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The Effects of a Sleep Extension on Reactive Strength and Decision Making in Agility Tasks

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THE EFFECTS OF A SLEEP EXTENSION ON REACTIVE STRENGTH AND DECISION MAKING IN AGILITY TASKS

A Master's Thesis presented to the Faculty of the Graduate Program in Exercise and Sport Sciences at Ithaca College

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In partial fulfillment of the requirements for the degree of Master of Science

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CERTIFICATE OF APPROVAL

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MASTER OF SCIENCE THESIS

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This is to certify that the Master of Science Thesis of

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submitted in partial fulfillment of the Master of Science in Exercise and Sport Sciences at Ithaca College has been approved.

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ABSTRACT

This study examined the effect of extended sleep on reactive strength index (RSI) performance and decision-making skills of agility tasks. Participants (*N* = 15) volunteered for the study providing informed consent and were varsity student-athletes at Ithaca College. Participants attended five lab sessions over a six-week period with testing occurring at four of the lab sessions. Performance was measured by trials of the reactive strength index-drop jump test (RSI-DJ), a pre-planned change of direction (COD) test, and a reactive agility test (RAT). Participants were familiarized with testing protocols that were followed by a baseline period where habitual sleep patterns were recorded. After the two-week baseline period, participants were randomly assigned to either a sleep or control group. During the intervention period, the sleep group was required to extend their sleep by one-hour and the control group continued there habitual sleep patterns. The intervention period was two-weeks in duration. Each participant recorded sleep duration and quality throughout the duration of the study. Data were analyzed using a mixed design measures ANOVA. A pairwise comparison if the ANOVA yielded significant effects. The results showed participants from the sleep group increased their sleep duration by 11% and RSI by 5%. The reactive agility tests showed no significant changes; however, the sleep and control groups had faster decision making times upon posttest (5%). Practical application of this study is that extended sleep shows potential positive effects on reactive strength.

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Thank you to the Ithaca College Field Hockey and Men's Basketball teams for volunteering for this study.

Thank you to my parents for their continued support through my journey.

DEDICATION

This thesis is dedicated to my parents, Ralph and Susan Wenger, for everything they have done and continue to do throughout my life.

TABLE of CONTENTS

LIST of FIGURES

CHAPTER 1

INTRODUCTION

Heavy emphasis is placed on athletes to perform frequently at elite levels; however, to be able to perform at high levels a sufficient recovery needs to be reached. Recovery is a multifaceted process consisting of nutrition, hydration, active recovery modalities, and sleep. Sleep plays an important role in recovery as it helps to restore the immune and endocrine systems, promotes protein synthesis and muscle growth, and allows for recuperation of the nervous system (Frank & Benington, 2006). Evidence suggests athletes and students fail to meet recommended sleep standards due to a number of factors including early morning or late night training sessions (Fondran et al., 2012), pre-competition anxiety (Fondran et al., 2012), mental and physical stress of training (Silva, 2012), and course work and exams (NCAA, 2017). The effects of sleep loss on performance has been studied extensively; however, research has yet to examine the effects of extended sleep and its effects on performance specifically its effects on fast stretch-shorten cycle function and decision making in agility tasks.

Statement of Purpose

The twofold purpose of this study was to examine the effects of extending sleep on:

1. Muscle power as measured by reactive strength performance and,
2. Decision-making in agility tasks.

A secondary aim was to examine the effect of extended sleep on sleep quality by assessing daytime sleepiness.

Hypotheses

The null hypotheses for this study were:

1. No differences in reactive strength performance will be observed between the sleep extension group and the control group after a two-week intervention period.

2. No differences in decision-making performance will be observed between the sleep extension group and the control group after a two-week intervention period.

Scope of the Problem

Student-athletes are faced with dual roles on their college campuses. They are expected to attend all their classes daily and train six days per week, with some of those days consisting of multiple training sessions. Expectations are to balance the two roles of succeeding in the classroom and performing at their best in practices and games. These demands require effective recovery, and athletes and coaches find sleep as the most important element to recovery (Venter, 2014). Despite this, athletes report that they are sleeping two-hours below national recommendations (Hicks & Pellegrini, 1991). Extending sleep to at least national recommendations would appear to aid recovery processes, yet a small body of research only reveals a partial picture of the effects of extended sleep on performance; more research is needed to draw a bigger picture on the effects of getting more sleep. Student-athletes are believed to be already performing below optimal sleep levels; therefore, it would be unethical to impose greater sleep restriction on student-athletes.

Assumptions of the Study

For the purpose of this study, the following assumptions will be made at the start of the investigation:

1. The participants are representative of college-aged Division III varsity student-athletes from field and court sports.
2. The participants will give maximal effort at all testing sessions.
3. The participants will be honest with their sleep recording.
4. Participants will be honest on their health-screening questionnaire.
5. The tester will be accurate and precise with all testing.

Definition of Terms

The following terms are operationally defined for the purpose of this investigation:

1. Sleep Quantity - the amount of sleep (time), expressed in hours per night.
2. Sleep Quality - efficiency and how well one sleeps.
3. Sleep Restriction - losing a partial night of sleep.
4. Sleep Deprivation - complete loss of sleep one night.
5. Sleep Extension - additive sleep to normal amounts.
6. Recovery - multifaceted process comprised of sleep, nutrition, hydration, and active recovery modalities.
7. Physical Performance - aspect of performance utilizing the musculoskeletal system and components of fitness.
8. Cognitive Performance - one’s ability to recognize, process, and respond to a stimulus.
9. Reactive Strength - the ability to efficiently use the fast stretch shorten-cycle.

10. Reactive Strength Index - one's effectiveness at using the fast stretch shortening cycle (SSC), calculated as the ratio of jump height to ground contact time.
11. Change of Direction - ability to change direction, movement speed, or mode in a predetermined manner.
12. Reactive Agility - a rapid whole body movement with a change in velocity of direction in response to an external stimulus.

Delimitations

The delimitations of this study are as follows:

1. College-aged Division III varsity student-athletes from field and court sports will be used as participants.
2. The performance tests – reactive strength drop jump, change of direction, and reactive agility tests – provide accurate and reliable measures of the participants' abilities.
3. The SleepBot cell phone application accurately and reliably measures sleep duration.

Limitations

The limitations of this study are as follows

1. The results may only be generalizable to Division III field and court athletes.
2. The small sample size limits the generalizability of the findings to all of Division III student-athletes.
3. The intervention period may have been too short to observe potential effects of extended sleep on performance measures.

4. A learning effect of the testing procedures may have masked the effectiveness of the sleep extension.

CHAPTER 2

REVIEW OF LITERATURE

Optimizing performance is a combination of balancing training stimuli, proper nutrition, adequate sleep, and allowing for complete recovery. Finding the perfect balance of these factors establishes a foundation for increased athletic performance. Anecdotally, one of the first factors to diminish during high volume training periods is sleep, especially in collegiate athletics where student-athletes' time is spread among athletics, academics, personal time, and social time. The present study investigated the effect of a sleep extension on reactive strength and agility components. This chapter reviews the literature on optimizing performance, the demand for recovery, sleep in student athletes, and the effect of sleep loss on various aspects of performance. The final sections focus on the effects of extended sleep to athletic performance and gaps in the literature, followed by a brief summary.

What is Performance?

Athletic performance is defined as an athlete's ability to perform and execute functions of their sport including biomechanical, physiological, and psychological factors (Joyce & Lewindon, 2014). Performance is a combination of physical and cognitive components. Physical components of performance consist of movement and fitness elements, whereas cognitive components of performance are the elements that require a high degree of focus of attention and information processing. The combination of physical and cognitive components is important in team and individual sport success. Particularly during times of competition and tournaments, peak performance is required from athletes.

The ability to peak at just the right time it an outcome of proper training and performance monitoring.

Physical performance focuses on movement and fitness elements of sports. Movement is the body passing through space by sequencing body regions to create locomotion or deliberate actions (Bartlett, 2007). The goal of movement is to advance to a specific location or perform an action that has purpose to the sport or situation (Bartlett, 2007). Movement is divided into two subcategories: gross and fine movement patterns (Ives, 2014). Gross movement consists of whole body movements utilizing large muscle groups in sequence to complete the intended goal (Ives, 2014). Fine movements are smaller in nature using smaller muscles and typically require a degree of attention and focus to execute in a precise manner (Ives, 2014). Fitness elements refer to the specific physiological requirements the body must be able to function under in a specified sport (Haff & Triplett, 2016). Some elements of fitness to consider are aerobic and anaerobic capacity, muscular power, strength and endurance, flexibility, and change of direction (Haff & Triplett, 2016).

Cognitive performance in athletics largely involves two processes, focus of attention and information processing (Ives, 2014). A common measure of cognitive performance is reaction time (RT), defined as the time it takes to respond to a stimulus (Wang, 2009). The ability to react is a combination of recognizing the situation, interpreting the new environment and preparing for the next action necessary (Sant'Ana et al., 2017). The final component to reaction skills is being able to initiate the intended response (Sant'Ana et al., 2017).

Sport skills are differentiated into open and closed skills. Open skills are characterized by the need to be able to respond to a changing environment or external stimuli like in volleyball where the athlete must react to the movement of the ball (Nuri, Shadmehr, Ghotbi, & Noghadam, 2013). Closed skills are characterized by the predictive nature of the environment and the performer dictates the pace at which the movement or skill is performed such as pole vault, sprinting, and long distance running (Nuri et al., 2013). The difference between the two skills is the decision-making and reactive demands to the constantly changing environment. Nuri et al. (2013) examined the differences between volleyball athletes and track sprinters in abilities in open versus closed-skilled sport athletes. They found that sport demands lead to better development of specific skills, such as auditory reaction time in sprinters and anticipator skills in volleyball player

Open skill qualities are becoming a focal point around recruiting student-athletes and distinguishing those who are prepared for the next higher level of performance (Wang, 2009). A major determinant of performance is an athlete's ability to process and respond to movements of opposing players quickly (Wang, 2009). Decision-making skills and RT can be trained through high volumes of specific strategies requiring athletes to interpret and react. One strategy to improve informational processing and RT is practicing skills in a fast-paced, chaotic or emotional environment (Ives, 2014; Wang, 2009). A second strategy is to develop sensory skills and elevating alertness and attentiveness (Ives, 2014). Emphasis should be placed on training a reaction to a stimulus rather than focusing on the movement (Ives, 2014). Reaction time can be trained and can show positive benefits during in-game performance (Gavkare, Nanaware, and Surdi, 2013).

Agility is a common characteristic in field/court-sport athletes and is a combination of physical and cognitive aspects of performance. Sheppard and Young (2006) defined agility as “a rapid whole-body movement with a change of velocity or direction in response to a stimulus.” With agility having a cognitive component, agility becomes difficult to train. Agility performance has been shown that linear sprint performance has very little impact on agility and change of direction performances (Sheppard & Young, 2006). Therefore, training change of direction and agility should be highly specific to sport demands (Sheppard & Young, 2006). Zemkova and Hamar (2014) investigated differences in agility times between different sports. Participants were required to respond to the stimulus on the screen by touching the corresponding pad with their left or right foot as quickly as possible. The results showed differences between sports as well as to various positions within a sport. The findings are significant as they represent the various demands of cognitive and physical performance across sports and also the specific training that different positions need within a sport. Fiorilli et al. (2017) found conflicting results in their study where they examined the differences between change of direction speed (CODS) and reactive agility (RA) across various positions in elite soccer players. The study concluded no significant differences were observed between positions indicating the need for all positions on the field to need a similar degree of COD and RA.

Only one study has examined the effects of agility training on reaction and speed abilities. Kovacikova (2012) looked at the changes in reaction and speed abilities after an

8-week agility training. The study examined the differences in training agility in a competitive versus a non-competitive condition. The study measured simple reaction time, multiple-choice reaction time, and maximal velocity of step initiation, jump height, and contact time of drop jump. An improvement in agility time was observed in the competitive training condition. However, no significant differences were found in reaction and speed abilities between the two conditions. The study concludes although improvements were seen in the competitive training condition, this type of training does not contribute more impactful improvement on reactive and speed abilities than non-competitive training. A gap in research exists that examines effective training protocols to maximize reactive abilities in sports; however, sport analyses have established that agility, a combination of cognitive and neuromuscular control, is a vital characteristic to open-skilled sports that require responding to the opposing team's moves.

Training for Peak Performance

Peak performance is the body's ability to perform at its greatest potential (Joyce & Lewindon, 2014). Performance can be measured and tracked to evaluate adaptations from training. Many components of performance can be tested to evaluate for adaptations such as maximal oxygen uptake, maximal strength and power, neurocognitive function, agility, force production, and flexibility. These components to sport performance are measured so programs can be implemented to achieve peak performance for competitive seasons (Haff & Triplett, 2016). Performance training needs to be sport-specific to develop the proper systems to meet the sport's demands (Haff & Triplett, 2016).

Power is a product of force and velocity (Haff & Triplett, 2016). Lower body power can be measured safely, quickly, and efficiently through the use of a countermovement jump (Haff & Triplett, 2016). Lower body power is a common demand across an array of sports. Power can be developed and improved by utilizing plyometric training. Plyometrics utilize the mechanism called stretch-shortening cycle (SSC) of the joints and surrounding muscles to store energy and generate power (Flanagan & Comyns, 2008). The SSC is an eccentric stretch of the muscle followed by an immediate concentric contraction of the pre-stretched muscle (Flanagan & Comyns, 2008). Furthermore, there are two types of SSC, fast and slow both of which are categorized by contact time. Fast SSC is characterized by a ground contact time <250 ms and slow SSC is characterized by a contact time >250 ms (Schmidtbleicher, 1992). A counter movement jump is slow SSC exercise, whereas a drop jump is categorized by a fast SSC (Flanagan & Comyns, 2008).

Training the fast SSC can benefit athletes that are required to transmit high forces into the ground quickly, such as sprinters (Flanagan & Comyns, 2008). Reactive strength is a reflection of one's ability to utilize the fast stretch-shorten cycle (Schmidtbleicher, 1992). Reactive strength is a major determinant of speed and acceleration, which are key components to field sport athletes (Kockie, Murphy, Knight, & De Jonge, 2011). Research suggest that faster athletes are able to generate high ground reaction forces in short contact times (Flanagan & Comyns, 2008). However, the impact of reactive strength on change of direction tasks show mixed results. Djevalikian (1993) found a significant relationship (r = .04) between reactive and change of direction tasks, whereas Young et al. (2002) found a non-significant negative relationship (r = -.47) between depth jumps and change of direction tasks.

The reactive strength index (RSI) is a tool to quantify plyometric performance and differentiate which type of SSC is being utilized during training and competition (Flanagan & Comyns, 2008). RSI looks at the relationship between jump height and ground contact time (Flanagan & Comyns, 2008). RSI is most commonly measured using the drop jump test where athletes step off of a various box heights (15, 30, 45 and 60-cm) and perform a quick rebound jump (Flanagan & Comyns, 2008). By obtaining RSI scores for athletes, a plyometric profile can be established for athletes and a plyometric program can be written to enhance performance (Flanagan & Comyns, 2008). Reactive strength can be improved by increasing jump height or decreasing ground contact time (Flanagan & Comyns, 2008).

Recovery & Regeneration

Recovery is a multifaceted process and is achieved by adequate nutrition, proper hydration, active recovery modalities, and sleep. Adaptations occur after being exposed to training stimuli and these adaptations can be positive or negative based on the recovery steps taken between performances (Kentta & Hassmen, 1998). Several models provide a structure on the relationship between training and recovery to optimize performance. Monitoring training loads and fatigue levels has been shown to be effective in monitoring recovery in athletes. Without proper monitoring, athletes are at greater risk of injury and overtraining syndrome.

Recovery Models & Monitoring Training

The first model is the general adaptation syndrome (GAS). The GAS has four phases to explain the role of recovery for athletes. As shown in Figure 1, the first phase is the alarm phase where the body responds to the stress by releasing hormones. The stress can be from practice, resistance training, or competitions. The second phase is the resistance phase where in the body is working to repair the damage from the stress. The third phase is an elevated state of performance as a result of training.

