Examining the Relationship Between Sleep and Athletic Performance:
A Synthesis of the Research Literature

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Abstract

Sleep has been regarded in recent years as an important factor in the improvement of athletic performance. The distinction, however, between what is necessary for a normative population and what is optimal for an elite athlete population relative to both quality and quantity of sleep is not clear. Therefore, this synthesis reviewed literature concerning how sleep can impact performance, the areas of performance it most impacts and the methods of improving sleep for athletes, in order to aid their performance. Data was collected primarily using the sport-centered *SPORTDiscus* database through SUNY Brockport's Drake Memorial Library database, EBSCO. Key words were utilized in order to develop a critical mass of 10 articles used to answer the following five research questions: (a) Does the number of hours of sleep impact performance, (b) Does the quality of the amount of sleep obtained impact performance, (c) What physiological aspects of athletic performance does sleep most impact, (d) What cognitive aspects of athletic performance does sleep most impact, and (e) What are practical applications for athletes to improve their sleep habits? Results indicate that an increase in both number of hours and quality of sleep improve athletic performance. The area's most positively affected are health, avoiding injury and illness, increasing recovery, sports specific competitive advantages, reaction time, and mood while, surprisingly, anaerobic power was not significantly affected. Further research in the subject needs to increase the number of subjects, as well as create a consensus recommendation for the number of hours of sleep athletes need and the way that sleep quality is measured in order to generalize the findings.

Keywords: Sleep, athletic performance, quality, quantity, physiological aspects, cognitive aspects, practical applications, health, injury, illness, recovery, reaction time, mood, anaerobic power.

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Chapter 1

Introduction

It is often heard among high school and collegiate student-athletes, “I’m so tired.” The statement can be made at 7:00 a.m., 7:00 p.m. or anywhere in between. It is common-place and a consistent common ground for athletes to talk about in passing or at the lunch table, the extent that their exhaustion has affected their day. But how tired are they really? More importantly, regardless of “how tired they are,” how are they performing on the field? And, is there something to the fact that they, as both athlete and individuals, need more, or better quality rest?

Whether discussing technology, medicine, or economics, there is a constant search in today’s modern world to be as efficient as possible when it comes to optimization. The same came be said for the competitive athlete today. They are constantly searching for new ways to become bigger, faster, and stronger in order to perform their best. There is of course the performance enhancing drug option which has been well documented, as have been the negative side effects these drugs can create. As such, especially at the high school and collegiate levels, athletes, coaches, and trainers alike are searching for new and different ways to optimize. One area that has been closely examined in recent years is sleep and how it can affect athletic performance. It has been determined that better sleep, compared to other performance enhancing methods, has no negative side effects and can improve all aspects of life including mood (Andrade et al., 2019), immune system health (Hausswirth et al., 2014), and more.

Over the past decade, researchers have begun to examine how sleep is better able to improve athletic performance. What they have found is that there are two vital aspects of sleep that can significantly impact athletic performance: the hours of sleep and quality of sleep obtained, also known as sleep hygiene (O’Donnell & Driller, 2017). While there is a consensus recommendation that young adults should get eight to 10 hours of sleep per 24 hours (Paruthi et al., 2016), much less is known about the sleep habits (i.e. quality and quantity) that it takes to optimize performance in elite athletes (i.e. quality and quantity) (Leeder et al., 2012). For example, is there an optimal number of hours for athletes to get on a daily basis? Is it possible that quality of sleep can replace the number of hours? Furthermore, if athletes don't get either the proper hours or quality of sleep, what are some successful methods to improve their sleep habits, in order to perform their best?

There is potential that the improvement of sleep can impact not only the health and wellbeing of athletes but also impact physiological and cognitive aspects of performance. These performance benefits can aid athletes' competitive success. Understanding the benefit of proper sleep may prompt the athletics community to implement strategies and plans to aid in obtaining better quality and hours of sleep, not only for themselves, but for their programs, teams, and teammates. This review of the literature, then, is significant due to the fact that it looks to examine this specific phenomenon.

Purpose Statement

The overall purpose of this synthesis is to examine the relationship between sleep and athletic performance.

Research Questions

1. Does the number of hours of sleep impact performance?
2. Does the quality of the amount of sleep obtained impact performance?
3. What physiological aspects of athletic performance does sleep most impact?
4. What cognitive aspects of athletic performance does sleep most impact?

5. What are practical applications for athletes to improve sleep habits? What are some specific methods and/ or treatments athletes can use to enhance sleep?

Operational Definitions

1. **Sleep Hygiene:** Combination of sleep efficiency that incorporates both duration of sleep and the quality of sleep (O'Donnell & Driller, 2017).
2. **Epworth Sleepiness Scale (ESS):** The total ESS score can range from 0-24 points. A score between zero-nine points is matched as no daytime sleepiness; between 10-12 equates to mild sleepiness; between 13-16 equates to moderate sleepiness; any figure above 17 equates to severe sleepiness. The ESS scale is one of several effective qualitative measure of sleep quality (Silva & Paiva, 2016).
3. **Pittsburgh Sleep Quality Index (PSQI):** The PSQI score ranges from zero-21 points. A total score less than or equal to five points is associated with a good quality of sleep while a total score greater than or equal to five is associated with poor sleep quality. The higher the score, the poorer the sleep quality. The PSQI is one of several effective qualitative measures of sleep quality (Silva & Paiva, 2016).

Assumptions

1. It was assumed that all the subjects involved in the studies reviewed participated in studies to the best of their ability and in accordance with provided protocols.
2. It was assumed that subjects involved studies were reflective of the population under study (high school and collegiate student-athletes).

Delimitations

1. All articles used were published in an academic journal.
2. The articles were published within the last 10 years (2010-2020).

Limitations

1. The studies were not conducted with a consistent age group.
2. The studies were not done with consistent sample sizes.
3. Not all athletes participated in the same sport.
4. Some studies were limited to one gender.

Chapter 2

Methods

The purpose of this chapter is to present the methods used to synthesize research that pertains to sleep and athletic performance such as sleep extension, quality of sleep, and athletic performance metrics. The following methods were utilized when gathering research articles and in data collection, data coding and data analysis/reporting.

Data Collection

All studies collected for this synthesis were obtained either using the *SPORTDiscus* database or Google Scholar. Originally, a critical mass of articles was created based on the search results using the keywords "*sleep AND athletic performance,*" "*sleep AND athletic performance AND cognitive function*" on *SPORTDiscus*, and "*sleep AND athletic performance*," "*effect of sleep AND athletic performance*," "*number of hours of sleep needed by athletes*," and "*hours of sleep AND athletic performance (effects of sleep extension 'athletic performance')*" on Google Scholar. The preliminary search through *SPORTDiscus*, limited by the factors "Academic Journals," a publication date between 2010 and 2020, and full-text options yielded 98 total results. It was imperative that the articles be published within the last 10 years in order to maintain the relevant legitimacy of the claims being made in the articles.

The first search on *SPORTDiscus* began with the terms "*sleep AND athletic performance*." When the search was narrowed down by publication type, "Academic Journal," and year, 2010-2020, the search yielded 98 results. One article was chosen from this initial search, Silva and Paiva (2016). A second article – a review article developed by Watson (2017) – led to the review of Simpson, Gibbs, and Matheson (2017), another review article. Simpson, Gibbs and Matheson (2017) contained the articles Taheri and Arabameri (2012), Leeder, Glaister, Pizzoferro, Dawson, and Pedlar (2012), and Mah, Mah, Kezirian, and Dement (2011) which were included as part of the critical mass.

A second search was then performed on *SPORTDiscus* by adding the keyword "*cognitive function,*" on top of the original "*sleep AND athletic performance*." When this search was conducted, it yielded five search results, reducing the original 98 that came from the original two keywords. Two articles was chosen, Milewski et al. (2014), Hausswirth et al. (2014), and another background article that was not included in the critical mass, Paruthi et al. (2016). Paruthi et al. (2016) was not included in the critical mass due to the fact that it was not a legitimate study but a review article as well. These first two searches did not yield a critical mass of 10 articles nor was there was not enough evidence in the literature to support the initial research questions developed. Therefore further searches were conducted as well as one research question, "Does sleep impact different phases of athletic development? If so, to what degree?," being removed from the synthesis.

The remainder of the articles chosen were found through the use of Google Scholar. There were three searches done in total in order to complete the critical mass of 10 articles. The initial search conducted through Google Scholar was "*sleep quality AND athletic performance*," in order to target specific research questions that had not yet been addressed in the synthesis. This search, when narrowed down by "*since 2010*," yielded 22,800 results. The two articles which proved to fit the criteria for this synthesis and provided access to a PDF version of the article were Andrade, Bevilacqua, Casagrande, Brandt and Coimbra (2019), and O'Donnell and Driller (2017). The second search conducted on Google Scholar was "*number of hours of sleep needed by athletes*," again conducted in order to answer a specific research question. This led to 17,400 results and led to the selection of Tuomilehto et al. (2017) to the critical mass. The last article added to the critical mass was found by another Google Scholar search, beginning with keyword "*hours of sleep AND athletic performance*." By clicking a related search (*effects of sleep extension 'athletic performance*') at the bottom of the third page of results, Arnal et al. (2016) was found and thus fulfilled the requirements of the critical mass.

Each of these articles needed to be presented for approval and accepted before they could officially become a part of the final critical mass. In order for these articles to be included and approved they had to be based on the research questions of the synthesis, centering on the topics of (a) number of hours of sleep impacting athletic performance, (b) quality of sleep impacting athletic performance, (c) physiological aspects of performance sleep most impacts, (d) cognitive aspects of performance sleep most impacts, and (d) strategies and treatment options to improve the sleep of athletes in order to aid their performance. The approved articles were obtained from the following peer reviewed academic journals; *The Physician and Sportsmedicine*, *Medicine and Science in Sports and Exercise*, *Journal of Sports Sciences*, *Sleep*, *Journal of Pediatric Orthopedics*, *International Journal of Exercise Science*, *Journal of Clinical Sleep Medicine*, *Sports and Exercise Medicine and Health*, and *Asian Journal of Sports Medicine*.

