, and found sleep time of athletes comparable to their non-athletic counterparts, but had significantly lower quality of sleep.[63] Although, this study was performed while the athletes were not competing and did not assess direct effects of competition on sleep. This is the last missing piece, a comparison of sleep during in-season competition and out of season training. All of these factors combine to form the basis of this research. The purpose of this study is to establish a novel and objective measure of sleep in collegiate athletes that can be used to better their health and performance in the future.

Outcome. This study will provide an objective measure of sleep in the collegiate athlete population, which has never been done before. This will give basis for possible further research regarding the effects of sleep quality in collegiate athletes and if sleep quality should be address in the sports medicine field. The participants will receive a report of the sleep patterns once the study is completed if they so desire, but there will be no other direct benefits to the participants.

Describe your subjects. There will be approximately 100 participants in this study, 50 soccer athletes from Georgia Southern University and 50 gender matched controls of active college students from Georgia Southern University. All participants will be selected on a volunteer basis. All participants will fall into the age group of 18-25, no minors will be included. Participants will be excluded if they have a BMI $\geq$ 30.0, GPA $<$ 2.0, part-time class enrollment, current sleep disorder diagnosis, medication that manipulates sleep, current depression or anxiety disorder diagnosis, or a Personal Health Questionnaire -2 (PHQ-2) score $\geq$ 3. Non-athletes will also be excluded if they participate in club sports. These stipulations ensure that the controls will be held to the same academic standards that the Division I athletes must uphold without the time commitments of a sport. Depression and anxiety have also been shown to alter sleep quality and these criteria aim to control this confounding variable.

Recruitment and Incentives: Participants will be recruited from the men and women's soccer teams at Georgia Southern University and in undergraduate kinesiology classes. The soccer coaches have given verbal permission to the principal investigator to recruit from both teams. Health and Kinesiology professors Ms. Vista Beasley, Dr. Gavin Colquitt, Dr. Bridget Melton, and Ms. Mary Beth Yarbrough have also provided verbal consent to the principal investigator to recruit in their undergraduate classes. The attached flyer (Appendix C) will also be posted in the Hollis Building and Hanner Fieldhouse to recruit non-athlete control participants. There will be no incentives given. Participants will be provided with their individual sleep data via email at the conclusion of data analysis.

Research Procedures and Timeline: Once the project is approved by the Institutional Review Board, the participants will be recruited. After all participants are recruited, each will sign an informed consent form. Then all participants will complete a demographics questionnaire and the PHQ-2 prior to any testing. This information will be used to determine what participants can be included based on inclusion/exclusion criteria. Any participant who scores $\geq$ 3 on the PHQ-2 will be referred to the Georgia Southern counseling center. The participant will be given the phone number for counselling services as well as provided the website outlining what services are available (http://students.georgiasouthern.edu/counseling/services/). Recruitment will be completed within the two weeks prior to the first testing period in October. The athletes will be in season during both testing periods and all participants will be full time students enrolled in the Fall 2017 semester.

Sleep data will be collected using wrist actigraphy, which will be worn at all times for one week time periods throughout the fall semester. Data will be collected at two separate time points with each time point lasting one week. The testing weeks are based on the soccer teams' schedules, by using weeks where the team is not on the road for ease of data collection. For this reason, all male subjects and all female subjects will be tested on different weeks. Both the male athletes and male controls will be tested

October 1-October 7 and October 22-October 28. All female athletes and female controls will be tested October 9-October 16 and October 25-November 1. The best five days of complete data will be used for data analysis. Any participant who does not complete both timepoints will be removed from the study. Prior to the first timepoint there will be an information session where height and weight of each participant is taken and the features of ActiGraph are explained. Each participant will have an ActiGraph calibrated for and assigned to them. They will be instructed not to alter their sleep patterns. After each timepoint the ActiGraphs will be returned until the next timepoint. During the testing weeks, the participants will fill out a sleep log stating when they go to bed, when they wake up, and any time where the device is not worn for greater than twenty minutes. This should only be when showering, swimming, or soccer game participation where the device is prohibited. The participants will also be enrolled in the Remind application, an application available for both Apple and Android phones. This will be used by the primary investigator to encourage adherence to the testing protocol. These messages will be sent to all participants and no personal information will be shared with non-investigators or other participants.