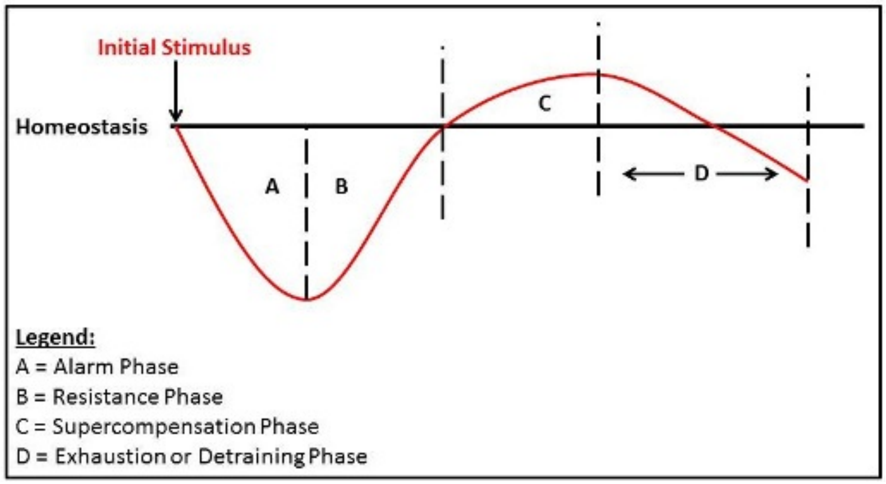

Figure 1. General adaptation syndrome. (Haff & Triplett, 2016)

With proper time and recovery between training sessions, the body will adapt to the training stimuli and come back in better form; this phenomenon is called supercompensation (Bompa & Haff, 2009). The final phase occurs only when adequate recovery is not given; the exhaustion phase. If an athlete reaches the exhaustion phase, they will encounter hormone imbalances, and an increase risk of illness and injury (Haff & Triplett, 2016). To prevent the exhaustion phase, athletes need rest and time off to recover.

The other model looking at the relationship of fitness, fatigue and preparedness is the fitness-fatigue model (Hoffman, 2012). Visible in Figure 2, training imposes two responses called aftereffects, fitness and fatigue, and both effect athletes' preparedness to perform. After training, fitness is elevated above baseline; however, a negative effect of fatigue ultimately brings an athlete's preparedness down below baseline. When recovery is allowed between training and competition, preparedness returns back to baseline and when timed perfectly, preparedness is greater than pre-training levels (Hoffman, 2012). The fitness-fatigue model and GAS give direction on how to program training sessions to prevent overtraining and allow for adequate recovery for adaptations to occur.

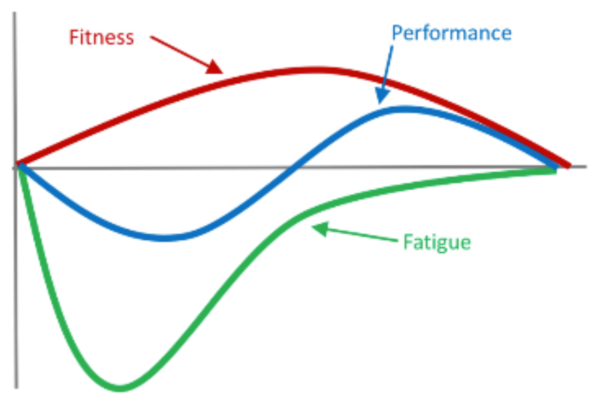

Figure 2. Fitness fatigue model. (Hoffman, 2012)

Fatigue Effects on Performance

Fatigue plays a big role in athlete preparedness and readiness to train or compete (Hoffman, 2012). Fatigue affects physical and cognitive aspects of performance. Physical fatigue is attributed to a decrease in neuromuscular function (NMF) and cognitive fatigue relates to neurocognitive function (Pyne & Martin, 2011). Fatigue is monitored and measured over the course of training and can play a crucial role in an athlete's ability to perform and while preventing injury or overtraining syndrome (OTS; Hoffman, 2012).

Physical performance can be measured using many different protocols; however, a survey has found that most practitioners rely on the counter movement and vertical jump tests to measure neuromuscular fatigue (Taylor, Chapman, Cronin, Newton, & Gill, 2012). Shearer et al. (2015) studied the effects an elite rugby match had on power output in a countermovement jump (CMJ). Baseline measures were taken 36-hours prior to the league match and post-game measures were taken at 12, 36, and 60 hours following the match. CMJs were performed on a force plate and participants were required to have their hands behind their heads to isolate the lower body. Power output was lowest 12-hours post-match and slowly neared baseline values; however, 60-hours past-match measures showed greater than a 2% decrease in power output. The study also looked at the correlation between power output and mood profiles of the Brief Assessment of Mood (BAM) questionnaire. Power output and total mood disturbance (TMD) showed a significant negative correlation, meaning as TMD increased, power output decreased similarly.

Thorpe et al. (2015) also utilized the countermovement jump (CMJ) to assess neuromuscular fatigue in elite soccer players over a 17-day in-season period. The aim of the study was to quantify the relationship between training load and potential measures of fatigue. Training load was measured via distance covered during a training session through GPS tracking. Fatigue was measured through a questionnaire examining perceived sleep quality, muscle soreness, and fatigue. Paired with the psychological measures, maximal effort countermovement jumps were tested for objective fatigue measures. The strongest relationship to increased training load was perceived fatigue (r = -.51). The CMJ had a weak, positive relationship with increased training load (r = .23) meaning as training load increased, increased CMJ was observed. The results suggest that the CMJ may not be sensitive to locate neuromuscular fatigue.

In addition to neuromuscular fatigue, neurocognitive function is also reduced under fatigued states. Sant'Ana et al. (2017) studied the effects of fatigue on reaction time, response time, performance time, and kick impact in the roundhouse kick. After baseline measures of reaction time, response time, performance time and kick impact, a progressive taekwondo test was administered to elicit fatigue on the participants. Reaction, response, and performance times were collected from participants responding to a light stimulus with a roundhouse kick. Reaction time was determined by the time interval between stimulus and muscle activation that was measured via surface EMG. Response time was defined by the interval of time between the light stimulus and max impact of the kick on the bag. Performance time was defined as the time interval between reaction time and response time. Reaction time and kick impact significantly changed after the progressive taekwondo test. The increase in reaction time was believed to be the result of reduced blood flow to specific regions of the brain involved with manual response and visual stimulus. The decrease in performance was thought to be due to the increased levels of lactate in the blood (a secondary measure), which impacted the ability to maintain force production. The study did not evaluate the technique of the kick; however, a previous study by Quinzi et al. (2016) saw adaptations to the roundhouse kick technique after a similar fatigue protocol. Fatigue affects the body's ability to maintain neurocognitive performance due to prioritization of energy (Quinzi et al., 2016).

The goal of training is to elicit positive physical and physiological changes to improve performance (Kentta & Hassmen, 1998). Overtraining typically results from insufficient recovery following training and competitions (Kentta & Hassmen, 1998). Common characteristics of overtraining include decreases in performance, severe fatigue, muscle soreness, overuse injuries, disturbed sleep habits, and difficulty concentrating (Kentta & Hassmen, 1998). Of the ways to approach recovery, three of the most common approaches are nutrition and hydration, stretching and active rest, and sleep (Kentta & Hassmen, 1998). Nutrition, hydration, stretching and active rest are beyond the scope of this discussion, and sleep will be the focus of the discussion.

Sleep

Sleep is believed to consist of various stages with each stage consisting of benefits to the human body. A single night of sleep consists of 90-minute cycles broken down into rapid eye-movement sleep (REM and non-rapid eye-movement (NREM) sleep (Lashley, 2004). The various phases of sleep have different roles in facilitating recovery and development. NREM sleep has exhibited the release of various hormones aiding in tissues and protein synthesis, lowering oxygen consumption and free fatty mobilization (Brebbia & Altshuler, 1965; Sassin et al., 1969; Weitzman, 1976). REM sleep has a role contributing more toward the recovery of neural pathways and regulation of emotions (Siegel, 2005). Possibly the most important aspect of sleep is its role in motor learning and cognitive development (Stickgold, 2005). Studies have examined the effects of sleep loss and extensions on the impact of athletic performance and cognitive abilities with inconsistent results. Athletes need to be prepared to compete at peak performances and adequate sleep plays a crucial role in optimizing sport potential.

Sleep can be measured in two ways: quantitatively and qualitatively (Ferrara, 2001). Quantity of sleep refers to the amount of sleep in hours or minutes an individual gets per night. Quality of sleep refers to how well an individual sleeps typically measured by levels of alertness and daytime sleepiness (Ferrara, 2001).

Sleep in Athletes and Student Athletes

The National Sleep Foundation recommends that a healthy night of sleep is centered around 8-hours of sleep per night (National Sleep Foundation, 2013); however, 53% of the US population falls short of these recommendations. A nationwide survey found that the national average of sleep per night is six hours and fifty-one minutes, over one hour less than recommended (National Sleep Foundation, 2013). University and college students are found to average about 5 hours of sleep per night, which is almost three hours less a night than the national average (Hicks, & Pellegrini, 1991). Poor sleeping patterns results from poor sleep hygiene such as high exposure to artificial light, high intake of caffeine around bedtime, and irregular sleep patterns (Klerman & Dijk, 2005).

Athletes and coaches recognize and rate sleep as a major component to optimizing performance (Venter, 2014); however, research reveals athletes get inadequate levels of sleep. A study examining 890 elite South African athletes revealed they were attaining sleep well below the recommendations (Sargent, Halson, & Roach, 2014). The elite athletes were averaging between six to eight hours per night with eleven percent attaining less than six hours of sleep (Sargent et al., 2014). A study examined sleep the night before competitions in Olympic athletes and revealed they had lower sleep quality and quantity when compared to a non-athletic control group (Leeder, 2012). Training intensities, volumes and training times have also been shown to effect student-athletes sleep patterns and quality (Forndran et al., 2012).

Competitions and training create additive stress and anxiety to student athletes. Student athletes suffer from disturbed sleep patterns the night prior to competitions effecting quality, efficiency and duration (Forndran et al., 2012; Silva, 2012). This sleep deprivation has not gone unnoticed by the National Collegiate Athletic Association (NCAA), college coaches, and athletic trainers. The NCAA administered a standardized questionnaire to gain insight on sleep habits, and mental and physical well-being in student athletes. A questionnaire was sent to Division 1 student-athletes across the country asking questions that assessed sleep, mental health, daytime function, and academic life (NCAA, 2017). The results were alarming in that two-thirds of student athletes are categorized as "poor sleep quality" and almost a quarter of student athletes suffer from excessively high levels of fatigue. Part of the questionnaire was a follow-up intervention study. The intervention consisted of a two-hour educational program followed by a 10-week period of sleep tracking via sleep diary and Fitbit Tracker. Students had access to peer support, study personnel and daily text messages reiterating healthy sleep patterns throughout the duration of the sleep-tracking period. Post-intervention, the study found improvements across a multitude of variables and most importantly, total sleep time and time in bed increased significantly by thirty-one and twenty-nine minutes, respectively. Sleep education may be an important step in getting student-athletes the additional sleep their bodies need (NCAA, 2017).

Performing physical activity on accumulated sleep debt has been compared to the equivalent of the human body functioning with a blood alcohol content of 0.05% (Williamson & Feyer, 2000). Research on the effects of sleep loss on athletic performance has revealed a dose-response relationship meaning the greater sleep debt accrued, the larger the performance decline (Van Dongen et al., 2003). Loss of sleep can be categorized in two areas: sleep restriction and sleep deprivation. Sleep restriction is when humans fall asleep later or wake earlier than typical sleeping habits (Boonstra, 2007). Sleep deprivation is when humans do not sleep for prolonged periods of time, such as an entire night (Boonstra, 2007). With student-athletes failing to meet national recommendations of sleep duration, it is relevant to discuss the impact sleep restriction and sleep deprivation has on athletic performance.

Effect of Sleep Loss on Aerobic Performance

Research has shown that aerobic performance appears to decrease with sleep loss greater than 36-hours (Martin, 1981; Martin & Chen, 1984) but aerobic performance can be maintained through a sleep restriction of 4-hours or less (Mejri et al., 2014; Mougin et al., 1991; Reilly & Deykin, 1983). The research is relatively unclear on the full effects of sleep loss on aerobic performance and can be explained by the various methods and measure of aerobic performance.

Aerobic performance is a critical component to a large number of sports as aerobic conditioning creates the foundation for other energy systems and team sport performance (Haff and Triplett, 2016). Martin (1981) examined the effects of sleep deprivation of 36-hours on time to exhaustion. After baseline measures, participants were required to stay awake for 36 consecutive hours at the lab and repeat the walking treadmill test. After 36-hours of sleep deprivation, the mean time to exhaustion reduced by 11% and participant's RPE was significantly higher. Meanwhile, heart rate and oxygen consumption remained unchanged during the duration of the treadmill test from baseline to post-sleep deprivation.

Another study utilizing a 50-hour sleep deprivation examined the effects on a treadmill test to exhaustion (Martin & Chen, 1984). The study looked at time to exhaustion, heart rate, and plasma norepinephrine, epinephrine and dopamine levels in after a treadmill test working at a heart rate of 160 bpm. Relative to baseline measures, time to exhaustion was reduced by 20% after the sleep deprivation; however, hormone levels, minute ventilation, oxygen uptake, blood lactate levels, and body temperatures did not change after the 50-hour sleep deprivation. The authors suggest the decreased time to exhaustion was due to the reduced tolerance or desire to exercise.

Conflicting findings on the effect sleep loss on aerobic performance have been found (Mejri et al., 2014; Mougin et al., 1991; Reilly & Deykin, 1983). Reilly and Deykin (1983) used a 3-hours sleep restriction on participants to see the effects on physical and cognitive performance. The authors found no changes in aerobic and anaerobic function and grip strength; however, cognitive measures of reaction time and hand steadiness declined after the sleep restriction. Mougin et al. (1991) found similar results to Reilly and Deykin (1983) on aerobic capacity after moderate sleep restriction. Participants' aerobic performance was compared after a night of normal sleep (8-hours) compared to a night of 5-hours of sleep. The authors found no significant changes in aerobic performance in a cycle ergometer test. A final study examined the effects of a 4-hour sleep restriction on aerobic performance measured using a YoYo Intermittent Recovery Test (Mejri et al., 2014). The studied examined the effects of a 4-hour sleep restriction on aerobic performance. Aerobic performance was defined by the total distance covered by the participants during the YoYo Intermittent Recovery Test. The study found no significant changes in performance from an 8-hour night of sleep compared to a 4-hour night of sleep supporting previous work (Mougin et al., 1991; Reilly & Deykin, 1983).

Effect of Sleep Loss on Anaerobic Performance

Many sports are defined by their anaerobic qualities that require high intensity bursts, repeated power, and quick recovery. Inconsistent findings have been established looking at sleep loss and anaerobic performance. Mougin et al. (1996) assessed the effects of a three hour sleep restriction on Wingate performance. Wingate performance was assessed at two time points, after a night of habitual sleep as a reference and again after a night of restricted sleep. The authors observed no change in mean or peak power, or peak velocity relative to baseline measures (Mougin et al., 1996). Another study utilized the Wingate cycle test to measure anaerobic power (Taheri & Arabamer, 2012). The participants conducted baseline testing after a night of normal sleep. The following night, participants were kept awake until testing the next morning. No significant differences were observed in peak or mean power after a night of no sleep relative to baseline measures.