Data Coding

Article information obtained for this synthesis involved a two-step process in an attempt to make the data more concise and easily accessible. The first step of this process was to obtain approval of a critical mass of 10 articles which would allow the research questions to be answered. The second step was to develop an article grid (see Appendix A). The purpose of the article grid was to have all of the information from the articles in one space for reference. The article grid consists of the following columns; (a) articles citation, (b) purpose, (c) methods and procedures, (d) analysis, (e) conclusion, (f) discussion and recommendations for future research.

Data Analysis

Of the 10 articles approved and utilized in the critical mass of this synthesis, nine were quantitative in nature (Andrade et al., 2019; Arnal et al., 2016; Hausswirth et al., 2014; Leeder et al., 2012; Mah et al., 2011; Milewski et al., 2014; O'Donnell & Driller, 2017; Silva & Paiva, 2016; Taheri & Arabameri, 2012) and one was a mixed methods study, Tuomilehto et al., (2017). The quantitative studies employed a variety of different methods to measure how sleep impacted performance. Many of these studies employed a multivariate analysis and ANOVA to determine standard deviations, confidence intervals, and P-values that determined the significance of the results. The mixed method study, again, utilized the same methods as quantitative studies but also incorporated an open-ended follow-up (Tuomilehto et al., 2017). The follow-up asked the participants to compare where they are now in their sleep quality as opposed to where they were before, and to discuss any noticeable difference in how they feel as a result.

In terms of the subjects examined in each study, one study consisted of 1,041 athletes, 671 men and 370 women. The mean age of the male subjects was 21.52 ± 6.90 years and the mean age of the females was 19.55 ± 5.89 years. These subjects participated in nine different individual sports - swimming, judo, gymnastics, taekwondo, biathlon, jiu-jitsu, tennis, mixed martial art, and karate – and six team sports - volleyball, handball, basketball, beach volleyball, indoor soccer, and sailing. A second study was comprised of over 100 subjects, 54 males and 58 females from grades seven-12 of the same middle school, who participated in an online survey to discover their injury history. A third study reviewed in this synthesis also involved more than 100 subjects, all male professional hockey players. The subjects had a mean age of 25.4 years (95% CI 24.4-26.3 years) with the youngest being 17 years old and the oldest being 40 years old.

There were also four studies in this synthesis which had over 25 subjects. The first was comprised of 27 male triathletes, 18 of which made up the experimental overload training group, and the remaining nine made up the normative control group. A second study was made up of 66 subjects, 46 of which were elite level Olympic athletes from team Great Britain, and the remaining 20 were a normative, non-athlete, control group. Of the 46 Olympic athletes, 11 were canoers, 14 were divers, 10 were rowers, and 11 were speed skaters. The third study was made up of 26 elite level female netball athletes. Their mean age was 23 years old with a standard deviation of ± six years. The last study that involved more than 25 subjects was a study that measured the precompetitive sleep habits of 76 elite level female gymnasts. These gymnasts were between the ages of 16 and 20 years old and were distinctly “elite” due to the fact that they averaged at least 30-40 hours of training per week.

The remaining three studies all involved less than 25 subjects and operated in acute settings, meaning they were studies with small sample sized, conducted in one location environments. The first study was made up of 12 males in two randomized groups, one being the experimental, sleep extension group, and the second being the control, habitual sleep group. The second study had a similar subject pool. This study involved 11 student-athletes from the Stanford University men’s basketball team. This group had a mean age of 19.4 years with a standard deviation of ± 1.4 years. The last study reviewed was made up of 18 male college student-athletes who were a part of a randomized cross-over study, whereby half of the subjects made up the baseline habitual sleep group and the other half made up the sleep deprivation group.

Chapter 3

Review of Literature

The purpose of this chapter is to present a review of the literature that served as the foundation for this synthesis. There were a total of 10 articles that fit the criteria to be considered as part of the critical mass of articles. Of the 10 articles, five focused on how sleep duration can effect athletic performance. Three of the articles focused on how the quality of sleep can effect athletic performance. Finally, three articles focused on providing information and strategies to improve the amount and/or quality of sleep for athletes.

Sleep Duration and Its Effect on Athletic Performance

Arnal et al.'s study (2016) was conducted in order to investigate the effects which six nights of sleep extension (i.e. when more than the recommended eight hours of sleep is obtained) had on motor performance and associated neuromuscular function before and after one night of total sleep deprivation (TSD). The study involved 12 healthy men who participated in two experimental conditions (randomized cross-over design), either habitual sleep (HAB) or sleep extension (EXT) following TSD. Depending upon their experimental condition, subjects performed six nights of sleep extension or habitual sleep at home followed by performance and function tests. The study was designed in two parts. The first part consisted of the sleep analysis, while the second was the performance analysis. Each subject participated in each aspect of the design.

For the HAB group, the first phase of the study consisted of five nights of baseline sleep while spending at least eight hours in bed (Arnal et al., 2016). The sleep extension period meant for the subjects to sleep for whatever time they could, with the requirement that they needed to spend at least 10 hours in bed (Arnal et al., 2016). One constant that was maintained across HAB and EXT was that the subjects tried to establish a wake time of 07:00, in order to accustom themselves to the protocol of the laboratory phase.

The second phase was the laboratory phase; and it began after the fifth night at home at 17:00, with explanation of protocol occurring from 17:00 to 20:00 (Arnal et al., 2016). Neuromuscular testing began on the next day. The next day also began the total sleep deprivation period, where all subjects were made to be in a state of continuous wakefulness (D1) for 34-37 hours. In order to further isolate the variables, subjects were psychoactive prohibited (caffeine, alcohol, tobacco, etc.) for 48 hours before and during laboratory phase and they maintained consistent calorie intake (2,600 kcal/ day) (Arnal et al., 2016).

The neuromuscular testing was based on a sustained isometric knee extension at submaximal intensity for as long as possible (Arnal et al., 2016). The target level of effort was made to increase at benchmarks of time doing work, at nine, 12, and 15 minutes of sustained contraction. Following muscular failure, whereby the subjects were not able to sustain within 5% of what their respective target effort was, femoral nerve electrical stimulation and transcranial magnetic stimulation was conducted. Each of the tests, in their own right, were done in order to establish the degree to which neuromuscular function was hindered or heightened during the laboratory phase. Both of these neuromuscular function tests measured the maximal voluntary contractions that the subjects could create (Arnal et al., 2016).

The results of the study indicated that six nights of sleep extension improved motor performance in a sustained contraction compared to the control condition (habitual sleep) (Arnal et al., 2016). Time to exhaustion was also longer in EXT than it was in HAB (Arnal et al., 2016). More importantly is the fact that this study determined that sleep extension is more important to short-term performance than sleep deprivation. The study concludes that the beneficial effects of sleep extension effort capacity could lead to significant prevention of total sleep deprivation induced performance degradation in longer exercise durations (Arnal et al., 2016). This conclusion had major implications to extreme endurance events where sleep deprivation occurs during that extreme endurance activity, namely Ironman Triathlons and ultramarathons (a race distance over 26.2 miles).

Mah, Mah, Kezirian, and Dement (2011) also conducted a study with the purpose of investigating how sleep extension impacted performance. Sleep extension is an important measure of sleep hygiene as it is based on acquiring more sleep than what is considered average. This study was conducted with 11 healthy student-athletes on the Stanford University men's basketball team. These student-athletes were of a mean age of 19.4 ± 1.4 years (Mah et al., 2011). The subjects maintained their habitual sleep schedule for a two to four week baseline period. This was then followed by a five to seven week experimental sleep extension period. The sleep extension period saw the student-athletes strive for a minimum goal of 10 hours in bed each night (Mah et al., 2011). During this sleep extension period, as well as previously during the baseline period, several measures of athletic performance were recorded during each practice including a timed sprint, shooting accuracy, reaction time, levels of daytime sleepiness and mood.

The less-easily measured aspects of performance, daytime sleepiness and mood, were measured in accordance with the Epworth Sleepiness Scale (ESS) and the Profile of Mood States (POMS), respectively. Reaction time was measured by the Psychomotor Vigilance Task (PVT) (Mah et al., 2011). The statistical analysis of the study was a paired t-test, implemented in order to measure the significance of each variable being tested during the period of sleep extension. The results indicated that, following sleep extension, essentially all of the performance metrics being tested improved significantly. First, sprint time improved following the period of sleep extension (16.2 ± 0.61 sec at baseline vs. 15.5 ± 0.54 sec at end of sleep extension, $P < 0.001$). Second, shooting accuracy significantly improved based on both free throw and three-point field goal percentage. Free throw percentage increased by 9% following sleep extension compared to the baseline period, and three-point field goal percentage increased by 9.2% ($P < 0.001$). Mean PVT reaction time and Epworth Sleepiness Scale scores decreased following sleep extension, therefore improving reaction time and improving daytime alertness ($P < 0.01$). And finally, POMS scores improved with increased vigor and decreased fatigues subscales ($P <0.001$) (Mah et al., 2011). The subjects even reported that they had improved overall ratings of physical and mental well-being during practices and competition, on a 10 point scale (Mah et al., 2011). These results allowed the researchers to conclude that essentially every measure considered in the study was significantly improved upon by a period of sleep extension. This led the researchers to further conclude that such improvements in performance after sleep extension indicate that sleep extension is highly beneficial in reaching peak athletic performance in collegiate student-athletes (Mah et al., 2011).

