Spring 5-7-2022

The Impact of Sleep on Athletic Performance: A Review of the Literature

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THE IMPACT OF SLEEP ON ATHLETIC PERFORMANCE:

A REVIEW OF THE LITERATURE

by

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A Thesis Submitted in Partial Fulfillment
Of the Requirements for the
University Honors Program

Division of Kinesiology and Sport Management
School of Education
The University of South Dakota
May 2022

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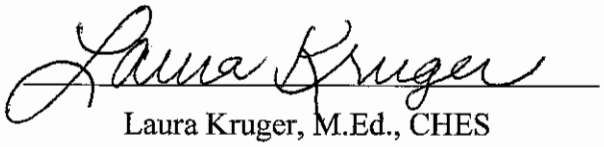

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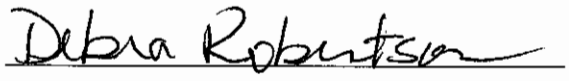

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ABSTRACT

The Impact of Sleep on Athletic Performance: A Review of the Literature

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This paper reviewed the literature regarding sleep and athletic performance, specifically identifying the problem of sleep debt in student athletes, the effects of sleep debt, and what factors negatively influence sleep, along with how to improve sleep. The literature revealed that it is common for athletes to not get adequate sleep. Sleep debt can have psychomotor and physiological effects on the body, which decreases optimal athletic performance. The many factors that negatively impact sleep include high intensity training sessions, travel, sleep disturbances, caffeine and/or alcohol consumption, and pre-competition anxiety. Recommendations for athletes that are struggling to achieve adequate sleep include, but are not limited to; ingestion of melatonin at night to help with sleep onset, removal of electronic device to improve total sleep duration, avoiding caffeine ingestion caffeine after 5:00PM, participating in mental skills training to prepare for competition and cope with pre-competition anxiety, avoid alcohol after heavy load days, try to achieve the recommended hours of sleep per the NSF guidelines, and use opportunities for sleep extension.

Keywords: sleep, sleep debt, student athletes, sports performance, recovery

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The strength and conditioning field is always progressing to enhance optimal performance in athletes, but there may be a vital component to maximizing performance that is commonly overlooked. Sleep is vital for recovery and optimal performance in athletes (Rae, 2017). The problem is that many athletes are not achieving the recommended amount of sleep per the National Sleep Foundation (NSF) guidelines, which negatively impacts recovery and performance (Burke, 2020; Patel, 2020). A 2015 report found that almost a third of student athletes reported sleep difficulties (Riegler et al., 2021). Without enough sleep and subsequent recovery, athletes will not be able to perform to the best of their abilities. Poor sleep quality and quantity can lead to decreased psychomotor vigilance, reaction times, fine motor skills, time to exhaustion, and ability to recover (Knufinke et al., 2018; Mah et al., 2011; Dattilo et al., 2020; Rae et al., 2017). To demonstrate how important sleep can be, Mah et al. (2011) showed that extended time in bed (TIB) was associated with improved performance outcomes in shooting accuracy, sprint times, and psychomotor vigilance. A case study of NBA Star, Andre Iguadala, showed significant improvements in performance outcomes on the court when achieving eight or more hours of sleep compared to less than eight hours of sleep (Burger, 2016). Eight hours of sleep per night meets NSF guidelines for adults (Hirshkowits et al., 2015). Due to the importance of sleep on recovery and performance, there are recommendations for athletes that are not achieving proper sleep quality and quantity (Dattilo et al., 2020). Recommendations include minimizing screen time at the end of the night, ingesting melatonin at bedtime, avoiding alcohol during key restorative periods, avoiding caffeine consumption after 5:00PM, and doing Mental Skills Training

to combat pre-competition anxiety (Jones et al., 2018,2021; Cheikh et al., 2018; Drake et al., 2013; Lastella et al., 2014,2015). Based on this information, the purpose of this literature review is to identify the problem of sleep debt in athletes, the effects of sleep debt, explore factors that negatively impact sleep, and determine how to improve sleep.

Sleep Patterns and Recommendations

The NSF recommends 8-10 hours of sleep for teenagers and 7-9 hours of sleep for young adults and adults (Hirshkowits et al., 2015). It could be hypothesized that athletes may need more sleep than the average person due to the increased physical and mental demands placed upon them in training sessions and during competition. Sleep has an essential role in human health and is vital for physiological and cognitive wellbeing (Simpson et al., 2016). Unfortunately, sleep debt seems to be fairly common among adolescents and college students. Sleep debt is the cumulative hours of sleep that one is not getting and is also referred to as sleep deficit. Patel et al. (2020) found that adolescents' average total sleep time was 6.2 hours. This is nearly 2 hours short of the NSF recommendations. Patel et al. (2020) stated that due to increased demands put on student athletes to perform well in academic and athletic pursuits, it is relatively easy for them to sacrifice sleep in order to dedicate more time to academics, sports, or other pursuits. This can be counterproductive because it can lead to an accumulation of sleep debt. While Patel et al. (2020) studied adolescents, similar sleep habits can be found in college students and college athletes.