Skein et al. (2011) investigated a 30-hour sleep deprivation on intermittent sprint performance and muscle glycogen stores. Participants were in a control (CTR) or sleep deprived (SD) group. Participants performed a 30-minute graded exercise run (GXR) and a 50-minute intermittent-sprint (ISE) protocol as baseline measures. After baseline assessments, the GXR and ISE were performed on consecutive days: the day before sleep deprivation (T1) and the day after sleep deprivation (T2). Muscle biopsies were collected before and after each session to look at blood lactate and glucose levels. Other key measures collected for this study were mean sprint times and distance covered. The SD group showed significant decreases in mean sprint times, distance covered in GXR and muscle glycogen from T1 to T2, and across groups examining T2. Skein (2011) found significant results on the effects of sleep deprivation on anaerobic training and its metabolites.

Another study examined the effects of a 4-hour sleep restriction on maximal power output (Souissi et al., 2008). The study looked at highly trained students and their performance on a Wingate cycle test. Participants were tested after a night of normal sleep (seven hours) and on two other occasions in random order: once after a night of restricted sleep at the beginning of the night and once after a night of restricted sleep at the end of the night. Wingate cycle tests were performed at 7:00 and 18:00 hours after the three testing conditions. Peak and mean powers were significantly lower at the 18:00 hour testing session following the sleep restriction at the end of the night. The performance drop is proposed to be due to a great disturbance in the circadian rhythms versus the effect a later bedtime has on the circadian rhythms and the extended time of wakefulness. The effect of sleep loss on anaerobic performance is not clearly defined and could use further research.

Effect of Sleep Loss on Strength & Power Performance

Similar to aerobic and anaerobic performance, research does not provide a clear understanding on the effects sleep loss has on muscular strength and power. A key study examined the effects of a 24-hour sleep deprivation on weightlifting performance (Blumert et al., 2007). The study examined weight lifting tasks and psychological measures in elite collegiate weight lifters. At preliminary testing, participants completed a 1-RM snatch, clean and jerk, and front squat. The study also measured daytime sleepiness via the Stanford Sleepiness Scale and mood through the Profile of Mood States (POMS) assessment. After preliminary testing, participants were randomly assigned to one of the two sleep conditions (8 or 0 hours of sleep) and reported to the lab the following day for training. Participants received the same workout regardless of sleep condition. Prior to the training session, daytime sleepiness and POMS were measured at 8:30 am before beginning any physical activity. All lab sessions were completed with one week between sessions. No differences in training load or intensity were found between the sleep and no sleep condition. The no sleep condition showed higher levels of fatigue, confusion, and perceived the sessions as more vigorous compared to the sleep condition pre and post exercise. The study concluded that weight lifting tasks could be maintained after acute sleep loss. Previous research findings have suggested that high-complex motor tasks may be attenuated by acute sleep loss; however Blumert et al. (2007) found differing results. A study by Reilly and Hales (1988) examined the effects of a night of sleep deprivation on isometric contractions. The study found no significant differences after a night of no sleep on back and grip strength in female athletes.

Other studies have examined the effects of sleep loss and found conflicting results. Reilly and Piercy (1994) examined the effects of consecutive nights of sleep restriction on muscular strength. The study design used a 3-hour sleep restriction on three consecutive nights. A submaximal test was used for the bench and leg press, bicep curl and deadlift to get an estimated maximal lift. The same submaximal protocol was used during the testing sessions to measure the effect of sleep restriction on muscular performance. Baseline measures were conducted after a night of normal sleep (8-hours) and testing sessions were conducted on consecutive days following the restricted nights of sleep. In addition to muscular performance, fatigue and mood were assessed via the POMS assessment tool. After one night of sleep restriction, muscular performance was not affected and performance was maintained; however, after the second night of restricted sleep, the bicep curl was the only muscular performance measure that was not affected by the reduced sleep quantity. Reilly and Piercy (1994) interpreted the decrement in muscular performance as a result of increased levels of feeling fatigued and increased perceived vigor of testing measured in the POMS assessment.

Studies have found a decrease in performance after a night of restricted or lack of sleep (Goh et al., 2001; Souissi, 2013). Souissi (2013) studied the effects of a sleep restriction on grip strength. The study had three conditions where participants received a night of normal sleep (8-hours) and two experimental nights restricting sleep by 3-hours at the beginning of the night or at the end of the night. Grip strength was measured at two time points during the day; grip strength was maintained at the first testing sessions for both conditions relative to normal sleep. However, grip strength was diminished during the second testing session in the condition waking the participants early. Goh et al. (2001) had similar results where sleep deprived participants displayed decreased grip strength in the testing sessions that occurred later in the day. The studies concluded the decreased grip strength could be a result of daytime tasks utilizing the muscles responsible for grip strength (Goh et al., 2001; Souissi, 2013).

The effects of sleep loss remain unclear; however, some patterns have been developed regarding the effects sleep loss has on muscular and power performances. Strength and power should be maintained after one night of altered sleep (Blumert et al., 2007), but strength begins to diminish after consecutive nights of disturbed sleep (Reilly & Piercy, 1994). Other studies have found a pattern that sleep deprivation greater than

30-hours negatively impacted peak extension and flexion forces in lower body exercises (Takeuchi et al., 1985; Bulbilian et al., 1996).

Effect of Sleep Loss on Sport-Specific Performance

Edwards and Waterhouse (2009) examined the effects of a sleep restriction on the accuracy and consistency of dart throwing. The study measured core temperature, levels of alertness and fatigue, and performance. Performance was calculated in three ways: distance from bulls-eye, number of times missing the dartboard, and the variability of the scores of dart throws. Participants were assigned to either a control group that received eight to nine hours of sleep the night before testing or the experimental group that had sleep restricted by four hours. Participants were familiarized with the protocol and received five practice sessions. Participants threw one dart at a time, throwing a total of 20 darts. The dartboard contained ten circles with diameters increasing by 2-cm increments the further from the bulls-eye. The bulls-eye was worth 10 points and each ring moving out was worth one less point than the previous. Data were collected at 8:00, 12:00, 16:00, 20:00, and 24:00 hours. The first and last three scores were thrown out due to the possible effects of warming up and “nearly finished” feeling. All measures had a clear pattern with the time of day for each measure. Looking at performance, mean scores for the sleep deprived group had a significant fall off at 8:00 hours and became more significant as time awake increased. The number of zeros followed the inverse pattern like that observed in fatigue assessment results. A significant difference between groups was seen at the 8:00 hours. As time awake increased, the number of misses significantly increased similarly to the trend observed in mean scores. The coefficient of variation of mean scores, sleep deprived scores divided by mean score, showed the same trend as fatigue levels and number of misses. A significant increase in variations of mean scores was seen at the 8:00 hour and throughout the day with an increase in time awake. All three measures of performance were significantly different in the sleep restricted condition versus the control. The performance differences were attributed to the deterioration of fine motor skills and hand-eye coordination after facing sleep loss.

Reyner and Horne (2013) examined the effects of sleep on the accuracy of tennis serves. The study was comprised of two interventions examining the effects of sleep restriction on the accuracy of tennis serves. For the first intervention, participants received a five-hour sleep restriction and were randomly assigned to the control group of normal amount of sleep or the group of restricted sleep (five-hours of sleep). A counter balanced approach was used to compare each subject's differences between receiving the sleep restriction and a normal night of sleep. The participants had 40 serves from a self-selected location on the baseline. The participants were aiming for a 1.8 m long by 1.1 m wide box in the opposing service box. The first 10 serves were excluded to prevent the warming up effect. The second intervention used a similar design and added a third condition. The three conditions were a control of normal sleep, and two sleep restricted groups (five hours) that received a sugar free drink containing either a placebo or 80 mg of caffeine. The participants aimed for the 1.8 by 1.1 m serving box and had 40 serves.
The same procedure as the first study was implemented in the second study. The caffeine condition resulted in no difference in serving performance compared to the placebo condition. The two interventions concluded that restricted sleep results in decreased tennis serving performance and supplementation of caffeine does not attenuate the deficit in performance created by sleep restriction.

Sinnerton and Reilly (1992) published different findings on partial sleep deprivation on sport performance in swimmers. The study evaluated the changes in lap times after consecutive nights of restricted sleep. After imposing a greater than two-hour sleep restriction on elite swimmers for four nights, no significant increases in lap times were found and performance was maintained through the duration of the sleep restriction. The study showed the human body's ability to maintain whole-body performances like swimming freestyle after chronic sleep restriction. Gross motor skills appear to be maintained through sleep loss (Sinnerton & Reilly, 1992); however, fine motor skills demanding high hand eye coordination or cognitive focus deteriorates after several hours of sleep loss (Edwards & Waterhouse, 2009; Reyner & Horne, 2013).

Effect of Sleep Loss on Neurocognitive Performance

Students facing sleep loss are preventing their bodies from fully recovering and hindering their memory and motor function (Stickgold, 2005). Student athletes need to be able to complete complex tasks in the classroom and complex tasks in their sports. Sports require more than physical abilities, but also demand high functioning cognitive abilities. Motor control can be thought of as a top-down approach integrating many systems. The brain creates the intention to move, and the spinal cord generates coordination between moving parts (Joyce & Lewindon, 2014). If motor control is viewed as a bottom-up system, feedback is still sent to the brain even if the movement is considered automatic for processing (Joyce & Lewindon, 2014). Athletes may have difficulty performing at a high level at practice or in games when competing with an accumulated sleep debt.

Sleep loss has detrimental effects on multiple aspects of cognitive function especially reaction time. Belenky et al. (2002) investigated how varying levels of sleep restriction effected cognitive performance in a psychomotor vigilance task (PVT). Participants were randomized to one of four groups based on the quantity of sleep the participants received each night: 3, 5, 7, or 9 hours of sleep per night. Participants reported to the lab for ten nights; seven days consisted of augmented sleep (assigned sleep condition) followed by three days of recovery where all participants received eight-hours of sleep. The PVT measured speed of reaction to external stimuli on hand-held device. Mean speed, number of lapses (responses > 500ms), and mean speed for fastest 10% of all responses were calculated for comparison between groups. Sleep latencies were measured along with subjective sleepiness and alertness using polysomnographic measures and the Stanford Sleepiness Scale. From baseline, total sleep times for all groups significantly changed in various sleep stages in the 3, 5, and 7-hour sleep groups. The study showed mean speed times had a dose-response decrease in the 3, 5, and 7-hour groups. All groups showed a significant decrease in PVT performance across the augmented sleep period, but more significant decreases in performance were seen with a greater sleep restriction. The 9-hour group saw no changes in mean speed over the duration of the study. The mean speed for the 3-hour group failed to return to baseline values after two nights of recovery sleep. Significant effects of mean speed were not observed until after two nights of restricted sleep. The study found a significant increase in lapses in the 3 and 5-hour groups only and those values did not return to baseline after the two-night recovery period. The last performance variable, mean speed of top 10% had the same trend as the mean speed on the 3 and 5-hour groups, but not the 7 or 9-hour group. The authors conclude that psychomotor vigilance performance decreased in a dose-dependent manner to sleep loss. Mild sleep restriction, five to seven hours per night, resulted in an initial decline in PVT performance; however, performance stabilized after a few days. Severe sleep restriction, three hours per night, showed a continuous decline in performance and required more than two nights of normal sleep to regain full cognitive function. The study demonstrates the body is able to adapt and create stable measures after consecutive days of moderate sleep loss.

Dinges et al. (1997) also investigated sleep deprivation for a week and its effect on cumulative decrements in sleepiness, mood, and neurocognitive performance. Participants were assessed at baseline on PVT response times and number of lapses, and on mood and sleepiness through the Profile of Mood States and Stanford Sleepiness Scale questionnaires. Over the course of a week, participants were subject to a sleep restriction cutting 2.5 hours of sleep per night. All measures were collected every day of the sleep restriction. After the week of sleep restriction, the participants had a recovery night where they received 10 hours of sleep. PVT scores showed performance decrements each day after the sleep restriction began. The study found similar results to Belenky and colleagues (2002) that sleep being restricted to five hours or less results in decreased PVT scores assessing the effect of sleep restriction on sustained attention and reaction time.

Jarraya et al. (2012) investigated the effects of sleep restriction on reaction time and attention capacities of handball goalkeepers. Participants were exposed to three conditions in randomized order; reference night (RN) where participants received nine hours of sleep, partial sleep deprivation at the beginning of the night (SDB), and a partial sleep deprivation at the end of the night (SDE). The study measured reaction time (RT), constant attention (CA), and selective attention (SA). Reaction time was influenced greatest by SDE with an increase in RT, whereas CA and SA were impacted greater by

SDB with a reduction in both. The study concludes time of day has an effect on cognitive performance and that sleep deprivation has a significant effect on cognitive performances the next day following sleep loss.

Jarraya et al. (2013) replicated the previous study and additionally examined the time of day effect on reaction time and attention capabilities in team handball players. The same measures were tested, but at multiple times throughout the day: 8:00, 12:00, 16:00, 20:00, and 24:00-hours. The results were consistent with the previous study showing sleep's effect on all cognitive measures. This study showed a time of day effect on RT, SA, and CA across all conditions. All scores were at their best at 8:00 hours and declined as the day progressed, which is consistent with the results found by Belenky et al. (2002). Studies provide consistent results that partial sleep deprivation significantly impacts reaction and other cognitive aspects in handball athletes (Jarraya et al., 2012; 2013).

Taheri and Arabamer (2012) investigated the effect of sleep deprivation on choice reaction time along with the effect on anaerobic power. Participants reported for baseline measures for the choice reaction time test (CRT). The CRT consisted of the participants responding to a stimulus by pressing up on a joystick after being exposed to the external stimuli on the computer screen. Response times were recorded for each stimuli and a mean was calculated. Mean CRT significantly increased after the sleep deprivation. The results were consistent with other studies examining reaction time after a night of sleep loss. Results consistently show that restricted hours of sleep negatively impacts reaction time.

Effect of Sleep Extension on Physical Performance

Sleep loss has received much of the attention of researches looking at its effects on athletic performance and other factors. Minimal research has examined the effects of extending sleeping on athletic performance and cognitive function. Using a sleep extension to measure the impact of sleep on performance proves worthwhile as college coaches constantly encourage their athletes to get more sleep versus sleeping less because of the role sleep plays in recovery. Mah et al. (2011) were the first to examine a sleep extension on sport specific performance. The study investigated the effect of extending the length of sleep on sport performance in collegiate basketball players. The study started with a two-week baseline phase where sleep of each player was tracked to develop a baseline for total sleep per night. Sleep was tracked via subjective sleep diary and wrist actigraphy. Other measures included psychological measures, PVT performance, a sprint test, and sport-specific measures. Psychological measures consisted of daytime sleepiness, and changes by administering the Epworth Sleepiness Scale (ESS) and Profile of Mood States. The PVT measured mean, minimum, maximum, and mean reaction times, and lapses greater than 500-ms. The PVT consisted of participants responding to a stimulus that appeared on the screen. Sprint times were assessed on a 282-foot shuttle running baseline to half court and back, and full court and back. Lastly, the sport-specific measures were percent of 10 free throws and percent of 15 three-pointers (five from the corners and top of the key). After the two-week baseline phase for sleep, all measures were tested for baseline measures. All participants received the sleep extension, which required the athletes to be in bed a minimum of ten hours per night. Participants that could not adhere to the sleep extension were excluded from the results. Sleepiness measures, shooting percentages and sprint times were collected each day at practice. The PVT was administered twice a day, completed at the same time of day in a 1-h window. The study showed significant increases in total sleep time by nearly 111 minutes. Significant improvements were seen in PVT scores across daily and weekly measures. Most notably, a significant drop in lapses after the sleep extension was observed. All aspects of athletic performance were increased: free throw and three-point shooting percentages and sprint times. Both psychological factors also improved during the sleep extension. Sleep extension has shown significant improvements across multiple domains on athletic performance, mood, and reaction time. Some other factors the authors mentioned that could attribute to improved sport performance could have been from nutrition, conditioning and coaching. Further research was suggested to investigate the effects a longer sleep extension to determine a degree of optimal sleep.