Milewski et al. (2014), contrary to the previous two studies, sought to examine the degree to which sleep *deprivation* has on the performance of student athletes (grades seven-12). More specifically, they sought to examine the rate of injury associated with sleep deprivation. These subjects were any student athlete who was entering grades seven through 12 at the time of consent, May 2011 until February 2012, and either had or planned to participate in at least one sport during the previous or upcoming year (Milewski et al., 2014). The study was conducted as an online survey with 160 student-athletes, of which 112 responded, 54 male and 58 female

(Milewski et al., 2014). The survey had 10 linked questions and the results were correlated to injury records provided by the school's athletic department.

The questions asked included (a) how many weeks per year do you participate in organized sports?, (b) during the average week, how many hours are spent in sports including training, practice, and competition? (excluding time spent reviewing films, playbooks, and team meetings), (c) have you had a private coach outside of normal school or club teams?, (d) if so, how many hours per week, on average, are spent in private coaching?, (e) during the season how many hours of sleep, on average, do you get per night?, (f) do you participate in strength training on a regular basis?, (g) how many times per week do you participate in strength training, (h) how long is each strength training session? (i) how many sports do you participate in per year on a school or club level?, and, (j) how much fun are you having in sports right now on a scale of one to 10? (one would be having no fun and 10 being the most fun possible) (Milewski et al., 2014).

The multivariate analysis was conducted using Strata 12.0. A generalized linear model was utilized with the probability of injury used as the primary outcome, with sleep deprivation being the other variable (Milewski et al., 2014). The results were based on a utilized 95% confidence interval and a significance level of $P < 0.05$, both standard measures of significance in statistical analysis. The conclusion was that sleep deprivation and increasing grade in schools was associated with increased probability of injury in adolescent student-athletes (Milewski et al., 2014). Also, the strongest predictor of injury, across the grades, was those student-athletes who accumulated less than eight hours of sleep per night ($RR = 2.1$; 95% CI, $P = 0.01$). Further, it was found that the increasing levels of competition make the amount of sleep more difficult to obtain. The increased physical and mental demands brought on by increased level of competition can lead to less sleep and more injuries. It was also concluded that the way to limit injuries in the older adolescent age bracket (grade 10-12) would be to maintain a legitimate sleep schedule where the student-athletes work to obtain an uninterrupted eight hours of sleep (Milewski et al., 2014). It was also recommended that daytime napping can also help, but further research would be needed to determine to the impact of napping and injury prevention.

Taheri and Arabameri (2012) sought to determine the effect of one day sleep deprivation on anaerobic performance and reaction. The study involved 18 male college athletes who were put through a balanced, randomized design with the first test being a baseline after normal habitual sleep and the second conducted after sleep deprivation. Subjects were measured for peak power using a Wingate test, which measures mean power over time. The test consists of a 30-second supramaximal cycling effort against a resistance load, calculated as 0.090 kg x kg – 1 body mass, to find a difficult load for each subject, despite their size (Taheri & Arabameri, 2012). The data analysis was carried out by measuring the mean standard deviation of the difference between the Wingate test following baseline sleep and sleep deprivation. The effect of sleep deprivation on anaerobic power was, again, measured by a paired t-test. What was found was that peak power output (Wingate test) was not significantly affected by sleep deprivation (P-value > 0.05). Also mean power output was not significantly affected by sleep deprivation (P-value > 0.05).

Reaction time was measured using a two-choice reaction task on a computer. The test was performed using two joysticks in front of handlebars. Two empty squares, (6 cm. sides) were lined up in the center of the screen, one blue and one yellow. When one of the squares became filled with the color red, the subjects were prompted to respond as quickly and as accurately as possible by prompting the appropriate joystick (Taheri & Arabameri, 2012). That being said, reaction time was measured to have been significantly affected by sleep deprivation based on the baseline test being 281.65 ± 31ms vs 244 ± 39 ms following sleep deprivation (P-value < 0.005) (Taheri & Arabameri, 2012).

The conclusions made by this study were that one night of sleep deprivation was not enough to create a significant difference in peak and mean power output though it did significantly affect reaction time. Therefore, despite the lack of correlation over a 24 hour period, more research would need to be done to examine whether a more significant effect on power output would be noticed if sleep deprivation was sustained. "Adequate sleep is essential for peak performance of those sports which need more cognitive functions and some unwillingly events in which sleep is disturbed prior to an athletic event can impair the athletes performance (Taheri & Arabameri, 2020, p. 19)."

Silva and Paiva (2016) sought to examine the sleep habits of elite female gymnasts prior to competition. Specifically, this study focused on the optimization of the sleep hygiene by examining the duration and quality of sleep which the gymnasts received during the week of the FIG World Cup and the RG International Tournament in 2011. The study involved 76 subjects, all female gymnasts, and all between 16 and 20 years of age. In order to be considered an "elite" gymnast, these subjects needed to train an average of anywhere from 30-40 hours per week. In order to create a baseline, the precompetitive sleepiness of each gymnast was measured using the Epworth Sleepiness Scale (ESS) and the Pittsburgh Sleep Quality Index (PSQI). Precompetitive anxiety was also measured using Sport Competition Anxiety Test form A (SCAT-A), and body composition was tested through a digital scale, accurate to 0.01 kg, and was obtained with each gymnast wearing a t-shirt and gym shorts before their warm up session (Silva & Paiva, 2016).

The researchers found that 56.7% of the 76 participating gymnasts did not obtain the recommended eight hours of sleep per night. Due to this fact, 67.2% of the gymnasts reported suffering from daytime sleepiness, (Silva & Paiva, 2016). For those who did get the recommended hours of sleep, however, there was a significant positive correlation between their sleep duration and higher energy availability, prior to competition (P-value = 0.001). These results enabled the study researchers to conclude that increasing the duration of sleep is imperative to increasing energy availability in the elite female gymnasts who were involved in this study. The impact which sleep has, however, on elite female gymnasts requires systematic research to measure more than just the precompetitive impacts (Silva & Paiva, 2016).

Sleep Quality and Its Effect on Athletic Performance

A study conducted by Andrade, Bevilacqua, Casagrande, Brandt, and Colmbra (2019) was aimed at analyzing the association between sleep quality and mood in elite athletes of differing competition levels. Mood was examined based on six mood states; anger, confusion, depression, fatigue, tension, and vigor (Andrade et al., 2019). This wide scoping study consisted of 1,041 athletes in total. Of those, 671 of those were men (21.52 ± 6.90 years) and 370 were women (19.55 ± 5.89 years) (Andrade et al., 2019). These athletes were pulled from a total of 15 competitive sports. Nine of those were individualized sports and six of those were team sports. The nine individualized sports were swimming, judo, gymnastics, taekwondo, biathlon, jiu-jitsu, tennis, mixed martial arts, and karate. The six team sports were volleyball, handball, basketball, beach volleyball, indoor soccer, and sailing. These athletes were sourced from competitions, regional, national, and international and were all consenting with the study. The study was approved, also, by the Institutional Ethics Committee, and in accordance with the Declaration of Helsinki (Andrade et al., 2019).

Data collected came, in part, in the form of surveys conducted 30 minutes prior to contests in which the athletes were competing. This data was provided by the subjects themselves through self-reporting of sleep quality based on a Likert-type scale as well as their mood using a Brunel Mood Scale (BRUMS) (Andrade et al., 2019). The data collected was analyzed using descriptive statistics such as mean, standard deviation, and percentage. Inferential analysis was performed using the Kruskal-Wallis, done to compare the moods of athletes with different self-reported sleep quality. Additionally, binary forward logistic regression analyses were conducted in order to determine the correlation between sleep quality and competitive level (Andrade et al., 2019).

The results of the study revealed that 84% of the athletes who compete internationally were more likely to have poor sleep quality than athletes who compete at a regional level (Andrade et al., 2019). Of those international athletes as a whole, however, those who obtained good sleep quality demonstrated greater vigor and perceived energy prior to competition ($P = 0.00$) (Andrade et al., 2019). Those international athletes who did not obtain good, or optimized, sleep quality recorded increased levels of confusion, depression, and fatigue prior to competition (Andrade et al., 2019). Overall, the researchers were able to conclude that sleep should be monitored with international athletes in order to optimize their quality of sleep they get and to perform better in their competitions. Not only to better perform, but to prevent disorders associated with lack of sleep, namely depression, which could further compound the negative impact on athletic performance. They also concluded that coaches and athletes should implement techniques and strategies for appropriate management of sleep and mood, in order to maintain the athletes optimal conditions before important competitions (Andrade et al., 2019).

Hausswirth et al. (2014) sought to examine the relationship between reduced sleep quality and the prevalence of upper respiratory tract infections in elite level endurance athletes. This study was used in order to understand the physiological aspects of athletic performance that sleep most impacts. The study was set up with 27 trained male triathletes, who had been competing regularly in triathlons for at least three years and trained a minimum seven times per week (Hausswirth et al., 2014). Of the 27 subjects, 18 were assigned as the overload training group and nine were assigned to the normal training group, representing the control group (Hausswirth et al., 2014). The two respective training programs included a one week moderate training phase, to mitigate injury and build up the athletes, followed by a three week period of their respecting training group. After the three week experimental period, a two week taper followed.

Throughout the duration of the study, maximal aerobic power and oxygen uptake was measured through a VO_2 Max reading. This was done from incremental cycle ergometry and was done after each phase of the training, the buildup period, the respective training group period, as well as the two week taper. Other data points, such as mood states and incidences and degrees of illness were determined via questionnaires. Sleep was monitored on every night of the six week training program by wristwatch actigraphy. Analysis led to the triathletes who demonstrated decreased performance and high perceived fatigue at the mid-point of the training program being diagnosed as functionally overreached (Hausswirth et al., 2014). The remaining subjects in the overload group who maintained or increased their performance after the overload period were considered acutely fatigued (Hausswirth et al., 2014). In addition because extended monitoring reduces the inherent measurement errors in actigraphy and increases reliability, subsequent analyses were conducted using the mean values of each sleep parameter over each week of the training protocol. Statistical analysis was done by a two-way ANOVA and the data was used to examine the differences in dependent variables, being perceived sleep quality and actimetry data.