College athletes face several problems when trying to achieve sufficient sleep, such as practices, training sessions, travel, and academics. Burke et al. (2020) assessed sleep in college football athletes by examining sleep patterns before the competitive

season and assessing subjective sleep metrics such as quality of sleep, daytime sleepiness, insomnia severity, sleep apnea risk, and circadian preference. Burke et al. (2020) found that of the 94 men included in the study, the subjective data indicated that most athletes have good sleep quality. When Burke et al. (2020) compared the subjective data to the objective sleep measures, it was discovered that the mean sleep duration collected during the season was only 6 hours, which is approximately 1 hour less than the 7-9 hours recommended by the NSF. This makes it plausible that most athletes on college football teams are not be getting sufficient sleep. Furthermore, it can be presumed that subjective measures of sleep may not be indicative of actual sleep quality. Therefore, despite reporting good quality sleep, none of the athletes met the recommendations. Conversely, a 2015 study found that almost a third of collegiate student athletes reported sleep difficulties and over 50% of student athletes reported that these sleep problems affected their academic performance, or per se, their psychomotor vigilance (Riegler et al., 2021). It is clear that athletes are putting themselves into sleep debt and experiencing the multitude of effects that sleep debt may have on the playing field and in the classroom.

The human response to stress is largely regulated by the autonomic nervous system (ANS) and can be observed easily by measuring beat-to-beat variations in resting heart rates, also known as heart rate variability (HRV) (Mishica et al., 2021). Decreased HRV is unfavorable. Commonly, cortisol is a hormone that is used as measure of overtraining and stress. Extended periods of increased or decreased levels of cortisol have a negative impact on health, therefore affecting athletic performance. Mishica et al.'s (2021) study was designed to characterize the relationships between HRV, salivary levels of cortisol, sleep duration, and blood lactate levels during submaximal running tests

(SRT) in young athletes during their training and competitive seasons. This study showed that cortisol and HRV have a negative relationship in young endurance athletes, where as an increase in cortisol yields a decrease in HRV (Mishica et al., 2021). Additionally, the positive correlation between changes in sleep and nocturnal HRV observed during the competition period indicates that individuals who obtained more sleep may have also had enhanced recovery (Mishica et al., 2021).

It appeared though, that pre-competition stress affected salivary cortisol levels the most, indicating that competition may alter the physiology of stress-related hormones (Mishica et al., 2021). This concurs with the findings of Lastella et al. (2014, 2015) that pre-competition stress can have a major impact on athletes and their sleep. In addition to this, a decrease in sleep quality and duration has been associated with increased cortisol levels (Spiegel et al., 1999). Also, when the subjects were focused on training, changes in sleep duration showed a negative relationship with the intense training group and cortisol, suggesting that a decrease in sleep may be associated with an increased amount of weekly strain (Mishica et al., 2021). The findings from this study showed that an increase in physical training in week 5, followed by competition stress in week 6, may have resulted in a delayed fatiguing effect that was displayed in week 7 (Mishica et al., 2021). This information is important to know, especially for strength and conditioning coaches determining who are creating training programs for their athletes. A delayed fatiguing effect can cause decreases in performance if not addressed correctly. This is highly applicable in a situation in which numerous games are played within one week withi minimal recovery time. If a coach wants their athletes to perform optimally, overtraining should be avoided.

Effects of Sleep Debt

Burke et al. (2020) and Patel et al. (2020) both concluded that the athletes in their respective age groups each failed to achieve the amount of sleep recommended by the NSF, putting them at risk of sleep debt. Sleep debt is the accumulated loss of sleep over multiple nights. One night of sleep debt could be total sleep deprivation, meaning no sleep in one night, or it could be the loss of .5hr in one night. Mainly, it is the amount of sleep not achieved under the NSF sleep recommendations. However, while .5hr of sleep debt on one night may seem insignificant, it is the accumulation of sleep debt over multiple nights that can have a detrimental impact on performance. Even while knowing that sleep is important for performance in general, athletes are commonly facing problems to achieve the correct quantity and quality of sleep (Knufinke et al., 2018; Burke et al., 2020; Patel et al., 2020). The physiological processes that occur during sleep are a fundamental aspect of an athlete's recovery and subsequent ability to train and compete at maximal capacity (Mishica et al., 2021). It has been shown that sleep loss may negatively impact athletic performance by decreasing alertness, fine motor skills, hand-eye coordination, reaction time, decision making, and overall recovery (Fullagar et al., 2015; Mah et al., 2011; Knufinke et al., 2018). Neurocognitive consequences of sleep deprivation include decreased attention, executive functioning, psychomotor speed, psychomotor vigilance, and working memory (Riegler et al., 2021). Furthermore, healthy individuals reporting sleep debt had worse performance on tasks including visual memory, reaction time, and visual motor speed compared to individuals getting adequate amounts of sleep (Riegler et al., 2021).