Mah et al. (2011) concluded from their study that additive sleep had a significant and positive impact on basketball performance and psychological variables. The study was limited by a small sample size ($N = 11$), making it difficult to generalize the findings to a larger population. In addition, the study did not have a control condition; all subjects received the sleep extension preventing data analysis across a control and experimental group. Another limitation was the variable travel schedule that disturbed any habitual sleep-wake patterns. The amount of travel time also negatively impacted quantity of sleep on those nights. Participants were advised to nap on nights that did not allow for 10 hours of sleep to fill the missing sleep totals. The final limitation was the reliance on wearing the actigraphy during sleep. Participants on some occasions forgot to wear the wrist actigraphy during either nighttime sleep or naps. A subjective sleep log was kept to monitor sleep quantity along with the wrist actigraphy, but there was still missing actigraphy data. Nevertheless, the sleep extension appeared to be beneficial in improving performance in real life settings.

Effect of Sleep Extension on Cognitive Performance

In addition to physical performance, cognitive performance has been shown to improve with additive sleep (Gillberg, Kecklund, Axelson & Akerstedt, 1996; Roehrs, Timms, Doorenbos & Roth, 1989; Waterhouse et al., 2007). Roehrs et al. (1989) examined the effects of extending habitual sleep of 8 hours to 10 hours a night for six nights on daytime sleepiness, alertness, and attention tasks. Attention was measured via a tracking assessment with central and peripheral reactive components and reaction time to auditory stimuli where participants had to listen to a series of tones. The variables of interest were reaction time to central and peripheral stimuli during the tracking assessment and reaction time, misses, and false-positives of the auditory test. Significant improvements in central and peripheral reaction times were observed in both the control and experimental groups. However, only the central reaction time effect was due to the extension condition. During the auditory test, the only improvement observed was in reaction time in the extension condition on day six. The study concluded that a practice effect might have masked the actual effects of the sleep extension on the psychomotor scores.

Short naps have been found to be effective in reducing the effects of a night of restricted sleep. Waterhouse et al. (2007) studied the effects of a short nap on cognitive and motor function after a night of restricted sleep. Participants were measured on a short-term memory test, visual choice reaction test, handgrip strength, and sprint times.

Participants underwent two conditions; in both conditions participants were restricted sleep by 4 hours and the following day, one group received a nap at 13:00 and the other group remained awake until testing at 14:00. Participants in the nap group received a 30-minute nap from 13:00 to 13:30 and had a 30-minute period to overcome sleep inertia before testing. No significant differences were found in the visual choice reaction time, or handgrip strength between the nap and no-nap group. A significant improvement in a memory test was found in the nap condition. Significant improvements were also found at the 2-m and 20-m marks of the sprint tests.

Another study examined the effects of a mid-day nap on reaction time, psychomotor vigilance tasks and subjective sleep measures (Gillberg et al., 1996). Participants received a 30-minute nap between 10:45 and 11:45 hours. A clear positive effect was seen in the nap condition on vigilance. Alertness and subjective sleep measures were not significantly different compared to the no nap condition. A nap could be a beneficial approach to supplement with a night of restricted sleep to decrease the effects of sleep loss on performance.

Extending a night's sleep has been shown to improve performance (Mah et al., 2011), however too much sleep can hinder performance (Taub & Berger, 1969). Taub and Berger (1969) examined the effects of extending a night of sleep from 8-hours to 11-hours on psychomotor scores. The study had two conditions for comparison; a night of normal sleep (8-hours) and a night of extended sleep (11-hours). A significant, negative impact was observed by extending sleep to 11-hours. Paradoxically, the 11 hours of sleep was comparable to the effects seen in humans facing chronic sleep loss.

A sleep extension to 10-hours a night has been shown effective in improving performance in as quickly as six days and continuing to improve up to five weeks and possibly further (Mah et al., 2011; Roehrs et al., 1989). However, by receiving more than 10 hours a night, performance can actually decreases similarly to the effects losing sleep. More research needs to examine the effects of extending sleep on athletic tasks that can be generalized to more sports versus the specifics of one (Mah et al., 2011).

Gaps in the Literature

Sleep and fatigue have been measured extensively and several key findings have emerged. The majority of the aspects of physical performance have been found to be unaffected by a sleep restriction of four hours. However, after a full night of sleep loss (sleep deprivation), aspects of physical performance begin to decline from baseline performances. An exception to this pattern was in weight-lifting tasks examining lower body power (Blummert et al., 2007). The findings by Blummert et al. (2007) are interesting in how they differ from the pattern of other sleep deprivation studies and raises the question if there is a more sensitive approach to measuring neuromuscular fatigue (NMF) other than weight-lifting tasks to measure lower body power.

The countermovement jump provides a quick and non-fatiguing protocol to measure neuromuscular fatigue (NMF); however, as research has demonstrated, the CMJ test may not be the most sensitive assessment to measure NMF (Thorpe et al., 2015). Gathercole et al. (2015) evaluated alternative ways to utilize the CMJ while still obtaining reliable results indicating NMF in athletes. The study notes the importance of the eccentric phase of the SSC, but a simple CMJ fails to account for the full SSC. Gathercole et al. (2015) looked to examine an alternative protocol that would evaluate the entirety of the SSC. Participants conducted six CMJs with a minute and a half between trials. After baseline CMJ's were performed, participants were exposed to a 3-stage Yo-Yo fatiguing protocol to elicit fatigue similar to a competition. CMJ tests were repeated immediately after, 24 and 72-hours after post-fatiguing protocol. The CMJs were analyzed under two conditions: the typical countermovement jump (CMJ-TYP) and alternative countermovement jump (CMJ-ALT). The main variables for the CMJ-TYP were peak and mean power, and jump height. For the CMJ-ALT, the variables of focus were eccentric, concentric and total contraction time. CMJ assessment immediately after post-fatigue showed significant decreases in peak and mean power, and jump height. Concentric and total duration increased slightly, but only eccentric time increased significantly. Twenty-four hours post-exercise, no significant differences were observed in peak or mean power, jump height, and concentric, eccentric and total duration. An interesting finding occurred 72-hours post-fatigue; mean, peak power and jump height were all maintained; however, concentric, eccentric and total duration all increased significantly from baseline measures. The participants were able to maintain the same power and jump height; however, to achieve the baseline measures, participants spent more time in contractive states to obtain those pre-fatigued measures. Gathercole et al. (2015) concluded that the typical countermovement jump (CMJ-TYP) is sensitive to 24-h NMF; however, the CMJ-TYP may not reliably measure NMF more than one day after competition or training.

The SSC is a movement that is a product of force production over time (Hoffman, 2012). Three factors contribute to SSC performance: elastic potential, tension development, and stretch reflex (Hoffman, 2012). A CMJ is executed by generating force against the ground, generating an impulse (force x time) and accelerating the body upward giving the body momentum (mass x velocity; Hoffman, 2012). Impulse and momentum have a direct relationship where athletes can mechanically alter a jump to accomplish similar jump performances. When performing jumps, athletes can achieve the same power or jump height (momentum) by altering the amount of force they produce or changing the contraction duration (Gathercole et al., 2015). The results found by Gathercole et al. (2015) support this notion. Participants demonstrated similar power outputs and jump heights relative to those achieved at baseline suggesting participants' neuromuscular systems were recovered. The CMJ-TYP would suggest athletes are fully recovered ready for high-intensity training; however, this may not be true; the CMJ-ALT suggests differently. CMJ-ALT examined the relationship that contraction duration has on SSC performance. Eccentric, concentric, and total duration were significantly elevated from baseline 72-h post-exercise. Although jump height and power production was maintained, SSC performance was not maintained and NMF still resides. The RSI-DJ test may be an effective test to measure NMF. The RSI examines the relationship between contact time with jump height (Flanagan & Comyns, 2008); the RSI accounts for overall jump performance (momentum) and the contact time (impulse) and can identify when an athlete adjusts one variable to improve the other (Flanagan & Comyns, 2008). For example, an athlete may try to jump quicker after contact but will be unable to achieve the same jump height, or an athlete may increase their contact time to generate more force to reach the same or a higher jump height (Flanagan & Comyns, 2008).

Hamilton (2009) utilized the RSI-DJ test to indicate whether the DJ test was a sensitive measure to NMF following match play. The study examined 16 youth soccer players and the effect of a four-game tournament had on fatigue levels and recovery. DJ tests were administered pre- and post-match for each tournament game. Significant differences (11%, 13%, & 7%) in RSI-DJ scores were observed from pre to post match in participants that played the entire match. Nicol et al. (1991) examined jump performance after running a marathon and found a significant decrease of 16% in rebound jump scores, whereas the CMJ showed an insignificant change of 8%. The results indicate the CMJ test was not sensitive to the accumulated fatigue.

The effects of sleep on cognitive performance have also been studied extensively. Research has shown that sleep loss has a dose-response relationship to cognitive performance (Van Dogen et al., 2003). Cognitive performance is most commonly assessed in reaction time utilizing handheld devices measuring the time to react to a stimulus; however, no research has examined the effects of sleep on cognitive performance as a whole-body function or in sport-specific tasks.

Summary

Peak performance is routinely expected from athletes, placing high demands on training while allowing less time for recovery. Recovery is a multifaceted concept that is comprised of proper nutrition and hydration, additive recovery strategies, and sleep. The effects of sleep loss on physical and cognitive performance have been studied extensively. However, minimal research has looked at the effects of extended sleep on aspects of performance. Research has shown the benefits of extended sleep on physical and cognitive performance. More research needs to be conducted that looks at the effects of extended sleep on athletic performance. Research also has yet to examine the effects of added sleep on reactive strength and the effects of decision-making in agility tasks.

CHAPTER 3

METHODS

This chapter describes the methods and procedures used in the current study. The study examined the effect of a one-hour sleep extension per night on reactive strength and change of direction agility tests. The methods examine the effects of the experimental period on the dependent variables, and the differences between the control and sleep groups. This chapter is comprised of the following subsections: Participants, Procedures and Testing Protocols, Sleep Intervention and Statistical Analysis.

Participants

Fifteen NCAA Division III student-athletes (10 female, 5 male) volunteered to participate providing informed consent approved by the Institutional Review Board. Participants were in the off-season training programming and injury free for at least six months prior to the beginning of this study. Participant recruitment began by contacting team coaches via email in order to receive permission to contact their student-athletes (Recruitment Statement, Appendix A). Participants were randomly assigned to one of two groups before the experimental period (control or sleep group). The control group ($n = 8$) had a mean age (M_{age}) of 19.25 ± 1.4 years, mean height (M_{height}) of 175.6 ± 14.7 cm, mean weight (M_{weight}) of 71.96 ± 11 kg, and a mean number of training sessions per week (M_{train}) of 5.7 ± .75. The sleep group ($n = 7$) had a M_{age} of 20.14 ± 1.2 years, M_{height} of 182.8 ± 28.0 cm, M_{weight} of 79.79 ± 10.2 kg, and a M_{train} of 5.42 training sessions a week. Participants were Ithaca College varsity student-athletes that were medically cleared by the Ithaca College's sports medicine staff. Participants were excluded if they could not comply with a sleep extension intervention and attend all five lab sessions. Participants were further excluded if they have a history of disturbed sleep and if they had any pre-existing lower body injuries effecting data collection. All eligible participants read and signed informed consent approved by the Institutional Review Board (Appendix B). Participant's data were omitted if an injury occurred during the intervention period that prevented a participant from testing, and if participants are unable to adhere to sleep extension in the sleep group.

Procedures & Testing Protocols

Participants attended five laboratory sessions; the first to familiarize them with testing procedures and four times for data collection (Figure 3). Each laboratory session began with standardized 5-minute warm up. Participants completed six repetitions of the drop jump test, and six trials of the preplanned change of direction and six trials of the reactive agility tests. Participants received 90-seconds rest between all drop-jumps and agility test trials to limit the effects of fatigue on recorded data (Gathercole, Sporer, Stellingwerff, & Sleivert, 2015).

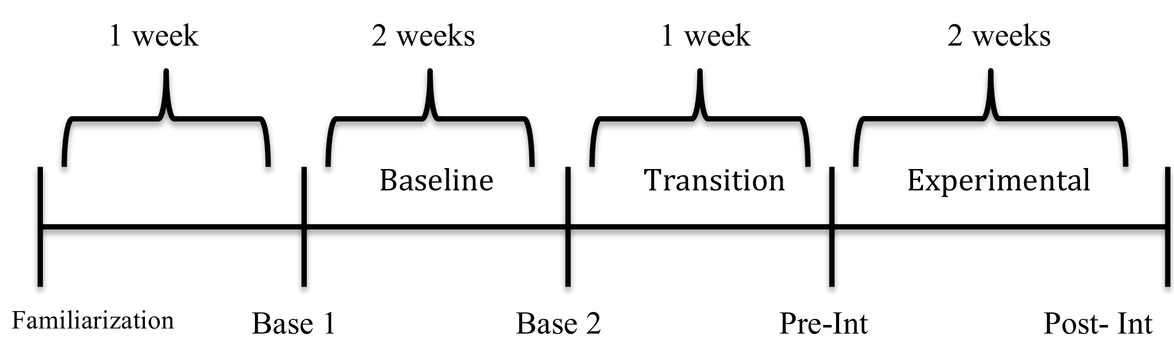

Figure 3. Timeline of events for the current study.

A familiarization session preceded a two-week baseline period. Participants received practice trials for the three tests to become familiar with the protocols. Participants were familiarized with the SleepBot app (SleepBot, LLC) and the Epworth Sleepiness Scale (ESS) questionnaire. The baseline period began and concluded with a lab session, Base 1 and Base 2, respectively. At each lab session participants were tested on the three measures; reactive strength index-drop jump (RSI-DJ) test, reactive agility (RA) test, and pre-planned change of direction (COD) tests. Participants were randomly assigned to either the control or sleep group at the end of the baseline period. A 1-week transitioning phase followed the baseline measures to allow for the participants in the sleep group to become familiar with their extended sleep patterns (Mah et al., 2011).

SSC Performance- Drop Jump test

Utilizing the RSI provides a more sensitive approach in examining neuromuscular function compared to vertical and countermovement jump tests (Cormack, Newton, McGuigan, & Cormie, 2008). RSI is a combination of two factors, ground contact time and jump height. Contact time was measured using the force plate by measuring the time from initial foot contact to when the foot left the force plate during take-off. Jump height was calculated using the following equation: $Height\ (m) = (g*(flight\ time)^2 / 8$, where g is the acceleration due to gravity. (Flanagan & Comyns, 2008). Flight time was defined as the time period with no foot contact with the force place during the countermovement jump and landing.

A baseline test for the drop jump at the first baseline testing established a standardized RSI-DJ intensity for each subject (Flanagan, 2016). For baseline testing, participants were instructed to step from a box onto the force plate and jump as high as possible and as quickly as possible. The force plate was an Advanced Mechanical Technology, Inc. (AMTI) unit sampling at 1000 Hz. The test evaluated ground contact time and jump height to measure RSI. Participants performed the drop jump test from three different box heights to obtain an individual experimental height. Participants were instructed to step from a 15, 30, and 45-cm box (Flanagan & Comyns, 2008). Testing at the various heights created a plyometric profile on the optimal height the participant was able to utilize their fast SSC (Flanagan, 2016). The maximum height the subject is able to maintain a contact time < 0.25-seconds was used for the testing measures during the second baseline testing and for intervention testing (Flanagan, 2016).

RSI-DJ test scores were evaluated by having the participants conduct three drop jumps off the standardized height established for each participant. Participants were instructed to step off the box and jump as high as possible and as quick as possible as if the ground was hot (Flanagan & Comyns, 2008). Participants were given 90 seconds between drop jumps to allow for recovery so neuromuscular fatigue did not affect RSI scores (Gathercole et al., 2015). The average RSI of the three drop jumps were used for data analysis.