The results indicated that out of the 18 subjects in the overload group, nine of them were diagnosed as functionally overreached after the overload period. This was based on their declines in performance VO2 max with concomitant high perceived fatigue ($P < 0.05$) (Hausswirth et al., 2014). This compared to the other nine control subjects showed no decline in performance ($P > 0.05$). There was also a significant interaction for sleep duration ($P = 0.02$), sleep efficiency ($P = 0.002$), and immobile time ($P = 0.006$) (Hausswirth et al., 2014). The significance of these results suggests substantial sleep disturbances in the functionally overreached group (Hausswirth et al., 2014).

There was a massively increased prevalence of upper respiratory tract infections in the experimental overreaching group as compared to the control group, 67% and 22% respectively (Hausswirth et al., 2014). To conclude the study, the researchers were able to come to two distinct conclusions. The study confirms that sleep disturbances and increased illness in endurance athletes who present with symptoms of the overreached group during periods of high volume training. This study also confirmed that lack of sleep has an immense impact on the immunological health of individuals, especially endurance athletes. Therefore, this study was successful in answering the research question about which physiological aspect of performance lack of sleep affects.

Silva and Paiva (2016) sought to examine the sleep habits of elite female gymnasts prior to competition. As reviewed in the previous section, this study incorporated both aspects of sleep hygiene, concerning both the duration and sleep quality. Again, this study focused on the optimization of the sleep hygiene by examining the duration and quality of sleep which the gymnasts received during the week of the FIG World Cup and the RG International Tournament in 2011. The study involved 76 subjects, all female gymnasts, and all between 16 and 20 years of age. In order to be considered an “elite” gymnast, these subjects needed to train an average of anywhere from 30-40 hours per week. In order to create a baseline, the precompetitive sleepiness of each gymnast was measured using the Epworth Sleepiness Scale (ESS) and the Pittsburgh Sleep Quality Index (PSQI). Precompetitive anxiety was also measured using Sport Competition Anxiety Test form A (SCAT-A), and body composition was tested through a digital scale, accurate to 0.01 kg, and was obtained with each gymnast wearing a t-shirt and gym shorts before their warm up session (Silva & Paiva, 2016).

The data was analyzed by a paired t-test implemented in order to measure the significance of the interaction of the different variables being considered. The significance of the P-values in this study were also upped to $P < 0.01$ in order to guarantee the significance of the results. A majority (77.6%) of the gymnasts also experienced poor sleep quality leading to 19.4% of the gymnasts presenting high levels of precompetitive anxiety (Silva & Paiva, 2016). For those who did get the recommended hours of sleep, however, there was a significant positive correlation between their sleep duration and higher energy availability, prior to competition (P-value = 0.001). These results enabled the study researchers to conclude that increasing the quality of sleep is imperative to increasing energy availability in the elite female gymnasts who were involved in this study. The impact which sleep has, however, on elite female gymnasts requires systematic research to measure more than just the precompetitive impacts (Silva & Paiva, 2016).

Practical Applications and Strategies to Improve Sleep

Leeder, Glaister, Pizzoferro, Dawson and Pedlar (2012) aimed to quantify sleep in elite athletes compared to normative sleep data, using wristwatch actigraphy. It was included in this synthesis in order to describe the way that athletes can optimize sleep through increasing their rest periods from training and competing to increase their sleep efficiency. The subjects of this study were comprised of 46 athletes from team Great Britain's Olympic rosters. Of the 66 total subjects, with the elite athletes combined with the normative control group, there were 23 males and 43 females (Leeder et al., 2012). These athletes were chosen from several teams, those being canoeing, n = 11, diving, n = 14, rowing, n = 10, and speed skating, n = 11 (Leeder et al., 2012). Their wristwatch actigraphy was compared to a normative control group consisting of 20 subjects, all of whom were recruited by the University of Surrey Clinical Research Centre. The data from all of the subjects was collected from their own individual sleeping environment. The elite athletes had some of their data excluded from analysis, if that sleep data was collected following a period of long travel or high altitude exposure (Leeder et al., 2012). The reason being because these two conditions are known to disrupt sleep and the researchers wished to isolate those variables from interfering with the data.

The actigraphy data collected was then analyzed using a software system called Statistical package for the Social Sciences, downloaded as SPSS for Windows by the researchers. The measures of centrality and spread of the data was presented as a mean and ± standard deviation. The data being analyzed was collected over a four day period, again excluding the data from the athletes that incorporated the undesirable variables of travel and altitude exposure. The further statistical analysis between the experimental group and the control group as conducted using ANOVA which implemented a 95% confidence interval that looked for a value of significance of $P < 0.05$ (Leeder et al., 2012).

The researchers found results that indicated there were significant measures between athletes and the controls in all measures collected from the actigraphy other than “time asleep” ($p = 0.27$). There was a significant effect of gender on “time awake” (mean: 12 minutes; 95% likely range: three to 21 minutes) and “sleep efficiency” (mean: 2.4, 95% likely range: 0.05 to 4.8), although time in bed returned a significant P-value of 0.05. Further, there was also a noted significance between athletic status (elite athletes vs. controls) and gender for time in bed ($p = 0.008$) with post hoc tests revealing that in contrast to controls, male athletes spent a significantly ($p < 0.001$) longer amount of time in bed than female athletes (mean difference: 54 minutes; 95% likely range: 23 to 85 minutes). However, the gender effect did not carry over to the controls as this difference was not deemed significant (Leeder et al., 2012).

The researchers were able to conclude several findings based on the results they obtained. The main one was that athletes appear to, in general, get a comparable quantity of sleep to a normative control group of non-athletes. However, there were significant differences between controls and athletes for all other variables suggesting that the quality of sleep experienced by the elite athlete is inferior to that experienced by a normal individual (Leeder et al., 2012). Various differences exist between athletes and a normal control group when considering training volume and intensity, amount of time, psychological and mental stress, and stress combination that both training, life activities and competition can contribute to an athletes life.

Another study was conducted to better provide a strategy and practical application measurements to increase the sleep hygiene, quantity and quality, of sleep experienced by athletes. O’Donnell and Driller (2017) conducted such a study with the purpose of evaluating the effect of a sleep hygiene education session on sleep indices in elite athletes. This study involved 26 elite female athletes. They performed one week of baseline sleep monitoring (PRE) followed by a sleep hygiene education session and an additional experimental week of sleep monitoring (POST). The sleep hygiene education session was focused primarily on providing information on the importance of sleep for athletes and practical tips to improve sleep quality and quantity. The sleep obtained throughout the duration of the study, by the female athletes, was monitored using wristwatch actigraphy.

The actigraphy device monitored a variety of different data points. Those were; sleep efficiency (SE), total time in bed (TTB), sleep latency (SL), wake episodes per night (WE), sleep onset variance (SOV), wake variance (WV), wake episode duration (WED), sleep onset time (SOT), and wake-time (WT). All of that data was collected and analyzed into means and standard deviation. This was done in order to maintain a 90% confidence interval of significance between the education session and the data being analyzed. The results obtained proved that there was a significant improvement in total sleep time (22.3 minutes ± 39.9 minutes, $P = 0.01$) from pre session to post session (O’Donnell & Driller, 2017). There was also a significant improvement in wake variance and wake episode duration, both of which were deemed significant by the P-value obtained ($P = 0.03$). Meaning that the subjects wake time and was more consistent time and they did not wake up as much throughout that night’s sleep. Both indicators of results exhibited that a heightened quality of sleep was achieved.

Overall, this study allowed the researchers to conclude that a sleep hygiene education session is effective in improving sleep quantity in elite female athletes. This was accomplished in two separate methods. First by providing the evidence that sleep can positively impact multiple aspects of life and the importance of it, it created a rationalization of optimizing sleep hygiene for the athletes. Second, by providing tips and guidelines for what good quality sleep looks like and how to obtain it. These two methods facilitated an easy of creation of a sleep hygiene strategy for the female athletes and made it easier for them to put that schedule into practice. However, with that said, the researchers acknowledged that this study they conducted represents an acute setting (O'Donnell & Driller, 2017).

Finally, Tuomilehto et al. (2012) conducted a study which further discussed the impact of sleep on athletic performance and recommendations to improve that sleep that athletes, especially elite level athletes, get. The purpose of the study was to evaluate the impact of a structured sleep counseling protocol on sleep with professional athletes. The study's subjects were comprised of 107 male athletes, all of whom play professional ice hockey. The mean age of the subjects was 25.4 (95% CI 24.4-26.3) with the youngest participant being 17 years old and the oldest being 40 years old. The methods of this study were based on monitoring the sleep habits of the subjects at baseline prior to any other aspects of the study being implemented. The sleeping habits of all the athletes was evaluated by the researchers via a simple sleep questionnaire (Tuomilehto et al., 2012). All of the athletes, further on in the study, received general sleep counseling and advice throughout the study and were offered a follow up by the same clinician a year following the original study. Athletes who were suspected of a sleep disorder, based on their answers to the sleep questionnaire, were further examined by an expert in sleep medicine. Further, this same group of subjects were able to be subjected to a polysomnography data collection process, which collects data similar to that of wristwatch actigraphy. This treatment, along with treatment plans, was devised based on the readings of those who participated in that aspect of the study. An ANOVA analysis was conducted with the quantitative results consisting of frequencies, means, and standard deviations. These figures were based on a 95% CI and these metrics were used to describe the basic sleep characteristics for the individuals who conducted the polysomnography (Tuomilehto et al., 2012).