Knufinke et al. (2018) aimed to investigate whether natural variations in sleep quality between days are reflected in the performance of elite athletes. Sleep is known to be critical in the restoration of metabolic processes and regulation of hormone secretions (Skein et al., 2011; Takahashi et al., 1981; Weitzman et al., 1976; Mishica et al., 2021). Research indicates that a reduction in sleep quality or sleep debt causes altered metabolic and physiological function which can cause a decrease in athletic performance (Skein et al., 2011; Takahashi et al., 1981; Weitzman et al., 1974, 1976; Mishica et al., 2021). The natural variation of time spent in the specific sleep stages, rapid eye movement (REM) or deep sleep, may be indicative of next day athletic performance. Specifically, human growth hormone and cortisol are important hormones involved in the recovery process that can be influenced by sleep patterns (Skein et al., 2011). REM sleep is important for brain processing and growth of new healthy cells and tissues (Shapiro et al., 1981). The deep sleep stage has been associated with the release of growth hormone, which contributes to muscle recovery (Shapiro et al., 1981). Growth hormone is an important regulator of protein synthesis, and its secretion follows a circadian rhythm (Takahashi et al., 1981). In fact, the highest concentrations of growth hormone are observed during deep sleep. The secretion of growth hormone increases at night during slow wave sleep and is dependent on sleep onset (Takahashi et al., 1981; Weitzman et al., 1976; Weitzman et al., 1974). Additionally, human growth hormone is important for muscle recovery and growth. Takahashi et al. (1981) showed that growth hormone secretions are diminished when sleep is deprived. Thus, athletes that are not getting sufficient sleep will have diminished growth hormone secretions at night, therefore having impaired growth and recovery. Furthermore, Dattilo et al. (2020) investigated more thoroughly the effects of

sleep deprivation on acute skeletal muscle recovery after exercise. It has been shown that only one night of partial sleep deprivation impairs recovery from a single exercise session (Rae et al. 2017). Skein et al. (2011) showed through intermittent-sprint performance that simulated team sport performance can be decreased due to a lack of sleep and insufficient recovery, which is due to diminished growth hormone secretions (Takahashi et al., 1981; Weitzman et al., 1976; Weitzman et al., 1974). Dattilo et al. (2020) concurs that hormones may contribute to the effects that sleep debt has, especially after skeletal muscle is stimulated in a way that results in damage. In both rats and humans, sleep debt is associated with an increase in catabolic hormones and a reduction in anabolic hormones, which could make one think that partial or complete sleep deprivation could, in some way, disrupt skeletal muscle homeostasis and affect its recovery and/or adaptation after exercise (Dattilo et al., 2020).

The catabolic hormone cortisol shows increased levels present during extended periods of wakefulness which can cause glycogen depletions, which may have been the reason for participants having a reduction in muscle glycogen (Skein et al., 2011). This implies that athletes who participate in team sports that involve bursts of intermittent sprinting can have decreased performance due to insufficient sleep, even if they are meeting nutritional goals. Dattilo et al. (2020) found that there were increased cortisol levels associated with the sleep deprivation protocol group. Furthermore, increased cortisol levels increase the cortisol/testosterone ratio, which is widely associated with impairment in physical recovery and physical performance (Dattilo et al., 2020). If these increases of cortisol were observed in chronically sleep restricted individuals, it is plausible to expect that muscle physiology was altered, hampering exercise-induced

muscular adaptations (i.e., muscle hypertrophy) (Dattilo et al., 2020). It seems that there is a connection between the findings of Dattilo et al. (2020) and Skein et al. (2011). Increased cortisol levels, from insufficient sleep, can decrease optimal performance because cortisol is a glucocorticoid. Glucocorticoids mobilize energy reserves, and skeletal muscle serves as a major body store of amino acids and protein, and cortisol will catabolize skeletal muscle tissue, thus breaking down muscle and hypothetically could dampen the cortisol awakening response, meaning less energy for training in the morning. Chronic sleep debt could then cause non-optimal muscle recovery because of chronically increased cortisol due to the lack of sleep. Insufficient sleep causes a decrease in optimal athletic performance. This is important for athletes and strength coaches to know, so that athletic performance can be optimized with sufficient recovery. However, this must be further investigated. The kinetics of hormones following sleep restriction/sleep debt during the recovery period need to be further investigated, because of the widespread debt of sleep in student athletes today (Patel et al., 2020; Burke et al., 2020; Riegler et al., 2021).