Decision Making

Decision-making was measured by comparing the differences in times between a preplanned COD test and a RA test. Both tests recorded time using electronic timing gates measuring to the nearest thousandth of a second (Fusion Smart Speed, Chicago, IL, USA). The COD test required participants to accelerate towards a marker cone and side shuffle to the predetermined direction (Figure 4). The RA test required participants to accelerate forward towards a marker cone and side shuffle to the correct side based on the external stimulus (Figure 5). A cognitively challenging component was utilized to force the participant to recognize the stimulus and respond accordingly based on the instructions provided. Four scenarios using four different colored lights were used as external stimuli. The four scenarios were: 1) red light - shuffle left; 2) blue light - shuffle right; 3) purple light – shuffle right; 4) yellow light – shuffle left. Participants performed six trials of both tests with a randomization of preplanned directions and colors. The best and the worst times were discarded in the case of unnatural occurrence for data reliability. The remaining four trials were averaged and used for analysis. The variable of interest was the difference in times between the COD and RA test scores (RA - COD).

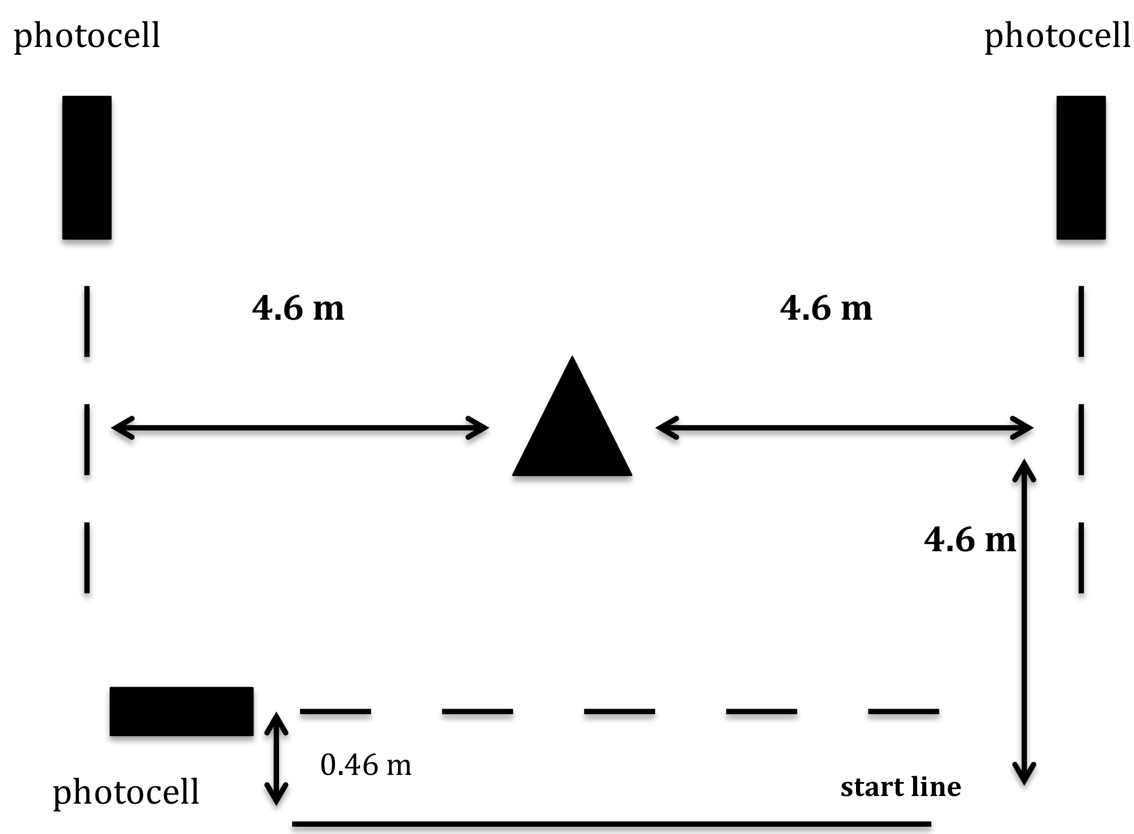

Figure 4. Diagram showing the layout of the pre-planned change of direction test.

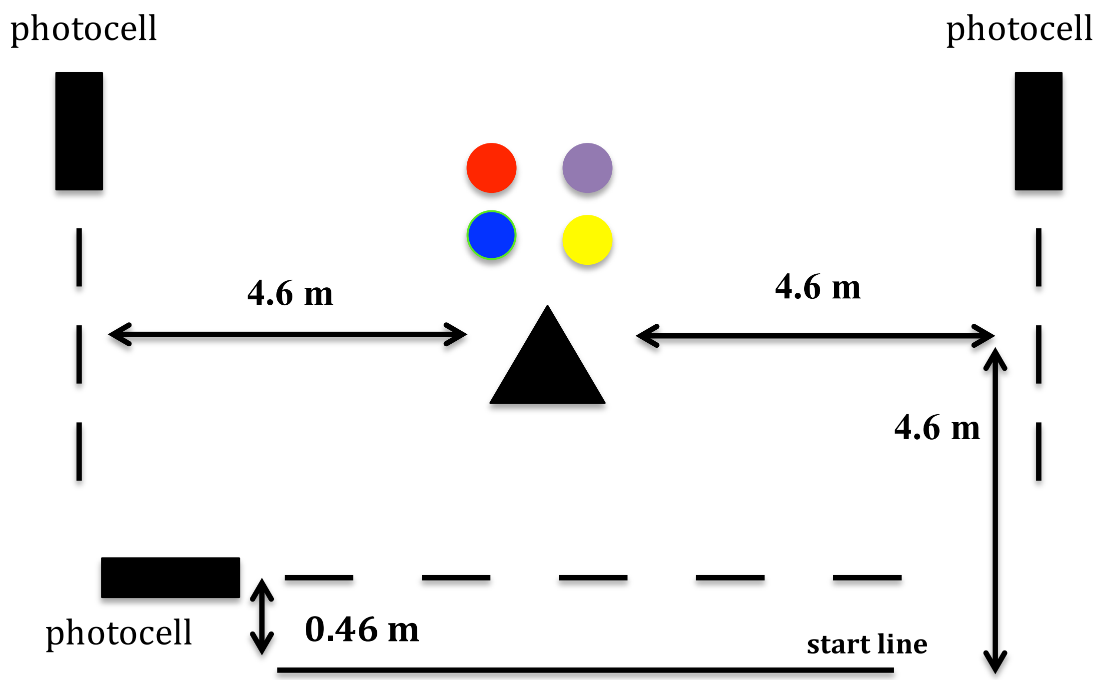

Figure 5. Diagram showing the layout of the reactive agility test.

Sleep Extension Intervention

The primary sleep variable for the study is the quantity of sleep each night. The cell phone application SleepBot (SleepBot, LLC) measured duration of sleep and had features that measure sleep cycles. Cell phone applications have been validated and can be used to provide a cost-effective approach to objectively monitor sleep (Ong & Gillespie, 2016). Pairing the use of a cell phone app with a paper diary has been found to improve adherence and consistent tracking during intervention studies (Carter, Burley, Nykjaer, & Cade, 2013).

During the two-week baseline period, sleep quantity was tracked through the use of the SleepBot cell phone application. Sleep during the baseline period was monitored to assess habitual sleep patterns for recommendations during the experimental period. All participants were expected to track the quantity of sleep during the baseline period. At the end of the baseline period, participants were randomly assigned to either the control group (habitual sleep) or the experimental group (extended sleep).

During the transitioning period, the participants in the control groups continued to track their habitual sleep patterns. The experimental group tracked their new sleep patterns as they begin to extend their sleep and prepared their sleep schedule for the two week intervention period. The goal for the subjects is to begin the extended sleep immediately, but the transition phase allowed participants to become familiar with their new sleep patterns and schedules.

The intervention phase was two weeks long; sufficient to enable the extended sleep to enable full recovery of the athlete. The experimental group was asked to sleep one extra hour a night for a minimum of five nights during the experimental period. All participants were asked to track their sleep to ensure adherence of the sleep group and to monitor for changed sleep patterns in the control group. Participants were encouraged to nap the following day if they are unable to sleep for the required amount of time during the experimental period (Waterhouse et al., 2007).

In addition to the cell phone app tracking quantity of sleep, participants were asked to fill out a sleep diary (Appendix D) clarifying the quantity and quality of sleep. The diary contained a section asking for the hours of sleep each night along with an Epworth Sleepiness Scale (ESS) questionnaire for after each night (Johns, 1991). Participants were instructed to log any kind of supplement that could affect sleep quality such as caffeine, melatonin, and other stimulants or sleep aids. Participants were asked to be consistent with any supplements to limit confounding effects on the dependent variables. Participants filled out the sleep diary 30 minutes after waking to allow them to overcome sleep inertia for accurate results on their quality of sleep (Waterhouse, Atkinson & Edwards, 2007). The ESS subjectively measured daytime sleepiness by measuring the likelihood of falling asleep in eight different scenarios (Chevrin, Aldrich, Picket, & Guilleminault, 1997; Johns, 1991). The ESS was analyzed through summation of the scores of the eight questions and interpreted as follows: 0-10 = normal daytime sleepiness, and >10 = excessive daytime sleepiness (Johns, 1991). The ESS has been shown to deliver internal consistency with a Cronbach's alpha score between 0.73 and 0.90 (Hagell et al., 2007; Johns, 1992). ESS also has test-retest reliability with intraclass correlation coefficients ranging from 0.81 to 0.93 (Cho et al., 2011; Izci et al., 2007; van der Heide et al., 2015). Daytime sleepiness is an effective way to measure quality of sleep in healthy humans (Johns, 1991).

Statistical Analysis

All data was examined for normality before statistical analyses were performed. Statistical analyses were chosen to evaluate the effects of the independent variable, quantity of sleep, on the dependent variables; RSI, cognitive function, and ESS. A mixed model analysis of variance with repeated measures (ReANOVA) was used to examine for effects between groups. One 2 x 2 (group x time) ReANOVAs and three 2 x 3 (group x time) ReANOVAs were run to analyze for effects between groups and variables. In case of violation of Mauchely's test of sphericity, Greenhouse-Geisser adjusted p-values were used. Post-hoc pairwise comparisons were performed to locate the source of significant effects in the repeated measures time factor.

CHAPTER 4

MANUSCRIPT

Introduction

Emphasis is placed on athletes to perform consistently at high levels. This requires athletes to train long hours to achieve elite levels of performance, and failure to achieve such levels could result in competition failure and loss of a career. Performance is a combination of cognitive and physical components (Joyce & Lewindon, 2014). The physical components include the fitness demands of sport, whereas the cognitive component is the mental processes of sports such as reaction time and decision-making (Joyce & Lewindon, 2014). To maximize performance, a balance between training and recovery needs to be met in order to allow for positive adaptations (Hoffman, 2014). To achieve athlete preparedness, athletes need to maximize recovery strategies and allow for fatigue to subside after training, which will result in an elevated level of fitness from pre-training status (Hoffman, 2014).

Recovery is a multifaceted process that consists of nutrition (Bishop, Jones, & Woods, 2008), active recovery modalities (Haff & Triplett, 2016), hydration (Beck et al., 2015; Bishop, Jones, & Woods, 2008), and sleep (Frank & Benington, 2006). Sleep is essential for the recovery process. It is believed sleep is responsible for the restoration of the immune and endocrine systems, regeneration of the nervous and muscular systems, cognitive development and motor memory (Frank & Benington, 2006). The muscular system benefits from sleep because of the release of growth hormone promoting muscle growth and preventing breakdown of amino metabolites (Sassin, Parker & Mace, 1969). The nervous system benefits from sleep as neural connections are developed or strengthened and in a sleep state, the nervous system is working at a lower level allowing for reorganization of the nervous system (Hobson, 2005). According to the National Sleep Foundation (NSF), the US population averages under seven hours of sleep a night, falling short of the eight to nine hours the NSF recommends daily (National Sleep Foundation, 2013). College students have been found to average almost two hours less than the national recommendations, due to late night studying and poor sleep hygiene (Forndran et al., 2012). Poor sleep hygiene consists of inconsistent sleep and wake times, exposure to artificial light prior to bed and uncomfortable sleeping conditions (Hicks & Pellegrini, 1991).

Although coaches and athletes recognize sleep as a major contributor to performance (Venter, 2014), athletes have been shown to average between six to eight hours of sleep a night with almost 11% averaging less than six hours of sleep (Sargent, Halson & Roach, 2014). If athletes and college students are sleeping two hours less than national recommendations, collegiate student-athletes would be anticipated to be sleeping even less due to their dual roles on their college campus. Research suggests that athletes require greater amounts of sleep (9-10 hours) during periods of high intensity and high volume of training and competition (Bird, 2013). If student-athletes are getting less sleep than recommended, performance could be affected as sleep plays an important role in recovery.

Examinations of the effects of sleep loss on physical performance have shown mixed results. Research has shown that aerobic function (Mejri et al., 2014), anaerobic capacity (Mougin et al., 1996), and maximal strength (Blumert et al., 2007) are unaffected after sleep loss less than 36-hours. However, after more than 36 hours of sleep loss, aerobic function (Martin, 1981), anaerobic function (Skein et al., 2011) and submaximal strength measures (Bulbilian et al., 1996) deteriorate. Cognitive performance has exhibited an immediate decline in performance after just one night of mild sleep restriction of two hours. Belenky et al. (2002) investigated the effects of various levels of sleep restriction has on cognitive performance element of reaction time in a psychomotor vigilance tasks (PVT) over the course of one week. The PVT tasks measures reaction time during a 10-minute span where an individual is exposed to stimuli at random time intervals on a hand held device (Belenky et al., 2002). The researchers found a dose-response relationship between the sleep restriction and reaction, meaning the greater the sleep restriction, the slower reaction time scores. These findings are consistent with other studies examining the effects of sleep loss on cognitive performance (Dinges et al. 1997; Taheri & Arabamer, 2012).

Although the effects of sleep loss on performance have been studied extensively, the research literature is incomplete and sometimes ambiguous. Some of the discrepancies in findings in sleep loss studies could be contributed to the different methods and measures of performance in the various studies. Also, some performance measures may be more resistant to fatigue or can be cheated in changes in mechanics. Muscular strength and power has been measured via weightlifting exercises (Blumert et al., 2007); however, these tasks may not be sensitive in measuring inadequate recovery. Strength and power measures examine how athletes produce force (Haff & Triplett, 2016). A problem with some strength and power measures is that when provided with the chance to produce force over greater time, the effects of fatigue can be masked (Thorpe et al. 2015). Gathercole et al. (2015) looked at how a common measurement of power, the countermovement jump (CMJ), may not be sensitive to measuring neuromuscular fatigue (NMF) days after training. The authors examined jump height, power, and eccentric, concentric, and total contraction time. The researchers found that by extending the time spent in muscle contraction, the participants were able to mask fatigue 72-hours post training (Gathercole et al., 2015). Reactive strength examines one's ability to generate force quickly through the use of the fast stretch shorten-cycle (SSC; Schmidtbleicher, 1992). The reactive strength index (RSI) quantifies fast SSC performance and is a ratio of jump height and ground contact time (Flanagan & Comyns, 2008). RSI may also provide a more sensitive approach to measuring fatigue through more sport specific measures compared to the CMJ with the inclusion of ground contact times (Hamilton, 2009). Sleep loss studies have failed to examine the effect between sleep and the production of force quickly.

Much of the literature of sleep on performance examines how sleep loss impacts performance. If the research shows that student-athletes are sleeping two-hours below national recommendations, then student-athletes may be performing below optimal. Therefore, it is reasonable that future research aim at understanding how extending sleep impacts performance. Mah et al. (2011) was one of the few to examine the effects of a sleep extension on physical and cognitive performance. Participants (N = 11) were required to extend sleep up to 10 hours per night over a five to seven week period during their competitive season. On average, participants extended sleep by two-hours during the extension period compared to the baseline time period. The authors reported improvements in sprint times (4%), made free throw (10%) and made three-pointers (14%) following the sleep extension period. Mean reaction times got significantly faster by 12% after the sleep extension intervention. Some limitations noted about the study were that the small sample size (*N* = 11) limits the generalizability of the results, and the lack of a control group to compare findings against. Minimal research examines the effect of sleep extension performance and no sleep extension research has examined the effects on reactive strength and agility tasks.