According to the research study sleep questionnaires, the majority of the athletes estimated their sleep duration to be around ~7.5 hours per 24 hours (95% CI 7.3-7.7). Approximately 17% of the athletes cited using sleep medication, specifically melatonin and zolpidem, with approximately 95% using one of these options. This sleep medication use occurred during the competitive season and was based on the fact that 48% of the athletes believe that proper sleep is important for aiding their athletic performance (Tuomilehto et al., 2012). Also, 75% of the athletes believed that sleep counseling would better improve their sleep. At the one year follow-up mark to the study, following the administration of the sleep counseling, 83% of those 40 athletes surveyed stated that they had noticeable improvements in their sleep. Statistical figures supported this finding, as researchers found that the baseline sleep quality of these athletes was 8.1 (95% CI 7.8-8.5), a mean increase of 0.6 (95% CI 02.-1.0) over baseline (Tuomilehto et al., 2012).

Overall, the study allowed the researchers to conclude that, for one, professional athletes experience significant problems with sleeping. This comes from the idea that whether they don’t get enough sleep or they don’t get the quality of sleep they need, they experience a level that is problematic for them. This study specifically revealed that the subjects averaged about 7.0 to 7.5 hours of sleep per night, which is similar to the normative population, prior to the sleep counseling. It has been cited in previous articles in this synthesis, however, that elite level athletes need more sleep than a similar demographic population. That being said, this study demonstrated that, in order to improve and increase the sleep that the athletes obtained, systematic examination and counseling could result in significant improvement in their sleep

(Tuomilehto et al., 2012). This examination and counseling led to the athletes being better in control of their sleep-wake cycle, daytime vitality, and having less of a need for sleep medication, all of which can aid in the overall well-being and athletic performance for the athletes.

Chapter 4

Results

Purpose

The purpose of this chapter is to report the results of this synthesis based on the original research questions. A total of 10 studies were found suitable for the critical mass were used to create the results for this synthesis. The following research questions were proposed for this synthesis:

Research Questions

1. Does the number of hours of sleep impact performance?
2. Does the quality of the amount of sleep obtained impact performance?
3. What physiological aspects of athletic performance does sleep most impact?
4. What cognitive aspects of athletic performance does sleep most impact?
5. What are practical applications for athletes to improve sleep habits? What are some specific methods and/ or treatments athletes can use to enhance sleep?

Does the number of hours of sleep impact performance?

There was one main study that discussed the number of hours of sleep that impact performance, in terms of what is the correct number of hours of sleep that optimize health and performance. Mah, Mah, Kezirian, and Dement (2011) sought investigate the effects of sleep extension over multiple weeks on specific measures of athletic performance as well as reaction time, mood, and daytime sleepiness. The main finding of Mah et al. (2011) in their study was that sleep extension, over eight hours of sleep, can help in aiding athletic performance. Specifically, a period of sleep extension, increased from baseline sleep by 110.9 ± 79.7 minutes, equating to about 10 hours on average for the subjects noted significant improvement to the experimental variables, anaerobic strength and reaction time. Further, the results the subjects experienced, specifically increase in free throw percentage (9%, $P < 0.001$), increase three-point field goal percentage (9%, $P < 0.001$) (Mah et al., 2011), and faster sprint time (16.2 ± 0.61 sec at baseline vs. 15.5 ± 0.54 sec at end of sleep extension, $P < 0.001$) (Mah et al., 2011), all suggest that elite level athletes can benefit from accumulating more than eight hours of sleep. Therefore, the data presented in this article suggests that, yes, the number of hours of sleep can affect athletic performance; the more sleep you obtain as an athlete, the better you can perform.

Does the quality of the amount of sleep obtained impact performance?

There were two studies that focused on the quality of sleep obtained and how that can aid and or hinder athletic performance (Andrade et al., 2018; Silva & Paiva, 2016). The trend found in both of these studies does support the fact that quality of sleep has an impact on how well athletes perform. Sleep quality was measured at a quantitative capacity and it was determined that it this can be done in a variety of different ways. Silva and Paiva (2016) measured the sleep quality of the gymnasts using the Pittsburgh Sleep Quality Index (PSQI), which is a survey that ranges from a score of zero to 21 (Silva & Paiva, 2016). The 67 total subjects that were examined, they were broken up into two separate groups; the highest scoring in competition (There) and the lowest scoring in competition (GYM2). The highest scoring group had a PSQI mean of 7.7 ± 2.5 while the lowest scoring group had a mean of 6.4 ± 2.4 (Silva & Paiva, 2016). Therefore, this study suggested a positive correlation between sleep quality and athletic performance such that improved sleep quality can cause improved athletic performance in athletes.

Andrade et al. (2018), differing from Silva and Paiva (2016), Andrade et al. (2018) involved mood, as opposed to competition standing, as a way to measure how sleep quality affected performance. Mood, in the case of this study was measured in six different states; tension, depression, anger, confusion, vigor, and fatigue. These six states are some of the most important precompetitive factors when it comes to performance in athletes (Andrade et al., 2018). Another difference between the two studies was the sample size. This study had a large sample size of subjects, with 671 being men (21.52 ± 6.90 years), and 370 being women (19.55 ± 5.89 years) (Andrade et al., 2018). The subjects self-reported their results qualitatively using the Likert type scale and their mood using the Brunel Mood Scale (BRUMS).

What was found was, since elite level athletes can be more exposed to stressors that impact their physical and mental health it is more difficult for them to obtain optimal quality of sleep, especially when taking travel into consideration (Andrade et al., 2018). The study further suggested that athletes with poor and/or bad sleep quality, as self-reported, were more likely to experience tension, depression, anger fatigue, mental confusion and less vigor than athletes that experienced good or excellent sleep (Andrade et al., 2018). The quantitative way that data was analyzed, and regressive nature of this study, discovered that as each percentage point increased with confusion and fatigue in the athletes, the likeliness of poor sleep quality increased by 10.5% and 5.4% respectively (Andrade et al., 2018). Therefore, this study further suggests that there is a direct correlation between sleep quality and athletic performance, such that, as sleep quality increases, athletic performance increases.

What physiological aspects of athletic performance does sleep most impact?

There were a total of three studies included in this synthesis that focused on the impact that sleep has on athletic development. There were several main areas that sleep impacted when it came to the literature on this topic. The main aspects of physiology and athletic performance that sleep impacted in these studies was overall well-being, aka illness, anaerobic power, reaction time, and injuries. The common theme among all of these physiological factors that affect athletic performance is that when they were not optimally experienced, often either lack of optimal sleep or legitimate sleep deprivation was experienced.

The first study examined in this synthesis that looked at the physiological impact that sleep, or lack thereof, can have on performance. This study, conducted by Hausswirth et al. (2014) focused on overreached endurance athletes. It discussed a common phenomenon of disturbed sleep and how that can affect an athlete's performance. The data collected in this study mainly exhibited a stark correlation between sleep deprivation and upper respiratory infections. As the level of sleep deprivation increased, the percentage of upper respiratory tract infection increased as well (Hausswirth et al., 2014). A limitation of the study is that it considered sleep deprivation only for a short amount of time.

Milewski et al. (2014) also collected data that indicated that athletes who slept, on average, less than the recommended eight hours per night could be at an increased risk of not achieving optimal performance. However, this study had more to do with injury and recovery than immunological affects. The data collected in this study indicated that athletes who get less than eight hours of sleep per night are at a 1.7 times (95% CI, 1.0-3.0; $P = 0.04$) greater risk of getting injured than those athletes who slept more than eight hours (Milewski et al., 2014). In fact, according to the data those athletes who slept more than eight hours per night were at the lowest relative risk of getting injured, at a relative risk of 0.8 (Milewski et al., 2014). The study also concluded that there was also a correlation between the age of the athlete and the risk of experiencing injury. In fact, the data collected indicated that the risk of injury for the athletes in this study increased by 1.4 times as each additional grade went by (95% CI, 1.2-1.6; $P < 0.001$) (Milewski et al., 2014). This was mostly due to the fact that the subjects in this study came from an academically difficult school with a good athletic history, so the physical demand at each additional grade increased, possibly impacting the amount of sleep obtained and therefore the risk of injury (Milewski et al., 2014). This study further suggests that lack of sleep can have a negative impact on the physiological performance of athletes

The third study that focused on the physiological impacts that lack of sleep can have on an athlete was conducted by Taheri and Arabameri (2012). There were two main findings that this study was able to come to. The first finding was that there was no statistically significant alteration in anaerobic performance resulting from one single night of sleep deprivation. This had to do with mean and peak power after the sleep deprivation, as compared to the baseline test (Taheri & Abarameri, 2012). The second finding however was that reaction time was significantly affected by lack of sleep. The data suggested that the mean reaction time experienced by the athletes who were exposed to sleep deprivation was significantly lower than baseline (baseline: 281.65 ± 31ms vs. sleep deprivation: 244 ± 39 ms; $P < 0.005$) (Taheri & Arabameri, 2012). The more sleep you obtain, as an athlete, the better reaction time you will have and, therefore, the better you will be able to perform. All in all, all of these studies were successful in answering the research question. Yes, sleep does have an impact on the physiological aspects of athletic performance.

What cognitive aspects of athletic performance does sleep most impact?

There was one main study utilized in this synthesis that highlighted the cognitive impact that good sleep, or lack thereof, can have on athletic performance. The study, by Arnal et al. (2016), focused on the cognitive impact that total sleep deprivation and sleep extension can have on performance by establishing a connection between brain function and muscle function. The multivariate analysis suggested that sleep deprivation induced a measurable increase in measured central fatigue in both the femoral nerve electrical stimulation and the transcranial magnetic stimulation (D1 VATMS = 95.5 ± 4 pre sleep deprivation vs. D1 VATMS = 77.8 ± 18) (Arnal et al., 2016). That being said, the study suggested that this data was not significant. Though there were reductions in voluntary activity following sleep extension and an increase following sleep extension, it is not clear based on the data whether or not that the absence of sleep extension or the experience of sleep deprivation led to these results. The beneficial effect on the neuromuscular function was likely due to the reduced ratings of perceived exertion after sleep extension as opposed to negative effects of sleep deprivation (Arnal et al., 2016). Therefore, though the data does suggest that sleep deprivation, or lack of optimal sleep, does have a negative effect on cognitive function, it is not significant.