Roberts et al. (2019) showed that sleep is important for endurance performance after discovering that total sleep deprivation showed a 10% decrease in self-paced endurance performance compared to regular times under normal sleep conditions. Mishica et al. (2021) showed the effects training can have on the hormonal profile of young endurance athletes and that extended sleep may be beneficial for recovery. Skein et al. (2011) found that sleep deprivation showed significant differences between the control group and the sleep deprivation groups. The sleep deprived participants' performance decreased on multiple tests including intermittent-sprinting and double-

legged bounding distance. Additionally, Dattilo (2020) found that there were increased cortisol levels associated with sleep deprivation.

In addition to hormonal disruptions, sleep debt can impact motor function as well. Knufinke et al. (2018) explained that athletic performance can be divided into fine motor skills and gross motor skills. Fine motor skills incorporate the use of smaller muscle fibers to coordinate precise movements and hand-eye coordination (Knufinke et al. 2018). Gross motor skills are used for whole body movements that incorporate large muscle groups (Knufinke et al., 2018). With fine motor skills requiring more cognition, it was proposed by Knufinke et al. (2018) that fine motor skills are more affected by sleep debt than gross motor skills. In the same study, Knufinke et al. (2018) found a negative association between reaction time and overall sleep. The athletes' mean reaction time increased or decreased by 5 milliseconds for every 60 minutes of sleep they gained or lost, respectively (Knufinke et al., 2018). While 5ms may seem insignificant, reaction time is critical to performing at a high level and preventing injury.

Similarly, Patel et al. (2020) investigated the impact of sleep debt on different aspects of cognitive performance, memory processing and neurobehavioral functioning. To investigate these aspects of cognitive performance, Patel et al. (2020) looked at fluid cognition and episodic memory. The fluid cognition tests assess one's ability to learn and respond to novel stimuli and task requirements. In a sports setting, the level of stimuli can be greatly increased, and task requirements may be more than novel. Sport performances require great attention to detail, are highly stimulating, and involve very difficult tasks. Lower total sleep time showed significantly lower scores in the fluid cognition tests, indicating that fluid cognition is a vital aspect of sport performance, especially on days of

competition (Patel et al., 2020) Patel et al. (2020) also looked at measurements on the Picture Sequence Memory Subset, which tests the episodic memory that stores events and experiences encoded in a time specific manner. Participants also scored lower on the Picture Sequence Memory Subset, which could have negative implications in training and playing (Patel et al., 2020).

To further support the impact sleep debt has on sport performance and cognitive function, Riegler et al. (2021) assessed athletes from a large Division I university who had previously participated in the sports concussion program from 2002-2018. Riegler et al. (2021) discovered that the effects of insufficient sleep at baseline concussion testing (before injury, often completed in the pre-season) made athletes appear similar to concussed athletes with sufficient sleep. The results from the study indicate that athletes who take a neurocognitive baseline assessment with insufficient sleep can underperform on the assessment (Riegler et al., 2021). This may skew any comparisons made post-concussion that affect return-to-play status. Athletes with skewed results taking a post-concussion test are at risk for re-injury of the brain and chronic traumatic encephalopathy, commonly referred to as CTE (Riegler et al., 2021). These findings indicate that there may be a need to consider sleep at baseline assessment, and furthermore, indications of insufficient sleep prior to baseline testing may call for assessment adjustments. Most importantly, when combined with the findings of Patel et al. (2020) and Burke et al. (2020), the number of athletes not achieving adequate sleep and going day to day, in a concussion-like-state, is a poor recipe for sport performance.

Factors that Negatively Impact Sleep

Now that the importance of sleep is clearly understood, the next step is to understand the factors that may negatively impact sleep. There are some factors that are obvious, such as having numerous academic and athletic commitments, high training load and volume, and pre-competition anxiety that can lead to poor sleep quality and quantity (Whitworth-Turner et al., 2019; Lastella et al., 2014, 2015). Other factors such as electronic device use, alcohol consumption, caffeine intake, time zone changes, and different sleep environments are also influential in the life of an athlete. (Jones et al., 2018, 2021; Dunican et al., 2017; Pavlovic et al., 2014; Whitworth-Turner et al., 2019; Lastella et al., 2014, 2015; Fowler et al., 2017; Sargent et al., 2014; Kölling et al., 2016). By identifying these common factors, athletes and coaches can implement strategies to combat them, improve sleep quality and quantity and enhance athletic performance.