The aim of the current study was to examine the importance of sleep in recovery. Limited research examines the effect of extended sleep on performance and no research to date has examined the effect of sleep on reactive strength qualities and agility tasks. The purpose of this study was to examine the effect of a sleep extension on reactive strength and decision-making in agility tasks.

Methods

Participants

Fifteen NCAA Division III student-athletes (10 female, 5 male) volunteered to participate providing written informed consent approved by the Institutional Review Board. Participants were field hockey and basketball athletes. Participants were randomly assigned to two groups before the experimental period (control and sleep groups). The control group (n = 8) had a mean age (M_{age}) of 19.25 ± 1.4 years, mean height (M_{height}) of 175.6 ± 14.7 cm, mean weight (M_{weight}) of 71.96 ± 11 kg, and a mean number of training sessions per week (M_{train}) of 5.7 ± .75. The sleep group (n = 7) had a M_{age} 20.14 ± 1.2 years, M_{height} of 182.8 ± 28.0 cm, M_{weight} of 79.79 ± 10.2 kg, and M_{train} of 5.42 training sessions a week. Participants were varsity student-athletes that were medically cleared by the sports medicine staff. Participants were in the off-season training phase and were injury free for at least six months prior to the beginning of this study.

Procedures

Participants attended the laboratory on five occasions for testing; the first to familiarize them with testing procedures and four times for data collection (Figure 6). Each laboratory session began with standardized 5-minute warm up. Participants completed six repetitions of a drop jump test, and six trials of the preplanned change of direction and six trials of the reactive agility tests. Participants received 90-seconds rest between all drop-jumps and agility test trials to limit the effects of fatigue on recorded data (Gathercole, Sporer, Stellingwerff & Sleivert, 2015).

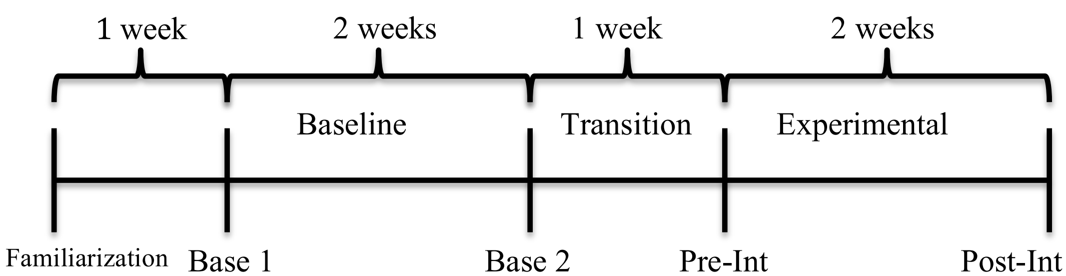

Figure 6. Timeline of events for the current study.

Following familiarization testing, participants completed a two-week baseline period. Demographic data was gathered and participants received practice trials for the three tests to become familiar with the protocols. Participants were familiarized with the SleepBot app (SleepBot LLC) and the Epworth Sleepiness Scale (ESS) questionnaire. The Baseline Period began and concluded with a lab session (Base 1 & Base 2). At each lab session, participants were tested on the three measures; reactive strength index-drop jump (RSI-DJ) test, reactive agility (RA) test, and pre-planned change of direction (COD) tests. Participants were randomly assigned to either the control or sleep group at the end of the baseline period to isolate the sleep extension on the performance variables.

A 1-week transitioning phase followed the baseline measures (Mah et al., 2011). The goal of the transition period was for the participants in the sleep group to become familiar with the extended sleep patterns (Mah et al., 2011).

Participants underwent a 2-week experimental period immediately following the transition phase (Mah et al., 2011; Roehrs et al., 1989). During the experimental period, the participants in the sleep group extended their sleep by at least sixty-minutes for a minimum of five of the seven nights each week and the control group continued habitual sleep patterns. Participants completed testing at the beginning and end of the experimental period for RSI-DJ, RA, and COD performance.

Testing Protocols

Reactive Strength Index - Drop Jump. Utilizing the RSI provides a more sensitive approach in examining neuromuscular function compared to vertical and countermovement jump tests (Cormack, Newton, McGuigan, & Cormie, 2008). RSI is a combination of two factors, ground contact time and jump height. Contact time was measured using the force plate by measuring the time from initial foot contact to when the foot left the force plate during take-off. Jump height was calculated using the following equation: $Height\ (m) = (g*(flight\ time)^2 / 8,$ where g is the acceleration due to gravity. (Flanagan & Comyns, 2008). Flight time was defined as the time period with no foot contact with the force place during the countermovement jump and landing.

A baseline test for the drop jump at the first baseline testing established a standardized RSI-DJ intensity for each subject (Flanagan, 2016). For baseline testing, participants were instructed to step from a box onto the force plate and jump as high as possible and as quickly as possible. The force plate was an Advanced Mechanical Technology, Inc. (AMTI) unit sampling at 1000 Hz. The test evaluated ground contact time and jump height to measure RSI. Participants performed the drop jump test from three different box heights to obtain an individual experimental height. Participants were instructed to step from a 15, 30, and 45-cm box (Flanagan & Comyns, 2008). Testing at the various heights created a plyometric profile on the optimal height the participant was able to utilize their fast SSC (Flanagan, 2016). The maximum height the subject is able to maintain a contact time < 0.25-seconds was used for the testing measures during the second baseline testing and for intervention testing (Flanagan, 2016).

RSI-DJ test scores were evaluated by having the participants conduct three drop jumps off the standardized height established for each participant. Participants were instructed to step off the box and jump as high and as quickly as possible as if the ground was something hot (Flanagan & Comyns, 2008). Participants were given 90 seconds between drop jumps to allow for recovery so neuromuscular fatigue did not affect RSI scores (Gathercole et al., 2015). The average RSI of the three drop jumps were used for data analysis.

Decision-Making. Decision-making was measured by comparing the differences in times between a preplanned COD test and a RA test. Both tests recorded time using electronic timing gates measuring to the nearest thousandth of a second (Fusion Smart Speed, Chicago, IL, USA). The COD test required participants to accelerate towards a marker cone and side shuffle to the predetermined direction (Figure 7). The RA test required participants to accelerate forward towards a marker cone and side shuffle to the correct side based on the external stimulus (Figure 8). A cognitively challenging component was utilized to force the participant to recognize the stimulus and respond accordingly based on the instructions provided. Four scenarios using four different colored lights were used as external stimuli. The four scenarios were: 1) red light - shuffle left; 2) blue light - shuffle right; 3) purple light – shuffle right; 4) yellow light – shuffle left. Participants performed six trials of both tests with a randomization of preplanned directions and colors. The best and the worst times were discarded in the case of unnatural occurrence for data reliability. The remaining four trials were averaged and used for analysis. A COD and RAT score was collected for each lab session and the decision making variable was the difference between the RAT and COD scores.

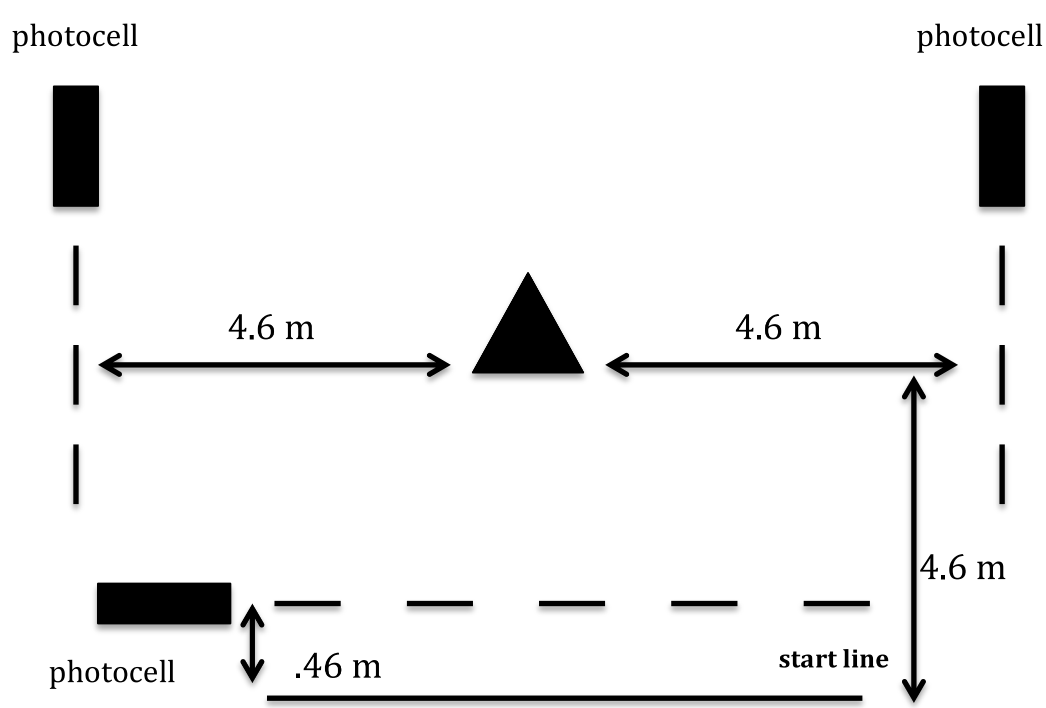

Figure 7. Diagram showing the layout of the pre-planned change of direction test

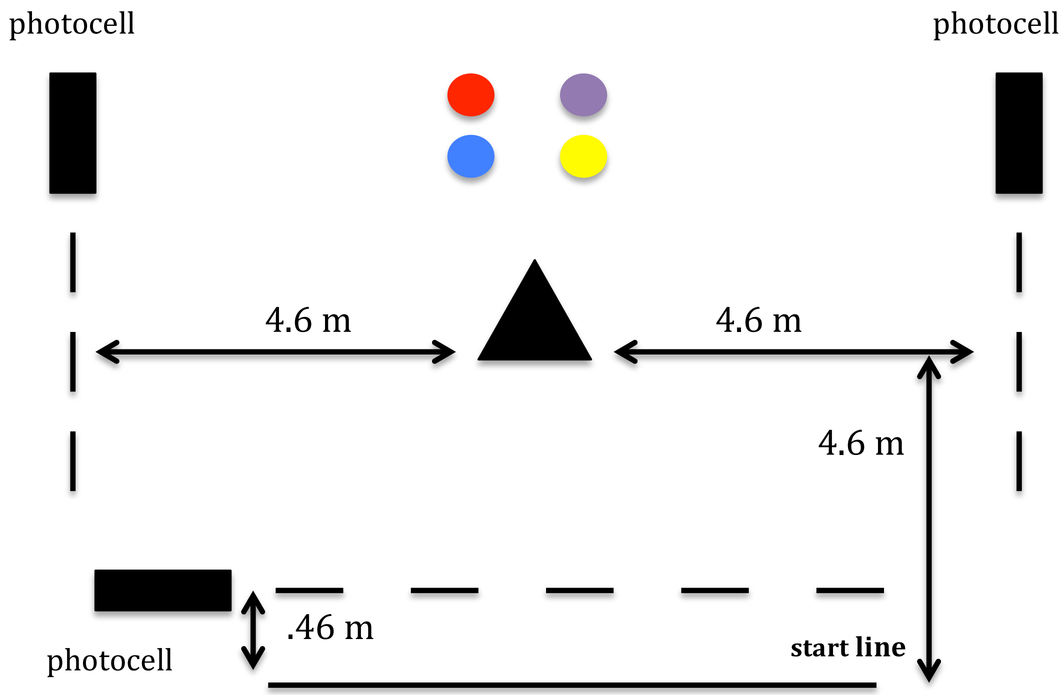

Figure 8. Diagram showing the layout of the reactive agility test.

Sleep Extension Intervention

Following baseline testing, participants were randomly assigned to either the sleep on control group. The experimental group extended their sleeping habits by 60 minutes per night for two weeks. The control group was instructed to continue habitual sleeping patterns found during the baseline period. Quantity of sleep was measured using a paper sleep diary paired with the cell phone application SleepBot (SleepBot LLC, New York, NY, USA). Cell phone applications have been found to be reliable when paired with paper sleep diaries (Ong & Gillespie, 2016). On the sleep diary, participants recorded time in bed, waking time, and total sleep time. Prior to falling asleep, participants logged into the app and hit ‘punch in’ to begin tracking sleep duration. In the morning, participants hit ‘punch out’ to stop recording sleep duration. Along with quantity of sleep, quality of sleep was also monitored utilizing the Epworth Sleepiness Scale (ESS) (Johns, 1991) to assess subjective daytime sleepiness. The ESS questionnaire was filled out thirty-minutes after waking in the morning to allow sleep inertia to subside (Waterhouse, Atkinson & Edwards, 2007). The ESS questionnaire has been shown to be valid in measuring subjective daytime sleepiness with an ICC ranging from 0.81 to 0.93 (Cho et al., 2011;) and internal consistency with a Cronbach's alpha score between 0.72 and 0.90 (Johns, 1992).

During the two-week baseline period, sleep quantity was tracked to establish habitual sleep habits for each participant and used for the experimental period. At the end of the baseline period, participants were randomly assigned to either the control group (habitual sleep) or the sleep group (extended sleep). The transition phase was given for the participants to begin to prepare their schedules for the experimental phase. Sleep was not monitored during the transition phase. The intervention phase was a two-week period to examine the effects of extended sleep on athletic performance (Roehrs et al., 1989). The sleep group was asked to sleep an extra 60 minutes per night for a minimum of five nights each week during the experimental period. All participants tracked their sleep in the paper sleep diary and SleepBot app to ensure adherence of the sleep group and to monitor for changed sleep patterns in the control group. Participants were permitted to nap the following day if they were unable to sleep for the necessary amount of time during the experimental period.

Statistical Analysis

All data were examined for normality before statistical analyses were performed. A mixed model analysis of variance with repeated measures (ReANOVA) was used to assess changes in the dependent variables between groups. One 2 x 2 (group x time) and three 2 x 3 (group x time) ReANOVAs were run to analyze for effects between groups and variables. In case of violation of Mauchely's test of sphericity for ESS, adjusted p-values were used (Greenhouse-Geisser). Post-hoc pairwise comparison analyses were performed to locate the source of significant effects in the repeated measures time factor. Statistical procedures were conducted using SPSS (version 25.0, IBM Corporation, Armonk, NY, USA).

Results

Sleep Quantity

Figure 9 shows changes in sleep duration in control and sleep groups across the intervention period. The results show that participants in the sleep group increased sleep duration by 11% (472 ± 38 min to 524 ± 29 min) across the testing period. In contrast, the control group exhibited a 2% decrease in mean sleep duration (517 ± 45 min to 505 ± 45 min) from pre- to post- testing. A significant group x time interaction effect was found ($F_{(1,13)} = 17.78$; $p = 0.001$). Post-hoc analysis showed the interaction effect is explained by the increase in mean sleep quantity by the sleep group from the baseline period to the experimental period. A significant time effect was observed ($F_{(1,13)} = 7.03$; $p = 0.02$) depicting a significant change in means between the baseline and experimental periods. No significant group effect was found ($F_{(1,13)}= 0.43$; $p = 0.522$), indicating no differences of sleep quantity existed between groups throughout the experimental period.