What are practical applications for athletes to improve sleep habits? What are some specific methods and/ or treatments athletes can use to enhance sleep?

There were three studies included in this synthesis that focused on the way that athletes can improve their sleep habits and, therefore, their performance. Specifically some of the methods and treatments that athletes can be exposed to that might enhance their sleep. Each of the articles reviewed for this specific research question were effective in developing a strategy of ways to improve the sleep of athletes. In each of these studies, a trend is visible that shows a direct correlation between that respective sleep improvement strategy and the sleep of the athletes.

The first study was conducted in 2017 by O'Donnell and Driller. In this study, 26 female athletes (mean ± SD; age = 23 ± six y) (O'Donnell & Driller, 2017) were involved in this study of having their sleep monitored using quantitative means, wristwatch actigraphy. Although the wristwatch actigraphy collected a lot of quality data, the one that the researchers were most concerned with was “Total Sleep Time (mins)” (TST). A significant increase in the absolute change of TST was seen from pre-sleep education to post-education session (22.3 ± 39.9 min) which the researchers notes significant (P-value = 0.008) (O’Donnell & Driller, 2017). However, a limitation of this study was that it was only conducted based on the findings of one education session. To better see the results of a sleep strategy and sleep education on duration of sleep and performance in athletes, further sleep education sessions, perhaps scheduled sessions weekly or bi-weekly, might prove to heighten the benefits even further (O’Donnell & Driller, 2017).

The second study presented a similar trend to O’Donnell and Driller in that athletes. Tuomilehto et al. (2016) conducted their study with the aim to examine the impact that a structured sleep counseling protocol had on professional athletes (Tuomilehto et al., 2016). The trend that the data established was similar to that of O’Donnell and Driller (2017) whereby as the amount of sleep strategy was implemented and increased, so too did the sleep of the athlete. In the case of Tuomilehto et al. (2016) the noticeable aspect of sleep hygiene affected was sleep quality, where in O’Donnell and Driller (2017) sleep duration was mainly affected. In the case of this study, the sleep treatment was not an education session but a sleep counseling session. However, this study represents an improvement of generalization of the data due to the fact that this study implemented multiple data collection methods incorporating both wristwatch actigraphy data and sleep questionnaires.

The third and final study that discussed the idea of improving sleep with athletes was Leeder et al. (2012). Differing from the previous two articles, this study provides a recommendation based on the data that it accumulated. This study also focused on both the duration and quality of sleep experienced by elite level Olympic athletes through wristwatch actigraphy. The researchers sought to examine the type of sleep that this population of subjects, 46 Olympic athletes, experienced as compared to that of a normative control population, n = 20 (Leeder et al., 2012). What they found, through the actigraphy data collected was that while the normative population experienced significantly better sleep (P-value < 0.05). In fact the control population had a higher sleep time (7:11 ± 0:25 vs. 6:55 ± 0:43) than the athlete population, higher sleep efficiency ($88.7 \pm 3.6_d$ vs. $80.6 \pm 6.4_d$) as well as a higher actual sleep percentage ($89.7 \pm 3.3_f$ vs. $84.3 \pm 5.7_f$) all while having a decreased moving time ($9.4\% \pm 2.4_h$ vs. $17.8\% \pm 6.2_h$) (Leeder et al., 2012). All in all, it can be seen that the normative population had a more efficient and higher quality sleep as compared to the elite level athlete.

The most important finding made by Leeder et al. (2012) was in regards to the differences in sleep across athletes from different sports. “Various differences exist between sports which may alter the requirement for sleep. These factors include; training volume and intensity, training timetable, psychological stress of training, or combining training with life activities… (Leeder et al., 2012).” That conclusion leads to the idea that if there are differences in stress from sport to sport, there is of course a difference from sport to no sport that has an incredible impact on sleep. Therefore, it is recommended that training induced stress is reduced in order to optimize the sleep health of elite level athletes. The researchers recommend that further research be required in order to investigate the true important of sleep and how it is related to training tolerance and training adaptation with elite athletes (Leeder et al., 2012).

Chapter 5

Conclusion/ Future Research

A total of 10 articles were examined as a part of a critical mass in order to investigate the relationship between sleep and athletic performance. The articles suggested that there are significant correlations between sleep and athletic performance in a variety of different ways.

Conclusion

The research revealed several aspects of sleep that can impact performance as well as the aspects of performance that the sleep, or lack thereof, can impact. The main findings found in the research was that as the amount of sleep and quality of sleep increases, so too does athletic performance (Andrade et al., 2019; Leeder et al., 2012; Mah et al., 2011; Silva & Paiva 2016;). Another main conclusion found in the research is that whatever aspect of performance that optimal sleep positively impacts, a lack of sleep negatively impacts that same aspect of performance. For example, optimal sleep positively impacts health (Hausswirth et al., 2014), improved reaction time (Mah et al., 2011), improved recovery (Milewski et al., 2014), improved neuromuscular function (Arnal et al., 2016), and better precompetitive mood (Andrade et al., 2019) while lack of optimal sleep can lead to illness (Hausswirth et al., 2014), slower reaction time (Mah et al., 2011), increased risk of injury (Milewski et al., 2014), lesser neuromuscular function (Arnal et al., 2016), and depression, fatigue, and confusion (Andrade et al., 2019). These results prove there is a significant correlation between sleep and athletic performance.

Another finding revealed by the literature is that elite athletes should, for the most part, obtain more than the recommended amount of sleep in order to perform at their best. The consensus belief was that eight to 10 hours of sleep is optimal in order to promote health and well-being and to optimize performance (Paruthi et al., 2016). Although this was suggested to be true in many studies, it seems that this eight to 10 hour threshold serves as a minimum for athletes, especially at the elite levels. More current research suggests that nine hours or more of sleep may be optimal when it comes to optimizing athletic performance (Arnal et al., 2016; Mah et al., 2011).

One finding that provided the most surprising results when evaluating the literature was that, in the short term, sleep deprivation does not have a significant effect on anaerobic power (Taheri & Arabmeri, 2012). Anaerobic power, at its core, is maximal intensity and maximal effort activity, with one working to exert the maximum amount of force that an individual can exert. Anaerobic power is an important factor when it comes to optimization of athletic performance so therefore, it is important to examine the effect that sleep can have on such a factor. The literature pointed to the fact that in the short term, sleep deprivation does not significantly affect anaerobic power (Taheri & Arabameri, 2012). This was essentially the only aspect of athletic performance, in the literature review, that was not significantly affected by lack of sleep hygiene, (i.e. lack of number of hours of sleep or lack of sleep quality).

Future Research

In order to better learn about the relationship between sleep and athletic performance there are several aspects of the research that need to be continued to generalize the findings. One suggestion for future research is for the researchers to expand their studies outside of such acute settings, specifically implementing larger sample sizes. Half of the studies involved in this synthesis had less than 50 subjects (Arnal et al., 2016; Hausswirth et al., 2014; Mah et al., 2011; O’Donnell & Driller, 2017; Taheri & Arabameri, 2012). Many of the authors of these studies cited the sample size of their study as a limitation.

A second suggestion for future research is to further describe the necessary amount of sleep needed by elite athletes and how that can affect their performance. Several of the studies involved sleep extension of athletes, whereby the subjects experienced nights of sleep with more than nine hours of sleep per 24 hours (Arnal et al., 2016; Mah et al., 2011). Others, however, involved sleep deprivation (Arnal et al., 2016; Milewski et al., 2014; Taheri & Arabameri, 2012) where the subjects had short term bouts of total sleep deprivation, zero hours of sleep per 24 hours. The trend established through the research was that sleep extension aided performance and sleep deprivation was detrimental to the performance of athletes. That coupled with the idea that most individuals should obtain a recommended eight to 10 hours of sleep per 24 hours (Paruthi et al., 2016) can lead to an assumption that athletes, specifically elite level athletes, should get more than eight to 10 hours. The added stresses that athletes experience compared to a normative population - including training volume, training intensity, training timetable, psychological stress, combination of training and life activities, combination of training and work, and combination of training and study – may lead to them needing more sleep than that normative population (Leeder et al., 2012). Further research needs to be conducted on what is the optimal range for elite level athletes that properly incorporates the necessary training adaptation that elite athletes face so that accurate recommendations can be made for athletes (Leeder et al., 2012).

A third and final suggestion for future research is to identify a consistent method to determine and measure quality of sleep. Throughout the literature review, there were essentially four different ways that sleep quality was measured throughout the synthesis. One study determined perceived quality through a sleep questionnaire (Hausswirth et al., 2014), a second study used wristwatch actigraphy (Leeder et al., 2012), a third study utilized the Epworth

Sleepiness Scale (ESS) and Pittsburgh Sleep Quality Index (PSQI) (2016), and a fourth study utilized a survey data to develop a mean sleep quality across subjects (Tuomilehto et al., 2017). Though all methods were effective for their particular study, a consistent method by which to measure sleep quality most effectively might help further research better generalize studies that examine the relationship between sleep quality and athletic performance.