Scheduling and Overtraining

First and foremost, demanding schedules and high training loads may certainly influence sleep. According to Whitworth-Turner et al. (2019), athletes commonly have a suboptimal sleeping pattern and certain disturbances to sufficient sleep can take place because of timing of competition, travel, changes in training environment, and scheduling of early morning training sessions. These suggested sleep disturbances suggest that sporting schedules are an important factor for sleep in athletes. Whitworth-Tuner et al. (2019) researched the habitual sleep patterns of youth soccer players, with the aim to investigate how the scheduling of youth soccer training and match load may influence sleep. Participants were 10 male soccer players around 18 years of age. The results from the study suggest that sleep quantity may be affected by the schedule of the day; game

day or training/practice day. Sleep duration was lower on the day after the match in comparison to the days preceding the match day (Whitworth-Turner et al., 2019). By understanding these findings, coaches may be able to adjust schedules to facilitate extended time for players to achieve sufficient sleep and avoid sleep debt, especially following matches (Whitworth-Turner et al., 2019).

Whitworth-Turner et al. (2019) also discovered that the volume of training and matches influence the sleep response. Small increases in sleep duration were noted when exposed to high-intensity loads (e.g., increased high-speed running distance), which may suggest the increased need for sleep after intense training sessions (Whitworth-Tuner et al., 2019). This is in congruence with the findings of Kölling et al. (2016), who also found an increased need for sleep during intense training in rowers. This information would also be beneficial for coaches, so that they can program accordingly to optimize performance.

Sleep/Wake Behavior

The pre-competition sleep/wake behavior and the relationship with subsequent performance is another factor that can affect sleep. Lastella et al. (2014, 2015) conducted research investigating "athletes' pre-competitive sleep behavior and its relationship with subsequent pre-competitive mood and performance" and "sleep/wake behavior of endurance cyclists before and during competition." Lastella et al. (2014) points out that the majority of sleep studies have used non-athletic populations and protocols of total sleep deprivation. Since there are many different terms used for sleep research, Lastella et al. (2014) operationalizes the term "disrupted sleep" to represent both periods in which sleep has been partially restricted and/or where sleep has been fragmented. This

definition is being utilized because disrupted sleep is a more common problem for athletes rather than sleep deprivation. Lastella et al. (2014) found that almost 70% of athletes reported having worse sleep on days of pre-competition compared to regular days. Combine these findings with the findings of Riegler et al. (2021), Patel et al. (2020), and Burke et al. (2020) which all indicate that a large percentage of athletes commonly do not achieve adequate amounts of sleep, leading to a sleep deprived athlete prior to competition.

Furthermore, 80% of athletes reported awakening at least once during the night before competition, and 70% reported awakening more than one time in the night (Lastella et al. 2014). Consequently, total sleep time was well below the recommended daily target of 8 hours (Lastella et al., 2014; Hirshkowitz et al., 2015). This in turn has negative consequences highlighted earlier. It was also important to find the reasons for such poor sleep quality on pre-competition nights and it was revealed that the three major reasons for disruption to participants' sleep were: anxiety, noise, and the need to use the bathroom. Twenty-one percent of the participants reported anxiety as the most common reason for sleep disruption (Lastella et al., 2014). It was also reported that athletes who experienced disrupted sleep on the night prior to competition woke up the morning of competition feeling more tense, fatigued, and less vigorous, which agrees with the findings of Skein et al. (2011) (Lastella et al., 2014).

The findings from the initial research of Lastella et al. (2014) indicates that athletes do suffer from pre-competition anxiety and it disrupts their sleep, leading them to feel less than optimal for performance, as Skein et al. (2011) also revealed. It is important for athletes to have sufficient and unfragmented sleep pre-competition. After the

conclusions were made in this study, Lastella et al. continued investigating pre-competition sleep/wake behavior in cyclists before and during competition.

Lastella et al. (2015) used wrist activity monitors as an objective form of sleep assessment and attempted to determine; (1) whether athletes slept poorly before and during competition and (2) whether sleep on the nights before and during competition were related to overall performance ranking. Twenty-one male endurance cyclists, with an average age of 20, volunteered to participate in this study. Length and quality of sleep was poorest the night of pre-competition (Lastella et al., 2015). Additionally, cyclists took more than half an hour to fall asleep, had 6.5 hr. of sleep, and reported the poorest sleep quality on the night before competition (Lastella et al., 2015). Sleep duration was almost an hour less on the night of pre-competition compared to regular sleep at baseline as well. Lastella et al. (2015) concluded that the cyclists in this sample confirmed anecdotes that athletes experience sleep disturbances before competition.

Electronic Device Use

Aside from sport-related factors, there are numerous other reasons why athletes have poor sleep quality. The increase in use of multiple electronic devices, such as smartphones, computers, and tablets, may present a challenge to sleep (Jones et al., 2021). As a common sleep hygiene strategy, the removal of electronic devices before bedtime is used (Jones et al., 2021). Surprisingly, Jones et al. (2021) found there were no correlations between removing electronic devices from netball players during training camp before bedtime to better subsequent sleep. Athletes that did not have their phones had earlier sleep onset time, however, there was no difference in the quality of sleep (Jones et al, 2021). Jones et al., (2018) did find that engaging in alert or stressful tasks

prior to bedtime (i.e., social media, games, or email) can cause an increased time to sleep onset, which decreases total sleep time and sleep efficiency.