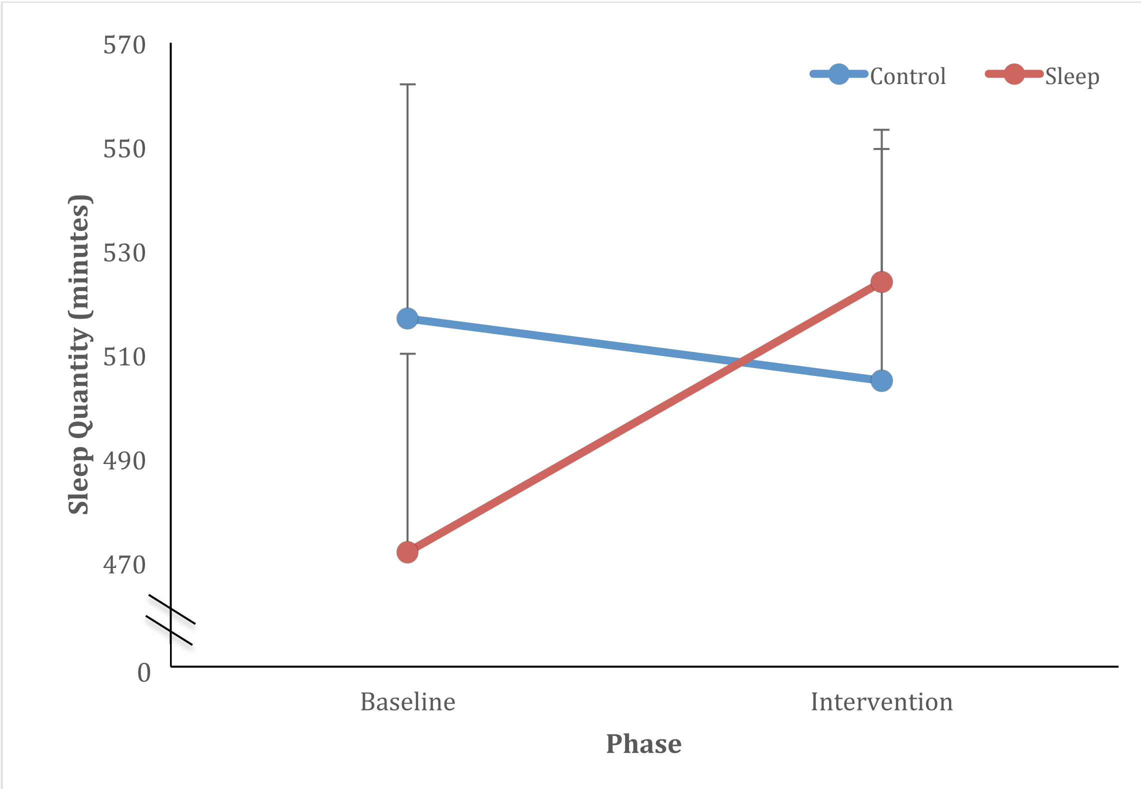

Figure 9. Mean (±SD) sleep habits of control and sleep groups from baseline and experimental periods.

<u>RSI-DJ</u>

RSI-DJ mean performances for the control and sleep groups from baseline 2, pre-intervention and post-intervention are illustrated in Figure 10. Mean RSI for the sleep group increased 1% from baseline to pre-intervention testing (1.28 ± 0.30 to 1.30 ± 0.48) and also increased 5% from pre- to post-intervention (1.30 ± 0.48 to 1.36 ± 0.43). Control group mean RSI scores increased 8% from baseline 2 to pre-intervention (1.30 ± 0.33 to 1.40 ± 0.65) and decreased 8% from pre intervention to post intervention testing (1.40 ± 0.65 to 1.29 ± 0.38). None of these changes were statistically significant, as evidenced by the effects for groups ($F_{(2,26)}$ = .015; p = 0.905) and time ($F_{(2,26)}$ = 0.101; p = 0.822). Group x time interactions of changes in RSI exhibited no significant change from pre- to post-intervention in either group ($F_{(2,26)}$ = 0.184; p = 0.741) exhibiting no change throughout the experimental period. Although no significant findings were found, a pattern was evident in the RSI results. The RSI scores in the sleep group increased by 6% after beginning the sleep intervention.

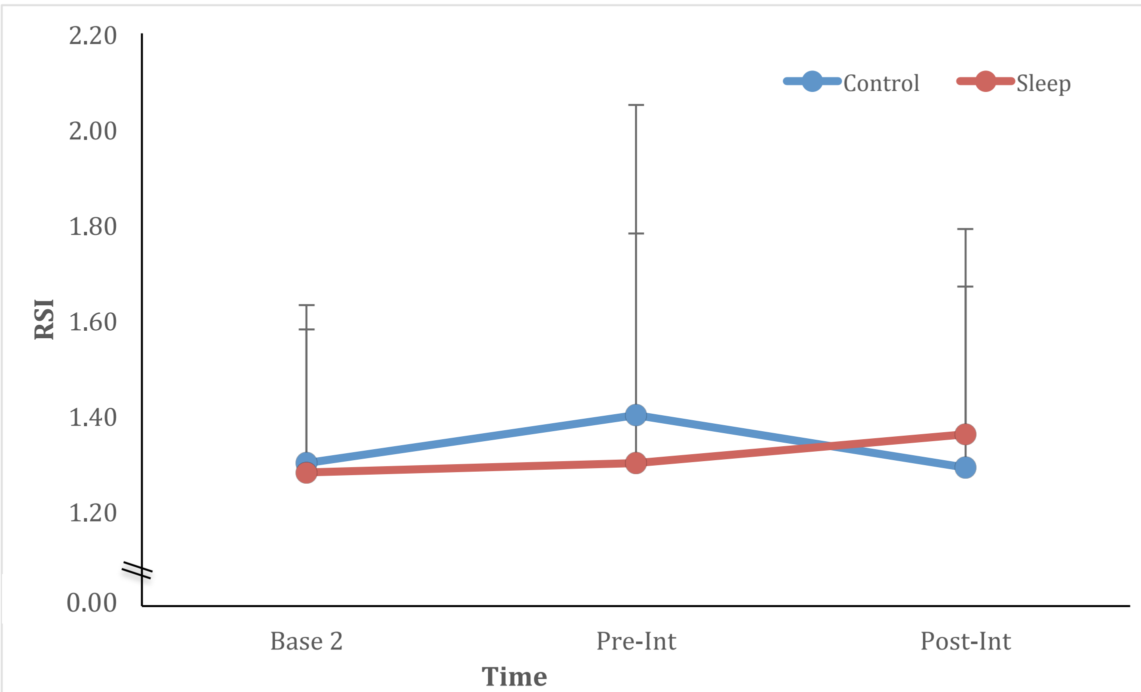

Figure 10. Mean (± SD) RSI scores of control and sleep groups from baseline 2 to pre-intervention to post- intervention.

Decision Making

Mean decision-making times for the control and sleep groups from baseline 2, pre- and post-intervention are presented in Figure 11. Mean decision-making time for the sleep group showed slower times (6%) from baseline 2 to pre-intervention (0.30 ± 0.18 s to 0.32 ± 0.14 s) and faster times (6%) from pre- to post-intervention (0.32 ± 0.14 s to 0.30 ± 0.16 s). The control group showed slower decision-making times (9%) from baseline 2 to pre-intervention (0.33 ± 0.13 s to 0.36 ± 0.17 s) and faster decision-making times (5%) from pre intervention to post intervention testing (0.36 ± 0.17 s to 0.34 ± 0.13 s). None of these changes, however, were statistically significant. Specifically, there were no significant group x time interaction effects was observed from between testing periods ($F_{(2,26)}$ = 0.32; p = 0.969). No significant effects were observed between groups ($F_{(2,126)}$ = 0.22; p = 0.647) meaning no differences in decision-making times were observed at any time point. No significant effects of time were found ($F_{(2,26)}$ = 0.466; p = 0.633) meaning that overall mean decision-making times did not change from any testing time points.

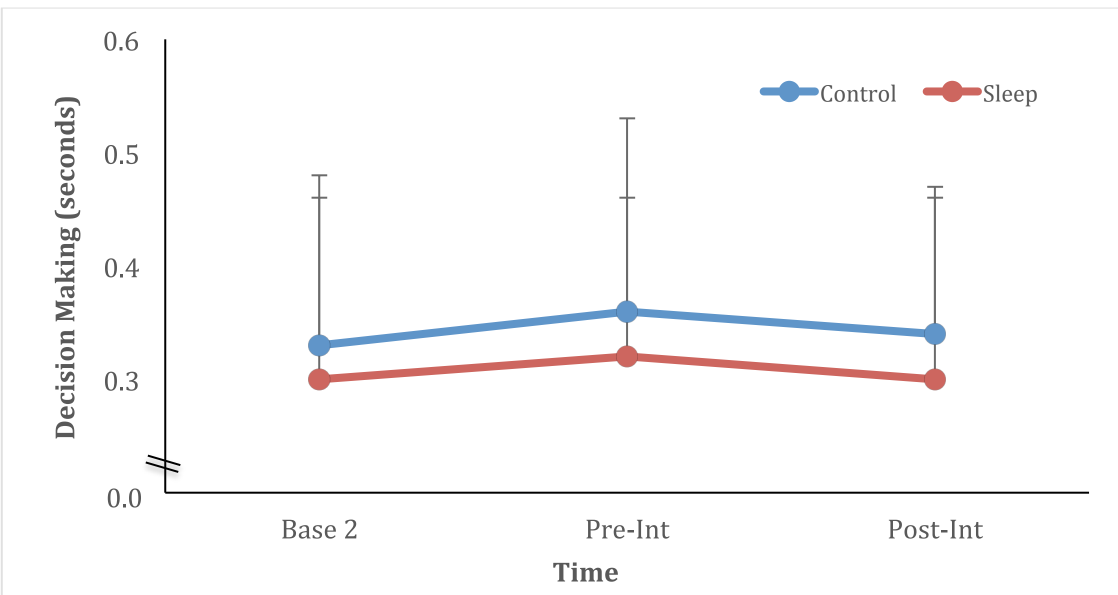

Figure 11. Mean (± SD) decision-making times of control and sleep groups from baseline 2 to pre-intervention to post-intervention.

ESS (Daytime Sleepiness)

Mean ESS scores from the first, fifth, and tenth nights of the sleep are reported in Figure 12. Sphericity was not violated (p = .865) meaning sphericity can be assumed for ESS analysis. No significant group x time interaction effect was found over the experimental period ($F_{(2,26)} = 0.76$; $p = .478$). No significant effects were found between groups ($F_{(2,26)} = 0.01$; $p = .946$) or between time points ($F_{(2,26)} = 1.97$; $p = .160$). Thus, participants exhibited little change in quality of sleep over the course of the experimental period.

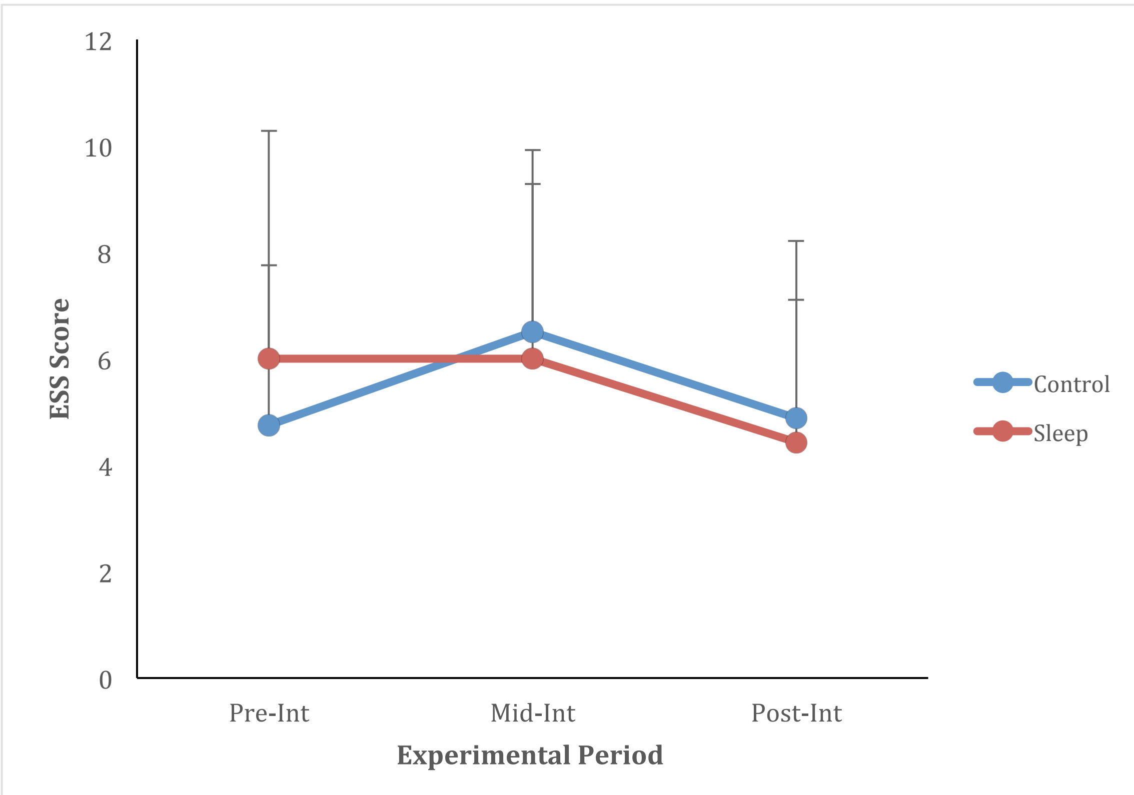

Figure 12. Mean (± SD) ESS scores of control and sleep groups from the first, fifth and tenth day of the experimental period.

Discussion

Sleep plays a large role in recovery with its impacts on nervous system recuperation and protein synthesis to promote muscle growth and recovery (Frank & Benington, 2006). Much of the sleep literature on performance has looked at how sleep loss impacts performance; however, minimal research has examined how extended sleep impacts performance. Also, patterns between RSI and sleep and agility and sleep have yet to be examined. This study examined the effects of a sleep extension on reactive strength and decision-making in agility tasks.

According to the RSI thresholds established by Flanagan (2016), the mean RSI values of the sample indicate a low level of reactive strength ability. RSI results show that changes in sleep behavior were accompanied by a 5% improvement in mean RSI for the sleep group (1.30 ± .48 to 1.36 ± .43) and an 8% decrease for the control group (1.40 ± .65 to 1.29 ± .38) from pre intervention to post intervention testing. Albeit non-significant, these findings merit a closer look. Previous studies using the RSI-DJ as a measure of fatigue found significant differences (12%) between pre and post-match RSI values after playing a full match in elite youth soccer players (Hamilton, 2009).

RSI scores exhibited no significant interaction effect between groups after the intervention; however, a pattern begins to emerge. It was hypothesized that the sleep extension group would increase or maintain RSI scores, whereas the control group would maintain RSI scores based on the role sleep has on nervous system regeneration and protein synthesis (Frank & Benington, 2006). Reactive strength is the efficiency with which one uses the fast SSC (Schmidtbleicher, 1992). Thus, RSI is one's ability to use the fast SSC and RSI is used to quantify reactive strength capabilities (Flanagan & Comyns, 2008).

The stretch-shortening cycle is a combination of neural, mechanical, and structural components and they are all interconnected (Nicol, Avela & Komi, 2006). Two important characteristics in SSC performance are: (1) muscle pre-activation and, (2) the braking and the reversing of stretch in the muscle (Nicol, Avena & Komi, 2006). The central nervous system (CNS) is responsible for the preactivation of muscle fibers preparing for action and is responsible for the braking force in the eccentric phase of the SSC (Regueme et al., 2007). The nervous system alters the stretch reflex at the muscle-tendon complex and when peripheral receptors recognize fatigued or damaged muscles, the nervous system inhibits maximal muscle contraction to prevent the muscle from injury or further damage (Gandevia, 2001). SSC fatigue is an interaction between decreased muscular function and deterioration of the nervous system (Nicol, Avela & Komi, 2006). In SSC fatigue, a dramatic drop in force and power production occurs due to the changes at the muscle-tendon complex and decreased muscle activation. During time of sleep deprivation or restriction, the body is not allowing for protein synthesis and recuperation of the nervous system (Frank & Benington, 2006). If the nervous and muscular system cannot properly regenerate, fatigue will reside and performance of the SSC may deteriorate. The RSI-DJ test has been used as a tool to measure neuromuscular fatigue and SSC in youth soccer athletes (Hamilton, 2009).