Data Analysis: All data will be rendered anonymous using randomized identification numbers. The participants will be given their identification number if they would like to retrieve their sleep data at the end of the study, but all names will be removed for data storage. The data sets will be stored for a minimum of 3 years per the Board of Regents policy. Descriptive statistics (means, standard deviations, and frequencies) will be run for all demographic variables as well as activity levels of both groups as recorded by the ActiGraph devices. The ActiGraph GT3X+ activity monitor (ActiGraph Corp, LLC Pensacola, FL) uses a 3-axis microelectromechanical system (MEMS) accelerometer to gather acceleration data of the desired extremity. The data are sampled using a 12-bit analog to digital converter at a rate of 100 Hz and stored on the device as raw, unfiltered data. This data can then be uploaded to a computer using the accompanying ActiLife software (ActiGraph Corp, LLC Pensacola, FL). Using the dates and times provided by the participant in the activity log data will be filtered into periods of waking and sleep in the ActiLife software. For waking periods, number of bouts of physical activity will be extracted and classified as light, moderate, vigorous, and very vigorous. These variables will be used to describe the activity levels of both athletes and non-athletes. For periods of sleep, the Sadeh algorithm can be applied to produce several variables describing sleep quality. A repeated measures study design will be used. The independent variables are NCAA Division I athlete status and recreationally active non-athlete college student. The dependent variables are sleep latency, wake after sleep onset (WASO), total sleep time (TST), and sleep efficiency and will be collected at two distinct timepoints using the ActiGraph devices. A repeated measures MANOVA will be used to determine the effect of athletic status on sleep quality, the effect of gender on sleep quality, and if there is a group-by-time effect. It will be assumed that all variables have a multivariate normal distribution, the variances of contrast variables are homogenous across the groups, and linearity among all pairs of dependent variables, pairs of covariates, and dependent variable-covariate pairs. A F-statistic will be calculated based on these assumptions. Degrees of freedom are equal to $n1+n2-p-1$ where n1 is the first group sample size, n2 is the second group sample size, and p is the number of variables measured. The null hypothesis that there is no effect of group, time, or group-by-time will be rejected at level $\alpha=0.05$ if it exceeds the critical value evaluated at α.

<u>Special Conditions:</u>

Risk. There is minimal risk of injury from wearing the device on the wrist, but are no greater than wearing commercially available activity monitors. The participants may be at risk of psychological distress or discomfort in answering the questionnaire and PHQ-2. The demographics questionnaire and PHQ-2 may bring up underlying depression or anxiety symptoms. There may also be stress and anxiety related to sleep data collection process. The participants will be offered information on counseling services at Georgia Southern University and how to access them if they express distress or score a 3 or above on the PHQ-2.

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Cover page checklist. None of the items listed on the cover page checklist apply.

COLLEGE OF HEALTH AND HUMAN SCIENCES

DEPARTMENT OF KINESIOLOGY

INFORMED CONSENT TO PARTICIPATE IN AN EXPERIMENTAL STUDY

1. Title of Project: An Objective Measure of Sleep in Division I College Soccer Players Compared to the General College Population
   Investigator: Natalie Brown   Email: nb03704@georgiasouthern.edu
   Participant Name:____________________________   Date:____________________

2. The purpose of this research is to determine if there are any effects of NCAA Division I athletic status and/or timepoint in a season on sleep quality compared to the non-athlete, recreationally active college student.

3. Participation in this research will include completion of a demographics survey, three 7-day data collection timepoints using a wrist activity monitor, and activity log including wear-time of the device. Prior to testing height, weight, and gender data will be collected and used to collaborate the device to the participant. For each testing session, the participant will be required to wear the device all the time and record any periods of 20 minutes or more when the device is not worn. The participant will return the device at the end of each timepoint.

4. There is minimal risk of injury from wearing the device on the wrist, but are no greater than wearing commercially available activity monitors. There is also minimal risk of psychological effects due to possible stress and anxiety related to sleep data collection and analysis. By participating in this study and signing this informed consent you are confirming you have read and agree to the following statement. “I understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. I also understand that I am not waiving any rights that I may have against the University for injury resulting from negligence of the University or investigators.”

5. The benefits to the participant include an analysis of individual sleep quality over the fall semester. There may be benefits regarding the research and care of poor sleep quality in college athletes. The benefits may include providing further knowledge to clinicians in the sports medicine setting to determine sleep needs of NCAA Division I athletes.