Dunican et al., (2017) studied the impact of electronic device removal on sleep in elite judo athletes. Negative effects seem to be particularly common in adolescents, with one in 5 reporting nightly bedtime delay and increased time taken to fall asleep as a consequence of electronic media use (King et al., 2014). This concurs with the findings of Patel et al., (2020) in which adolescents were approximately 2 hours short of the NSF sleep guidelines. The data from this study supports the notion that an extended morning sleep opportunity may be necessary to increase sleep duration in young elite athletes (Dunican et al., 2017). This research also implies that it is not the device itself that may cause poor sleep, it is the extended use and accessibility of the device at bedtime that reduces total sleep time. There may be correlation to Patel et al., (2020) and Burke et al., (2020) finding an excessive sleep debt in student athletes, because device use could be seen as a method of relaxation, where instead it is simply keeping one from getting the necessary sleep. Dunican et al. (2017) and Jones et al. (2021,2018) have each concluded that electronic device use does not negatively impact subsequent ability to sleep. However, while these studies have concluded that electronic device use does not negatively impact sleep, the hidden truth here may be that electronic device use at night decreases total sleep time because of a pathological need to check social media before bedtime, which can turn 15 minutes of scrolling into an hour due to the algorithms in place in apps like TikTok, Snapchat, Facebook, and Instagram.

Alcohol Consumption

A challenge unique to college-aged athletes is the use of alcohol and other substances. Alcohol consumption is a common pastime that has detrimental effects on sleep, recovery, and performance. Celebrations after big events or games often include the consumption of alcohol. Pavlović and Đinđić (2014) investigated the influence of alcohol consumption on the quality and length of sleep of the first-year students of doctoral studies. Alcohol is one of the most widely used psychoactive substances because it is easy to produce, available, and quick to action (Pavlović and Đinđić, 2014). According to Pavlović and Đinđić (2014) people often think that one or two drinks can improve sleep quality because it will make them fall asleep easier, but the truth is quite the opposite. Alcohol consumption has many negative effects. At low to moderate doses, alcohol can have a stimulating effect that might lead to problems with falling asleep, usually during the first hour after its use (Pavlović and Đinđić, 2014). At high doses, alcohol has a sedating effect, but the sedative effect wears off quickly and is followed by sleep disruptions, especially during the second half of the night (Pavlović and Đinđić, 2014). During the first part of the sleep cycle, the body adjusts to the presence of alcohol in an effort to maintain a normal sleep pattern, but once alcohol has been eliminated from the body, however, certain physiological variables, such as REM-sleep patterns, change in the opposite direction (Pavlović and Đinđić, 2014). These changes result in sleep disruptions. The results obtained in this study indicate that alcohol consumption is associated with poor quality of sleep. Thus, athletes that consume alcohol are at risk for impaired sleep and recovery, thus, decreasing performance.

Caffeine

Caffeine consumption is popular among student athletes to improve performance and increase alertness (Ali et al., 2015). Caffeine is frequently used by athletes to enhance athletic performance and it has been reported that 74% of elite athletes may use caffeine as an aid prior to or during competition (Walsh et al., 1990). While it may be used to improve sport performance, caffeine can disrupt sleep (Myllymäki et al., 2011). Caffeine will prolong sleep latency, reduce total sleep time and sleep efficiency, and worsen the perceived quality of sleep (Ramos-Campos et al., 2019). Ramos-Campo et al. (2019) found that athletes reported significantly worse subjective sleep quality, calm sleep, ease of falling asleep, and not feeling refreshed after waking after caffeine ingestion in comparison to placebo. In addition, caffeine ingestion impaired the sleep quantity and quality (reducing sleep efficiency, increasing the number of awakenings, and increasing the actual wake time) in 800-m athletes as measured by actigraphy, a noninvasive method of monitoring human rest (Ramos-Campos et al., 2019).

Similarly, Drake et al. (2013) found that 400 mg of caffeine taken 0, 3, or even 6 hours prior to bedtime significantly disrupts sleep, and even at 6 hours before bedtime, caffeine reduced sleep by more than 1 hour. It was also found that caffeine-induced sleep disturbances were only objectively detected using actigraphy when caffeine was taken 6 hours prior to bedtime, which implies that there is a subjective lack of awareness of a caffeine induced sleep disturbance (Drake et al., 2013). This is an important finding because it shows that athletes may be unaware of the disrupted sleep they are experiencing due to caffeine ingestion during later periods of the day. The present results suggest the common practice of afternoon consumption of caffeine should at a minimum

be restricted to before 5:00PM, particularly regarding the moderate-large doses of caffeine commonly found in increasingly popular premium coffees and energy drinks (Drake et al., 2013).