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Tuomilehto, H., Vuorinen, V., Penttilä, E., Kivimäki, M., Vuorenmaa, M., Venojärvi, M., Airaskinen, O., & Pihlajamäki, J. (2017). Sleep of professional athletes: Underexploited potential to improve health and performance. *Journal of Sports Sciences*, 35(*7*), 704-710. https://www.tandfonline.com/doi/pdf/10.1080/02640414.2016.1184300?needAccess=true

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Citation	Purpose	Methods & Procedures	Analysis	Results	Discussion/ Recommendations
Andrade, A., Bevilacqua, G., Casagrande, P., Brandt, R., and Colmbra, D. (2019). Sleep quality associated with mood in elite athletes. *The Physician and Sportsmedicine*, 47 (3), 312-317.	The purpose of this study was aimed to analyze the association between sleep quality and mood in elite athletes of different competitive levels.	• The subjects consisted of 1041 athletes. • Of those involved, 671 were men (21.52 ± 6.90 years) and 370 were women (19.55 ± 5.89 years). • Nine individual team sports were swimming, judo, gymnastics, taekwondo, biathlon, jiu-jitsu, tennis, mixed martial arts, and karate and six team sports were volleyball, handball, basketball, beach volleyball, indoor soccer, and sailing. • subjects self-reported sleep quality on a Likert type scale and mood was measured using Brunel Mood Scale (BRUMS).	• Data collection was performed during important competitions that the athletes were a part of, completing the survey 30 minutes before. • The data was mainly analyzed using mean, standard deviation, frequency and percentage. • The statistical analysis was performed using the Kruskal-Wallis test to compare the mood of athletes with different self-reported sleep quality. • Also, the connection between mood and sleep quality was analyzed by the researchers using the survey data.	• Results revealed that athletes who compete internationally are 84% more likely to have poor sleep quality than athletes who compete at a regional level. • International athletes with good sleep quality showed greater vigor/ perceived energy. • National athletes with poor sleep quality showed more confusion, depression, and fatigue. • Thus, mood and competitive level are associated with sleep quality. • Confusion, fatigue, and tension impair sleep and vigor increased the likelihood of poor sleep.	• The researchers conclude that sleep should be monitored in international level athletes, where there are high demands of travel and competition. • This was mostly done and concluded in order to prevent sleep disorders during competition. • They also included that coaches and athletes should use techniques and strategies for appropriate management of sleep and mood, to maintain the athletes optimized condition before important competitions.

Citation	Purpose	Methods & Procedures	Analysis	Results	Discussion/ Recommendations
Arnal, P., Lapole, T., Erblang, M., Guillard, M., Bourrilhon, C., Chennaoui, M. and Millet, G. (2016). Sleep extension before sleep loss: Effects on performance and neuromuscular function. *Medicine & Sports in Sports & Exercise*, 48 (8), 1-33.	The purpose of this study was to investigate the effects of six nights of sleep extension on motor performance and associated neuromuscular function before and after one night of total sleep deprivation (TSD).	• 12 healthy men participated in two experimental conditions (randomized cross over). • Each condition, subjects performed six nights of EXT or HAB at home followed by performance and function tests.	• Results were analyzed based on baseline readings of force recordings from knee extensor force by a calibrated force transducer at baseline and before and after sleep ext and tsd. • Neurocognitive function was measured by femoral nerve electrical stimulation and transcranial magnetic stimulation. • Statistical analysis of recordings was performed using two-way and three-way ANOVA's and interpreted using P values.	• Results indicated that six nights of sleep extension improved motor performance in a sustained contraction compared to a control condition. • Further, one night of TSD significantly decreased the performance of these metrics across the subjects.	• Mainly that sleep extension positively impacts performance and sleep deprivation negatively impacts performance. • The study has implications to sleep strategies with extreme endurance events where sleep deprivation occurs during activity.

Citation	Purpose	Methods & Procedures	Analysis	Results	Discussion/ Recommendations
Hausswirth, C., Louis, J., Laubry, A., Bonnet, G., Duffield, R., and Le Meur, Y. (2014). Evidence of disturbed sleep and increased illness in overreached endurance athletes. *Medicine and Science in Sports and Exercise*, 46, 1036-45.	The purpose of this study was to examine whether objective markers of sleep quantity and quality are altered in endurance athletes experiencing overreaching in response to an overload training program and to also note the potential that reduced sleep quality would be accompanied with a higher prevalence of upper respiratory tract infections in this population.	• Twenty-seven trained male triathletes were randomly assigned to either overload (18) or normal training groups (nine = control). • Respective training programs included a one-wk moderate training phase followed by a three-wk period of overload or normal training, respectively, and then a subsequent two-wk taper. • Maximal aerobic power and oxygen uptake ($\dot{V}O_2max$) from incremental cycle ergometry were measured after each phase, whereas mood states and incidences of illness	• Data analysis led to the triathletes who demonstrated decreased performance (vs Pre) and increased perceived fatigue (very tired to extremely tired on the POMS scale) at Mid with subsequent performance restoration or super-compensation were diagnosed as functionally overreached. • The remaining subjects in the overload group who maintained or increased their performance after the overload period were considered acutely fatigued (AF= 21).	• Of the 18 overload training group subjects, nine were diagnosed as functionally overreached (F-OR) after the overload period, as based on declines in performance and $\dot{V}O_2max$ with concomitant high perceived fatigue ($P < 0.05$), whereas the other nine control subjects showed no decline in performance (AF, $P > 0.05$). • There was a significant time–group interaction for sleep duration (SD), sleep efficiency (SE), and immobile time (IT). • Only the F-OR group demonstrated a decrease in these	• This study confirms sleep disturbances and increased illness in endurance athletes who present with symptoms of F-OR during periods of high volume training. • This study confirmed that lack of sleep has an immense impact on the physiological and immunological health of individuals, specifically athletes.

		were determined from questionnaires. • Sleep was monitored every night of the six week using wristwatch actigraphy	• In addition, because extended monitoring reduces the inherent error in actigraphy and increases reliability (28), subsequent analyses were conducted using the mean value of each sleep parameter over each week. • Values at baseline for age, weight, height, experience in endurance sport, MAP, and V˙ O_{2max} were compared between groups (i.e., CTL, AF, and F-OR) using ANOVA. • Two-way (group time) ANOVA were used to examine differences in perceived sleep quality and actimetry data	three parameters (j7.9% T 6.7%, j1.6% T 0.7%, and j7.6% T 6.6% for SD, SE, and IT, respectively, P G 0.05), which was reversed during the subsequent taper phase. • Higher prevalence of upper respiratory tract infections were also reported in F-OR.	

			during sleep, between group means at each time point.		
Citation	**Purpose**	**Methods & Procedures**	**Analysis**	**Results**	**Discussion/ Recommendations**
Leeder, J., Glaister, M., Pizzoferro, K., Dawson, J., and Pedlar, C. (2012). Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *Journal of Sports Sciences*, 30 (6), 541-545.	The purpose of this study was to quantify sleep in elite athletes, compared to normative sleep data, using wristwatch actigraphy. It is included in this synthesis in order to describe a way that athletes can optimize sleep, through increasing rest periods to increase sleep efficiency.	• 46 athletes from team GB and their actigraphy data was compared to a non-athlete control group (n= 20), for a total of 66 subjects.. • Elite athlete subjects came from a variety of Olympic sports (Canoeing, n = 11; diving, n = 14; rowing, n = 10; speed skating, n = 11). • The control group was recruited by the University of Surrey Clinical Research Centre. • Data was collected from the subjects home sleeping environment, barring	• Actigraphy data was analyzed using Statistical Package for the Social Sciences (SPSS for Windows). • Measures of centrality and spread was presented as a mean and ± standard deviation. • Analysis was based off the data collected over a four day period. • Statistical analysis was done through an ANOVA and a 95% confidence interval, looking for a significant P-value < 0.05.	• There were significant differences between athletes and controls in all measures apart from ‘time asleep’ (p = 0.27). • There was a significant effect of gender on ‘time awake’ (mean difference: 12 minutes; 95% likely range: three to 21 minutes) and ‘sleep efficiency’ (mean difference: 2.4; 95% likely range: 0.05 to 4.8); although ‘time in bed’ returned a P-value of 0.05. • There was also significance between athletic status	• The main finding was that in general, athletes appear to get a comparable quantity of sleep to controls; however, there were significant differences between controls and athletes for all other variables, suggesting the quality of athlete sleep was inferior. • Various differences exist between sports which may alter the requirement for sleep. These factors include: training volume and intensity, training timetable, psychological stress of training, or

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		the athletes who had some data excluded following travel and altitude exposure, both of which are known to disrupt sleep.		(athletes versus controls) and gender for 'time in bed' ($F_{(1,62)} = 7.492$; $p = 0.008$), with post hoc tests revealing that in contrast to controls (no gender effect: $p = 0.35$), male athletes spent significantly ($p < 0.001$) longer in bed than female athletes (mean difference: 54 minutes; 95% likely range: 23 to 85 minutes).	combining training with life activities, e.g. employment or study. • Though the conclusion was that elite athletes fall in the norm of what is consensus considered "healthy sleep," due to the effects of training-induced stress in elite athletes, further research is required to investigate the importance of sleep and its relationship with training tolerance and adaptation as well as what kind of sleep do elite athletes *really* need.