6. The duration of the study will be three 7-day collection periods over the course of the Fall semester.

7. Deidentified or coded data from this study may be placed in a public available repository for study validation and further research. You will not be identified by name in the data set or any reports using information obtained from this study, and your confidentiality as a participant in

this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

8. Participants have the right to ask questions and have those questions answered. If you have questions about this study, please contact the researcher named above or the researcher's faculty advisor, whose contact information is located at the end of the informed consent. For questions concerning your rights as a research participant, contact Georgia Southern University Office of Research Services and Sponsored Programs at 912-478-5465.

9. You will not receive any form of compensation for participation in this study.

10. You do not have to participate in this study if you do not want to. Participation in this study is completely voluntary. Even if you begin the testing, you can choose to withdraw at any time.

11. There are no penalties for removing yourself from the study or denying participation in the study.

12. You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date on the following page.

You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number H__________.

______________________________________ _____________________

Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

______________________________________ _____________________

Investigator Signature Date

Participant ID: __________

Demographics Questionnaire

1. Name: ____
2. Gender: M / F / other: ___________
3. Year: FR / SO / JR / SR
4. Age: ____________
5. Are you a Division I college athlete: Y / N
6. What is your current GPA: ____________
7. Are you a full-time student: Y / N
8. Are you currently diagnosed by a medical professional with any of the following (check all that apply):

   - ☐ Insomnia
   - ☐ Sleep Apnea
   - ☐ Any major depressive disorder
   - ☐ Any major anxiety disorder

9. Over the past 2 weeks, how often have you been bothered by any of the following problems? 0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day

   a. Little interest or pleasure in doing things:

      0 1 2 3

   b. Feeling down, depressed, or hopeless

      0 1 2 3

10. The following will be measured by the researcher, DO NOT fill out:

Height: ____________

Weight: ____________

BMI: ____________

Participant ID:____________________

ACTIGRAPH GT3X+ ACCELEROMETER LOG

PLEASE RECORD ANY TIMES DURING WHICH YOU WERE **NOT** WEARING YOUR ACCELEROMETER FOR AT LEAST 20 MINUTES. PLEASE ENTER THE **EXACT** TIME AND ONE OF THE FOLLOWING CODES:

1 - BATHING/SHOWERING 2 – SWIMMING/WATER ACTIVITIES 3 – FORGOT 4 – OTHER

Please record the time you get into bed for the night and time you get out (not necessary time you fall asleep)

Date / **Time**	**Day you receive monitor** Bedtime: ______	Waketime: ______ Bedtime: ______	Waketime: ______ Bedtime: ______	Waketime: ______ Bedtime: ______	Waketime: ______ Bedtime: ______	Waketime: ______ Bedtime: ______	Waketime: ______ Bedtime: ______	Waketime: ______ Bedtime: ______	Waketime: ______ **Day you return monitor**
12:00 am									
01:00 am									
02:00 am									
03:00 am									
04:00 am									
05:00 am									
06:00 am									
07:00 am									
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09:00 pm									
10:00 pm									
11:00 pm									

Your next scheduled appointment is:__________________________________.

Georgia Southern University
Office of Research Services & Sponsored Programs

Institutional Review Board (IRB)

Phone: 912-478-5465 | Veazey Hall 3000 | PO Box 8005
Fax: 912-478-0719 | IRB@GeorgiaSouthern.edu | Statesboro, GA 30460

To:	Brown, Natalie Melton, Bridget
From:	Office of Research Services and Sponsored Programs
Initial Approval Date:	9/28/2017
Expiration Date:	8/31/2018
Subject:	Status of Application for Approval to Utilize Human Subjects in Research – **Expedited Process**

After a review of your proposed research project numbered **H18045** and titled **"An Objective Measure of Sleep in Division I College Athletes throughout a Season Compared to the General College Population."** it appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable. You are authorized to enroll up to a maximum of **100** subjects.

Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your proposed research. **Description: The purpose if this study is to use actigraphy to determine sleep patterns and sleep quality of collegiate athletes in Division I in comparison to the general college population.**

If at the end of this approval period there have been no changes to the research protocol; you may request an extension of the approval period. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to notify the IRB Coordinator, so your file may be closed.

Sincerely,

Eleanor Haynes

Eleanor Haynes