In conclusion, there are multiple factors that can negatively impact sleep. Training loads, especially at high intensities, can have implications for psychological and physiological recovery during key restorative periods. Pre-competition anxiety is a major problem for athletes, leading to disrupted and fragmented sleep (Lastella et al., 2014;2015). Pre-competition anxiety led to longer sleep onset times and disrupted sleep with awakenings in the night, which then correlated with athletes feeling more tense and fatigued, and less vigorous on competition day (Lastella et al., 2014; 2015). Electronic device removal seems to have little effect on subsequent quality of sleep. However, it seems that electronic device use may decrease total sleep duration due to use late at night before bedtime (Jones et al., 2018; 2021). Furthermore, alcohol is commonly thought to aid in sleep onset. However, the opposite is the case, and alcohol consumption before bedtime leads to disturbances to REM sleep cycle, decreasing sufficient sleep (Pavlović and Đinđić, 2014). Finally, caffeine consumption after 5:00PM, at minimum, can disrupt and impair sleep (Drake et al., 2013; Ramos-Campos et al., 2019). These factors are not conducive for optimal athletic performance.

Suggestions for Improving Sleep

While it is apparent that many different aspects of a student athletes' life can negatively impact sleep, there are also many things that athletes can do to improve sleep. Giving athletes extended sleep opportunities may be one solution. Because of the many stressors put on athletes, proper recovery from high performance levels might be delayed

because of the accumulation of training stress and other non-training stressors (Meeusen et al., 2013). Kölling et al. (2016) examined data regarding objective and subjective sleep parameters as well as subjective ratings of recovery and stress during a four-week training camp of junior national rowers in preparation for the World Championships. Participants were 55 members of the Junior German National Rowing Team. The objective sleep data gathered indicated that sleep may have been less restful during the first half of the camp, in which training was more intense and the training load was increased compared to usual home training (Kölling et al., 2016). However, during the second half of the camp, fewer training sessions and more training-free afternoons allowed for more time for recovery, and consequently, the sleep duration and ratings of restfulness were higher in this interval (Kölling et al., 2016). This data implies that overtraining may result in disturbed sleep, which supports the findings of Hausswirth et al. (2014), who also found indicators of disturbed sleep during an overload training period and a return to baseline scores in the ensuing recovery period. Kölling et al. (2016) found that sleep log data and subjective ratings of the recovery and stress state revealed a negative influence of a reduced night, whereas an extended night resulted in positive effects. Additionally, Kölling et al. (2016) suggests that in anticipation of important events, such as competitions, a period of sleep extension might be a beneficial measure for optimized athletic performance.

Sleep extension and higher quality of sleep appear to be solutions to combatting sleep debt and its effects to performance. Supplementation and nutrition are often methods of combatting fatigue in athletes. Based on the evidence, a diet rich in vegetables has been found to have an optimal effect on physiological functions and it has

been shown that beetroot juice supplementation (BJS) improves performance in cycling, walking, and running (Pinna et al., 2014). Shamloo et al. (2019) concluded that there is a direct relationship between these two factors. Additionally, these results are consistent with Pinna, et al. (2014), who also reported that BJS improved the sleep cycles in athletes. According to the research presented by Shamloo et al. (2019) and Pinna, et al (2014), beetroot juice should be consumed by athletes to help improve their sleep and subsequently their performance. These results raise the possibility that taking BJS may be one component of improving the athletic performance in athletes via optimizing the sleep quality and physiological fatigue (Shamloo et al., 2019).

Melatonin supplementation may also be beneficial. Melatonin levels normally have a nocturnal increase, which is associated with sleep onset, but light exposure at bedtime can adversely affect the nocturnal increase in melatonin and increased electronic device use in the evenings may disrupt the natural circadian rhythm controlling sleep and melatonin release (Chellappa et al., 2011; Wyatt et al., 1999). Cheikh et al. (2018) investigated melatonin ingestion after exhaustive late-evening exercise and its effects on sleep quality, quantity, and short-term performances in teenage athletes. The purpose of the study conducted by Cheikh et al. (2018) was to explore the effects of a single dose of 10mg of melatonin after late-evening intensive exercise on sleep quality and quantity, cognitive performance, and short-term physical performances the following morning in healthy trained teenagers. Ten male adolescent national-level judo competitors volunteered to take part in the study. It was found that administering a single dose of melatonin-10mg after vigorous late-evening exercise could serve as a pharmacological solution that promotes increased sleep quality, cognitive performance, some short-term

physical performances, and state of wellness the following morning in teenage athletes (Cheikh et al., 2018). Additionally, regarding deep sleep and REM sleep, nocturnal melatonin-10mg administration resulted in higher sleep stage durations by 9.5% and 13.0%, compared with placebo (Cheikh et al., 2018). An increase in both Deep Sleep and REM sleep stages will result in higher quality sleep, which is good for growth and restorative processes, specifically the release of hormones that contribute to recovery such as growth hormone (Shapiro et al., 1981; Cheikh et al., 2018; Takahashi et al., 1981; Weitzman et al., 1976; 1974). Melatonin ingestion before bedtime may be a solution to athletes that have trouble with sleep onset at night.