Mah, C., Mah, K., Kezirian, E., and Dement, W. (2011). The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*, 34 (7), 943-950.	The purpose of this article was to investigate the effects of sleep extension over multiple weeks on specific measures of athletic performance as well as reaction time, mood, and daytime sleepiness.	• Eleven healthy students on the Stanford University men's varsity basketball team (mean age 19.4 ± 1.4 years). • Subjects maintained their habitual sleep-wake schedule for a two-four week baseline followed by a five-seven week sleep extension period. • Subjects obtained a minimum goal of 10 h in bed each night. Measures of athletic performance were recorded after every practice including a timed sprint, shooting accuracy, reaction time, levels of daytime sleepiness, and mood.	• The methods were monitored via a Psychomotor Vigilance Task (PVT), Epworth Sleepiness Scale (ESS), and Profile of Mood States (POMS), respectively. • T-tests implemented to measure the significance of each variable being tested by sleep extension.	• Following sleep extension: • Sprint time improved (16.2 ± 0.61 sec at baseline vs. 15.5 ± 0.54 sec at end of sleep extension, $P < 0.001$). • Free throw shooting % increasing by 9% and three-point shooting field goal % increasing by 9.2% ($P < 0.001$). • Mean PVT reaction time and Epworth Sleepiness Scale scores decreased following sleep extension ($P < 0.01$). • POMS scores improved with increased vigor and decreased fatigue ($P < 0.001$). • Subjects also reported improved ratings of physical and mental well-being during competition.	• Essentially every measure of performance being tested improved following the experience of sleep extension. • Improvements in specific measures of basketball performance after sleep extension indicate that optimal sleep is likely beneficial in reaching peak athletic performance.

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Milewksi, M., Skaggs, D., Bishop, G., Pace, J., Ibrahim, D., Wren, T., and Barzdukas, A. (2014). Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *Journal of Pediatric Orthopaedics*, 34 (2), 129-133.	The purpose of this study was to examine the degree to which sleep deprivation has on the injury rate on adolescent athletes (grades seven-12).	• Mixed method study • Online survey conducted with 160 student-athletes (grade seven-12), 112 completed the survey, 54 male and 58 female. • The injury report was taken from the training room of the school over a 21 month period. • Survey had 10 linked questions and results were correlated to injury records provided by the school's athletic department.	• Multivariate analysis using Stata 12.0 • A generalized linear model was utilized with Probability of injury used as the primary outcome • Results based on utilized 95% CI, and significance level $P < 0.05$.	• Sleep deprivation and increasing grade in school are associated with increased probability of injury in adolescent student athletes • Strongest predictor of injury was < eight hours of sleep/ night (RR = 2.1; 95% CI, P = 0.01)	• Increasing levels of competition make the amount of sleep more difficult to obtain • Increased physical and mental demands brought on by increased level of competition can lead to less sleep and more injuries. • Ways to limit injury in this age demographic are to maintain a legitimate sleep schedule where they work to obtain an uninterrupted eight hours of sleep. Daytime napping can also help.
Citation	**Purpose**	**Methods & Procedures**	**Analysis**	**Results**	**Discussion/ Recommendations**

O'Donnell, S., and Driller (2017). Sleep-hygiene education improves sleep indices in elite female athletes. *International Journal of Exercise Science*, 10 (4), 522-530.	The purpose of this study was to evaluate the effect of a sleep hygiene education session on sleep indices in elite athletes.	• The subjects consisted of 26 elite level female netball athletes with a mean age of 23 years, ± six y. • They performed one week of baseline sleep monitoring (PRE) followed by a sleep hygiene education session and an additional experimental week of sleep monitoring (POST). • The sleep hygiene education session was focused primarily on providing information on the importance of sleep for athletes and practical tips to improve sleep quality and quantity.	• The sleep obtained by the female athletes was monitored using wrist actigraphy. • The actigraphy device monitored total sleep time, sleep efficiency, total time in bed, sleep latency, wake episodes per night, sleep onset variance, wake variance, wake episode duration, sleep onset time, and wake time. All of that data was analyzed into means and standard deviations in order to maintain a 90% confidence interval of significance between the education session and the data being analyzed.	• The researchers were able to conclude that there was a significant improvement in total sleep time (22.3 minutes ± 39.9 minutes, P = 0.01) PRE to POST sleep hygiene education session. • There was also significant improvements in wake variance (P= 0.03) and wake episode duration (P= 0.03). Meaning that the subjects' wake time and was more consistent time and they did not wake up as much throughout that night's sleep, both indicators of heightened quality of sleep.	• This study allowed the researchers to conclude that a sleep hygiene education session is effective in improving sleep quantity in elite female athletes. • By providing tips, awareness, guidelines and noting how important sleep is, creating a strategy for acquiring better sleep is easier to do and easier to put into practice. • That being said, the researchers acknowledge that this study represents an acute setting and in order to further generalize findings, sample size of subjects would need to increase.

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Silva, M., and Paiva, T. (2016). Poor precompetitive sleep habits, nutrients' deficiencies, inappropriate body composition and athletic performance in elite gymnasts. *Sports and Exercise Medicine and Health*, 16 (6), 726-735.	The purpose of this article was to evaluate the precompetitive habits of elite female gymnasts and analyze what and where optimization of their precompetitive habits could lead to a performance improvement. Namely with the increase of sleep and nutrition.	• 76 gymnasts (age 16-20) who trained on average 30-40 hours/ week • Precompetitive sleepiness was measured (ESS and PSQI) • Anxiety and Body Composition also measured • Nutrition was assessed	• T-test implemented in order to measure significance of interaction of variables with performance. • Significant P-values were upped to $P < 0.01$	• Many of the gymnasts in the study did not get the recommended eight hours (56.7%) • 77.6% of the gymnasts presented poor sleep quality. • This sleep quality is what leads to daytime sleepiness and takes into account more of the cognitive aspect of performance, more so than sleep duration does. • The subjects were broken up following competition as GYM1 and GYM 2.	• Increasing the quality of sleep and duration of sleep is imperative to increasing EA (energy availability) in elite female gymnasts in this study. • Participating in high performance sports gives increased responsibility to the young gymnasts and certainly high levels of satisfaction and personal achievement. • However, the present and future impact upon sleep, general

				• GYM1 had a much higher mean PSQI than GYM2 (7.7 ± 2.5 vs. 6.4 ± 2.4) therefore proving that sleep quality effects athletic performance.	health and lifetime achievements require systematic research.
Citation	**Purpose**	**Methods & Procedures**	**Analysis**	**Results**	**Discussion/ Recommendations**
Taheri, M., and Arabameri, E. (2012). The effect of sleep deprivation on choice reaction time and anaerobic power of college student athletes. *Asian Journal of Sports Medicine*, 3 (1), 15-20.	The purpose of this study was to determine the effect of one's sleep deprivation on anaerobic performance and reaction time of subjects in the morning of the following day.	• 18 male college student athletes were studied twice in a balance, randomized design (one baseline after normal habitual sleep, one after sleep deprivation). • Subjects were measured for peak power using Wingate test, mean power and reaction time.	• Mean standard deviations were calculated based off the baseline test and the tests following sleep deprivation. • Effect of sleep deprivation and anaerobic power/ reaction time were evaluated by a paired t-test.	• Peak power output (Wingate) was not significantly affected by sleep deprivation ($P > 0.05$). • Mean power output (Wingate) was not significantly affected by sleep deprivation ($P > 0.05$). • Reaction time was significantly affected by sleep deprivation (Baseline: 281.65 ± 31ms vs. 244 ± 39 ms; $P < 0.005$).	• One night of sleep deprivation was not able to make a difference in peak and mean power output but had significant effect on reaction time. • Therefore, despite the lack of correlation over a 24hr period, a conclusion can be made that a longer duration in sleep deprivation might lead to a more significant effect on power output.

					• "Adequate sleep is essential for peak performance of those sports which need more cognitive functions and some unwillingly events in which sleep is disturbed prior to an athletic event can impair the athletes performance (Taheri and Arabameri, 2012, p. 19)."
Citation	**Purpose**	**Methods & Procedures**	**Analysis**	**Results**	**Discussion/ Recommendations**
Tuomilehto, H., Vuorinen, V., Penttilä, E., Kivimäki, M., Vuorenmaa, M., Venojärvi, M., Airaskinen, O., and Pihlajamäki, J. (2017). Sleep of professional athletes: Underexploited potential to improve health and performance.	The purpose of this study was to evaluate the quality of sleep and the prevalence of sleep disorders as well as the impact of a structured sleep counseling protocol in professional athletes.	• The study was made up of 107 male athlete subjects across three professional ice hockey teams. • The mean age of the subjects was 25.4 years (95% CI 24.4-26.3, min. 17, max. 40). • The sleeping habits of all athletes was evaluated via a sleep questionnaire.	• ANOVA analysis was conducted resulting in quantitative results consisting of frequencies, means, 95% CI values, and standard deviations in order to describe the basic sleep characteristics from the polysomnography.	• According to the questionnaires, the majority of the athletes estimated their sleep duration to be ~ 7.5 hours (95% CI 7.3-7.7). • About 17% of the athletes cited using sleep medication to aid in their sleep during the season based on 48% citing they believed proper	• This study allowed the researchers to conclude that, for one, professional athletes experience significant problems with sleeping, whether it be getting enough of it or having good quality sleep. • The study revealed that the subjects averaged about 7-7.5 hours of sleep per

Journal of Sports Sciences, 35 (7), 704-710.		• All of the athletes received general sleep counseling and advice throughout the study. • Athletes who were suspected of a sleep disorder were further examined by an expert in sleep medicine (n = 23). • Data was collected via a Polysomnography similar to that of wristwatch actigraphy. This data was only given to those who were suspected of having a sleep disorder (n = 23).	• The questionnaires and the counseling data was analyzed by the sleep experts and researchers.	sleep being important to performance. • Also 75% of the athletes believed that sleep counseling would better improve their sleep, therefore improving athletic performance. • At 1-year follow up after sleep counseling had been administered, 83% of the 40 athletes who filled out the questionnaire noted improvements in their sleep. • Following the sleep counseling follow up, the baseline sleep quality was 8.1 (95% CI 7.8-8.5) exhibiting a mean increase of 0.6 (95% CI 0.2-1.0).	night, which is similar to the normative population, prior to the sleep counseling. • The study also demonstrated that systematic counseling and examination of sleep resulted in improvement of athletes sleep. • This examination and counseling led to the athletes being in better control of their sleep-wake cycle, daytime vitality, and having less of a need for sleep medication, all of which can aid in overall well-being and athletic performance for the athletes.