In the current study, the extended sleep group began to see an improvement in RSI scores after the two-week extension increasing by 5%. Although the results were insignificant, the literature on the role of sleep on recovery and the relationship between factors of the SSC support that increasing the quantity of sleep would maintain or potentially improve SSC performance. The relationship of increased sleep and improved SSC function is supported by Mah et al. (2011), where they found a significant improvement (4%) in sprint performance times over the course of the sleep extension period.

Previous research that has examined the effects of sleep on cognitive performance has shown positive results. Mah et al. (2011) found a significant improvement in reaction time in psychomotor vigilance tasks (PVT) after extending habitual sleep up to ten hours per night. The authors reported improvements (12%) in reaction time after the sleep extension period. Other research suggests that supplementing a night of sleep with a thirty-minute mid-day nap positively impacts reaction time in PVT (Waterhouse et al., 2007). Although no previous research has examined the effect of sleep on the cognitive function during agility task performance, it was hypothesized that the sleep extension group would exhibit improved times relative to the control group.

Faster decision-making times were found in the sleep (6%) and control (5%) groups from pre- to post-intervention. With both groups improving in decision-making times over the experimental period, the improvements are attributed to a learning effect of the reactive agility test. Similarly to RSI, lack of sleep would be believed to demonstrate slower times in COD and agility performance due to the utilization of the SSC in COD and agility tasks to plant and absorb and to push-off (Young et al., 2001). However, based on the improvements in times of the current study, it is possible that the participants became better at the RAT masking any effects the sleep extension had on decision-making in agility tasks.

Sleep is recognized as an important element of recovery by coaches and athletes (Venter, 2014) and evidence supports that athletes need more sleep than sedentary counterparts (Bird, 2013). However, in a study with over 800 South African athletes, almost 75% reported sleeping less than eight hours a night (Venter, 2014). The current study examined the effects of extending sleep on performance measures. Although there was a significant increase in sleep quantity in the sleep extension group, no significant changes in RSI-DJ and decision making scores were observed after the two-week experimental period. Duration is one component of sleep, but the quality of sleep has been increasingly recognized as the key element to recovery, and overall well-being (Bird, 2013). Good sleep hygiene is effective in improving sleep quality (Bird, 2013). The current study asked the participants to focus on the duration of sleep specifically. Sleep quality was measured using the ESS questionnaire, which has been shown as a valid measure of daytime sleepiness—a direct characteristic of sleep quality (Bird, 2013). ESS scores were reported after the first night of the experimental period, the midway point and after the last night of the sleep extension. A pattern was observed (Figure 8) in which the sleep extension group began to have a drop in ESS scores indicating lower levels of daytime sleepiness suggesting a connection between sleep duration and quality. A major factor in sleep quality is maintaining a regular sleep schedule (Bird, 2013). Belenky et al. (2002) examined the effects of sleep restriction over the course of a week on cognitive performance. Results showed an initial decrease in performance when sleep was restricted from habitual patterns; however, they found that after a few days performance leveled off and remained steady for the remainder of the study's intervention period. The results demonstrated how the body learns to adjust to a change in sleep habits and the importance consistency has on cognitive performance (Belenky et al., 2002). The authors also noted that a sleep debt could not be attenuated by sleeping longer after consistent sleep loss, reinforcing the importance of a regular sleep schedule (Belenky et al., 2002). The current study examined the effects of extending sleep on performance; however, the consistency of sleep was not required, which could have significantly impacted the outcome of the performance variables.

A few limitations exist within this study. First, a very small sample was collected for the study. In the sleep group, the current study found similar percent changes in fast SSC performance in RSI-DJ trials (5%) compared to mean sprint times (4%) in a similar sleep extension study (Mah et al., 2011). Mah et al. (2011) had 11 participants receive the sleep extension compared to seven participants receiving the sleep extension in the current study. If the study were to be replicated, it would be recommended to use a larger sample size so more generalizable assumptions could be made and potentially see significant effects of the sleep extension. Also, the experimental period may have been too short to see significant changes in performance measures. Mah et al. (2011) used a five to seven-week extension period where the current study used a two-week experimental period. Another limitation is that a learning effect may have masked any changes in cognitive function times between the RA and COD tests. Attempts were made to reduce the chances of a learning effect by having a familiarization and two baseline testing time points prior to experimental testing; however, that may not have been enough. Another cognitive performance measure could have been paired with the cognitive function tasks to examine for patterns in various aspects of cognitive performance. A fourth limitation is the lack of objectivity in measuring sleep. To measure sleep, a paper sleep diary was paired with the cell phone application SleepBot. Strong adherence has been observed in intervention studies when paper diaries are paired with cell phone applications (Ong & Gillespie, 2016); however, the cell phone application still has subjectivity.

Practical Applications

Sleep plays an important role in recovery; however, sleep is sacrificed in student-athletes due to timing of training sessions or due to mental stress of pre-competition anxiety or exams. With the role sleep has on nervous system regeneration and protein synthesis for muscle growth and recovery, losing sleep could result in a decreased preparedness to train or compete leading to a decline in performance. Student-athletes need to be aware of their sleeping habits as their performance may be suffering due the role of sleep on recovery. It is encouraged for student-athletes to obtain more sleep especially during times of high volumes of training.

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APPENDIX A

Department of Exercise and Sport Sciences

Recruitment E-mail / Poster

The effects of a sleep extension on reactive strength and decision-making abilities in agility tasks.

- Are you a trained and competitive varsity athlete aged 18 – 24?
- Are you currently in your off-season training cycle and cleared to participate by IC sports medicine?
- Are you interested in having your lower body power output measured?

We are conducting a study that aims to examine the effects of a sleep extension on various aspects of athletic performance. If interested in participating or would like more information, contact Mr. Michael Wenger (mwenger@ithaca.edu or 717 645 8309).

This study has been approved by the Institutional Review Board (IRB) of Ithaca College (IRB 1217-01). If you have any concerns about this study and wish to contact someone independent, you may contact the IRB at:
Tel: (607) 274 3113 Email: irb@ithaca.edu

APPENDIX B

Department of Exercise and Sport Sciences

Informed Consent Form

Project Title: The effects of a sleep extension on reactive strength and decision-making skills in agility tasks.

1) Purpose of the study?

Performance is a combination of physical and cognitive attributes. Sleep plays a role in the recovery of the body's functions. Little is known on the impact of extending sleep on performance and no research has examined the effects of sleep on explosive and agility tasks. This study aims to examine the effects of a two-hour sleep extension on explosive qualities and decision-making abilities in athletes.

2) Benefits of the study?

Participant Benefits: As a participant in this study, you will have the potential to learn useful knowledge on the effects of additive sleep on athletic performance. With the results of the study, you will be able to implement personal strategies to improve sleep habits to improve readiness and performance.

Researcher Benefits: Following project completion, the investigator will submit a manuscript for grading to fulfill Master's Graduation requirements. In addition, data will be presented to scientific and coaching communities in the form of journal articles and / or conference presentations. Members of the research team will also improve their scientific research experience.

Scientific Community Benefits: On publication of our research findings it is expected that the data collected will enhance our knowledge in the field by identifying effective ways to measure athletes readiness for training / competition.

3) What are you asked to do?

In agreeing to participate, you will be asked to attend the Ithaca College the Biomechanics labs (CHS 308) at five time-points (familiarization, baseline 1 & 2, pre-experimental, post-experimental) to undergo testing. After baseline testing, you will be randomly assigned to either a control or experimental group. The control group will continue their regular sleeping habits whereas, the experimental group will be receiving a sleep extension of two hours per night for the two week experimental period. Each testing session will take place at the same time of day.

3) What are you asked to do?

In agreeing to participate, you will be asked to attend the Ithaca College the Biomechanics labs (CHS 308) at five time-points (familiarization, baseline 1 & 2, pre-experimental, post-experimental) to undergo testing. After baseline testing, you will be randomly assigned to either a control or experimental group. The control group will continue their regular sleeping habits whereas, the experimental group will be receiving a sleep extension of two hours per night for the two week experimental period. Each testing session will take place at the same time of day.

Familiarization Testing:

Testing procedures completed here are designed to familiarize you with all future testing procedures (detailed within this section). This session will give you the opportunity to ask any questions you may have and to become comfortable with the testing environment. Data collected during these procedures will not be included in analysis. Procedures will last approximately 95 minutes.

Sleep Monitoring

Daily Sleep Diary: The daily sleep diary will require you to track when you go to sleep, when you wake in the morning, list any supplements taken, and Epworth Sleepiness Scale Score each morning. A daily log for each day will be provided.

Epworth Sleepiness Scale (ESS) Questionnaire: This questionnaire requires you to answer a series of eight questions on your likeliness to fall asleep in noted scenarios. You will be required to answer the questionnaire thirty minutes upon waking.

SleepBot Application: You will be given a username and password for the free cell phone application SleepBot to objectively measure how much sleep and how well you sleep each night.

- You will be required to log into the application each night and ‘punch in’ saying you are going to bed.
- You will place your cell phone beside you while you sleep to track motion while asleep.
- Upon rising, you will ‘punch out’ of the application saying you’re awake for the day

Performance Testing

Reactive Strength Testing: These tests require you to complete a series of maximum effort vertical jumps. Therefore, on arriving at the Biomechanics lab (CHS 308) you will be requested to complete a five-minute dynamic warm-up followed by;

- Three-repetitions of a drop jump from four different heights (15, 30, 45 or 60 cm) onto a force plate, with hands on hips. You will step from the random box heights and jump as high as possible while spending the least amount of time in contact with the ground. One minute and thirty seconds rest will be given between repetitions. (Familiarization and Baseline Testing)

- Three-repetitions of a drop jump from your individualized optimal box height onto a force plate, with hands on hips. You will step from the random box heights and jump as high as possible while spending the least amount of time in contact with the ground. One minute and thirty seconds rest will be given between repetitions. (Pre- and Post-Experimental Testing).

Change of Direction Testing: This test requires you to complete a series of maximum effort preplanned changes of direction.

- Four to six repetitions of a preplanned change of direction test will be performed at each laboratory session. One minute and thirty seconds rest will be given between repetitions.
- You will be required to run forward towards a cone where you will then change direction and run towards the predetermined side.

Reactive Agility Testing: This test require you to complete a series of maximum effort change of direction tasks where you will have to correctly respond to an external stimuli.

- You will be required to run forward toward a cone where you will observe an external stimulus; you will respond as quickly as possible and run to the correct side.
- You will perform four to six repetitions of the reactive agility test and will receive one minute and thirty seconds rest between repetitions.

What is the total time commitment associated with participating in this study?

The total time commitment associated with participation in this study will be a maximum of 5.75 hours spread out across five laboratory sessions as follows:

Test Type	**Test Duration (mins)**			
	RSI-DJ	*COD*	*RAT*	*Total Time*
Familiarization Session	35	30	30	95
Baseline 1 Session	30	20	20	70
Baseline 2 Session	30	20	20	70
Pre-Experimental Session	15	20	20	55
Post-Experimental Session	15	20	20	55
Total Participation Time	5.75 hours			

4) Risks?

There is minimal risk of injury to your lower limbs during testing and training. Risks will be reduced as you will be familiarized with all testing equipment and protocols before testing. Prior to jump testing, you will also be instructed on correct technique by an accredited instructor. Your technical performance will also be monitored carefully throughout testing.

5) Compensation for Injury?

If you suffer an injury that requires any treatment or hospitalization as a direct result of this study, the cost for such care will be charged to you. If you have insurance, you may bill your insurance company. You will be responsible to pay all costs not covered by your insurance. Ithaca College will not pay for any care, lost wages, or provide other financial compensation.

6) If you would like more information about the study.

If you would like more information about the study feel free to contact the principal investigator Mr. Michael Wenger: **Email:** mwenger@ithaca.edu.

Phone: 717 645 8309.

7) Withdrawal from the study.

You are not obliged to take part in this study. Also, please be assured that as the participant, you reserve the right to withdraw from the study at any stage (without explanation) and completely without prejudice towards you.

8) How will the data be maintained in confidence?

Please be assured that all recorded information will be treated with the strictest confidence and will not be disclosed to any party other than the investigator, supervisor or yourself (if desired). Your results will also remain completely anonymous at all times and will be stored on the investigators password protected personal computer. Data on the computers will be coded by participant number. Only members of the research team will have access to the names associated with the code, and the code will be kept separate from data files in a locked filing cabinet (CHS 303A) Data files will be kept for at least 5 years.

I have read the above and I understand its contents. I agree to participate in the study. I acknowledge that I am 18 years of age or older.

Participant's Name (Please print): ....

Participant's Signature: .... **Date:** ..../......../.............

Investigator's Signature: .... **Date:** ..../......../.............

This study has been approved by the Institutional Review Board (IRB) of Ithaca College (IRB 1217-01b). If you have any concerns about this study and wish to contact someone independent, you may contact the IRB at:

Tel: (607) 274 3113 email: irb@ithaca.edu

APPENDIX C

Department of Exercise and Sport Sciences

Health Screening Questionnaire

As you agreed to participate in this study, you are required to complete the following questionnaire. Please be assured that any information contained herein will remain completely confidential. Your cooperation in this is greatly appreciated.

Participant's Name: ……………………………………… ***Date of Birth:*** …………………………….

 # Weekly Training Sessions: ……………………………… **Age:** …………………………………………..

Demographic Details:				
	Baseline 1	**Baseline 2**	**Pre-Experimental**	**Post-Experimental**
Height:				
Weight:				

Persons to contact in case of emergency:

Name: …………………………………………………………***Phone Number:*** ………………………………..

Are you currently cleared by the IC Sports Medicine professionals (AT/doctors) to fully participate in athletics? Yes ☐ No☐

If 'no' please give details:

………

………

………

Even if cleared*, do you have any current injury or condition that may influence your performance on the experimental tasks?* Yes ☐ No ☐

If yes please provide details of:

- Type of injury; …………………………………………………………………………
- How it occurred; ………………………………………………………………………..
- When it occurred; ……………………………………………………………………..

Could these injuries prevent / limit your performance in the forthcoming exercise testing?

Yes ☐ No ☐

I ……………………………………………….. declare that the above information is correct at the time of completing this questionnaire **Date** ……../……../………

Participant's signature ………………………………….. **Date** ……../……../………

Investigator's signature ……………………………….. **Date** ……../……../………

Please Note: If your health changes so that you can then answer YES to any of the above questions, please inform the experimenter / laboratory supervisor. You should also consult with your doctor regarding the level of physical activity you can conduct.

This study has been approved by the Institutional Review Board (IRB) of Ithaca College (IRB 1217-01b). If you have any concerns about this study and wish to contact someone independent, you may contact the IRB at: Tel: (607) 274 3113 Email: irb@ithaca.edu

APPENDIX D

Sleep Diary

Date: _____________ # of Hours Slept: ____________

Time in Bed: ___________(am/pm) Time out of Bed: ___________ (am/pm)

Epworth Sleepiness Scale Score: ______________

Supplements (cups of coffee, melatonin, Nyquil, etc.): ______________________________

____.

Epworth Sleepiness Scale

How likely are you to doze off or fall asleep in the following situations?
Answer considering how you have felt over the past week or so.

0 = Would never doze
1 = Slight chance of dozing
2 = Moderate chance of dozing
3 = High chance of dozing

1. Sitting and reading	
2. Watching TV	
3. Sitting inactive in a public place (e.g., theater or meeting)	
4. As a passenger in a car for an hour without a break	
5. Lying down to rest in the afternoon when able	
6. Sitting and talking to someone	
7. Sitting quietly after a lunch without alcohol	
8. In a car while stopped for a few minutes in traffic	