Finally, application of mental skills training appears to be beneficial when implemented so that athletes' pre-competitive psychological and physiological states are conducive for peak performance. Realistic application of these findings would be making considerations for athletes to have psychological preparation in the form of mental skills training, to help cope with any problems that may arise. Mental skills training can be implemented by sports psychologists, or anyone else who is certified. Proper mental skills training in place prior to competition can promote increased pre-competitive sleep quality which appears to be key for the maintenance of pre-competitive psychological states conducive for optimal performance (Lastella et al., 2014).

Conclusion

This paper reviewed the literature regarding sleep and athletic performance, specifically identifying the problem of sleep debt in student athletes, the effects of sleep debt, and what factors negatively influence sleep, along with how to improve sleep. The literature revealed that athletes are very commonly not getting adequate sleep, per NSF

guidelines (Burke et al., 2020; Patel et al., 2020; Riegler et al., 2021). Sleep debt can have psychomotor and physiological effects on the body, which in turn decreases optimal athletic performance (Knufinke et al., 2018). The deep sleep stage has been associated with the release of the highest concentrations of growth hormone, which contributes to muscle growth and recovery, and it is an important regulator of protein synthesis (Takahashi et al., 1981) (Shapiro et al., 1981). Glucocorticoids, such as cortisol, mobilize energy reserves, and skeletal muscle serves as a major body store of amino acids and protein, in which cortisol will catabolize skeletal muscle tissue, thus breaking down muscle and hypothetically dampening the cortisol awakening response, meaning less energy for training in the morning. (Dattilo et al., 2020) (Skein et al., 2011) (Takahashi et al., 1981) (Weitzman et al.,1976). Chronic sleep debt could then cause non-optimal muscle recovery because of chronically increased cortisol due to the lack of sleep.

There are multiple factors that may impair quality sleep. Whitworth-Turner et al. (2019) found that the volume of training and matches influence the sleep response. Small increases in sleep duration were noted when exposed to high-intensity loads, which may suggest the increased need for sleep after intense training sessions (Whitworth-Tuner et al., 2019). Pre-competition anxiety is a major problem for athletes, leading to disrupted and fragmented sleep (Lastella et al., 2104, 2015). Pre-competition anxiety led to longer sleep onset times and disrupted sleep with awakenings in the night, which then correlated with athletes feeling more tense and fatigued, and less vigorous on competition day (Lastella et al., 2104, 2015). Electronic device removal seems to have little effect on subsequent quality of sleep (Jones et al., 2018, 2021). However, it seems that electronic device use may decrease total sleep duration due to use late at night before bedtime (King

et al., 2014; Jones et al., 2021). Alcohol consumption before bedtime leads to disturbances to REM sleep cycle and deep sleep, decreasing sufficient sleep (Pavlović and Đinđić, 2014). Caffeine ingestion can significantly impact quality sleep, especially if taken later in the day, and Ramos-Campo et al. (2019) found that athletes reported significantly worse subjective sleep quality, calm sleep, ease of falling asleep, and feeling refreshed after waking after caffeine ingestion.

Melatonin ingestion before bedtime may be a solution to athletes that have trouble with sleep onset at night (Cheikh et al., 2018). Melatonin ingestion can cause increases in both deep sleep and REM sleep stages will result in higher quality sleep, which is good for growth and restorative processes (Cheikh et al., 2018; Dattilo et al., 2020; Pavlović and Đinđić, 2014; Shapiro et al., 1981). The positive correlation between changes in sleep and nocturnal HRV observed during the competition period indicates that individuals who obtained more sleep may have also had an enhanced recovery (Mishica et al., 2021).

Recommendations for athletes that are struggling to achieve adequate sleep include, but are not limited to: Ingestion of melatonin at night to help with sleep onset, removal of electronic device to improve total sleep duration, avoid ingesting caffeine after 5:00PM/17:00, work on mental skills training to prepare for competition and be able to handle emotions that come with pre-competition, avoid alcohol after heavy load days, and try to achieve the recommended hours of sleep per the NSF, and use opportunities for sleep extension (Cheikh et al., 2018; Jones et al., 2018, 2021; Drake et al., 2013; Ramos-campos et al., 2019; Lastella et al., 2014, 2015; Pavlović and Đinđić, 2014; Kölling et al., 2016). These findings confirm (1) student athletes are not achieving proper amounts of

sleep for optimal recovery, (2) that sleep is significantly important to athletic performance and recovery. This research will help educate coaches and athletes on why sleep is important for recovery and optimal performance in different aspects of sports.

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