Chapter

The Importance of Sleep in Athletes

Júlio Costa, Pedro Figueiredo, Fábio Y. Nakamura and João Brito

Abstract

Sleep is an essential component for athletes' recovery from fatigue, due especially to its physiological and psychological restorative effects. Moreover, sleep is extremely important for numerous biological functions, and sleep deprivation can have significant effects on athletic performance in short-, medium-, and long term. For example, and considering the physiology of sleep for athletes, some hormonal responses that take place in the lead up to and during sleep (e.g., growth hormone—important role in muscle growth and repair) may be affected following exercise (i.e., training and competition), especially when compared with non-athlete's populations. Thus, monitoring sleep is also crucial to understand responses to training and readiness, enabling appropriate planning. Importantly, sleep monitoring also intends to reduce the risk of injury, illness, and nonfunctional overreaching. Moreover, an "individual approach" in athletes monitoring could help in better prescribe training contents and more adequately manage fatigue, as well as recommend pertinent post-match recovery strategies, such as sleep hygiene interventions. Overall, for understanding the athlete's sleep patterns/responses and to optimize the recovery strategies, it is crucial for comprehensive monitoring of his/her health, performance, fitness, and fatigue status.

Keywords: athletes, sleep interventions, sleep technology, performance, health

1. Introduction

Sleep is fundamental for sports performance, as well as for emotional regulation and development of the physical and mental health of athletes. In fact, inadequate sleep (e.g., reduced sleep duration and quality) may lead to an increased risk of injury and illness in athletes.

In recent years, growing interest in understanding the sleep of athletes has seen an increase in published studies [1]. In fact, athletes and coaches have ranked sleep as the most important recovery strategy [2]. Interestingly, the fundamental difference between recovery interventions with established protocols (e.g., cold water immersion, compression garments, electrical stimulation) [3] and sleeping lies in the fact that sleep initiation does not depend entirely on the willingness of the athlete [4].

During sleep, anabolic metabolism is upregulated [5], procedural memories are consolidated [6], and immune responses are augmented [7]. However, sleep loss or deprivation can have significant effects on performance, motivation, perception of

effort, and cognition as well as numerous other biological functions [8]. Furthermore, sleep is associated with many physiological processes that may facilitate recovery from, and adaptation to, athletic training and competition [9]. Studies have analyzed the importance of sleep to regulate key molecular mechanisms (i.e., transcriptional regulatory proteins [10–12]), demonstrating that sleep has an integral role in metabolic homeostasis [13]. The capacity of humans to cope with physiological and psychological stressors is fundamental to athletic performance outcomes [14] and may be influenced by numerous factors, such as experience, fitness, motivation, and the normal fluctuation of physiological and behavioral procedures across a 24-h period (i.e., sleep–wake cycle, body temperature, hormone regulation) [15].

Importantly, the circadian rhythms are mainly controlled by the suprachiasmatic nucleus within the hypothalamus [16]. However, the suprachiasmatic nucleus is unable to continuously sustain control over these patterns (i.e., between the suprachiasmatic nucleus within the hypothalamus), as humans are extremely sensitive to changes in their normal environment [16, 17], most notably through the light–dark cycle [18]. When athletes face disturbances to their environments (e.g., training and/or competing close to bedtime sleep and travel), endogenous circadian rhythms and normal sleep-wake cycles can become desynchronized [16, 19]. These perturbations in sleeping patterns can cause an increase in homeostatic pressure and affect emotional regulation, core temperature, and circulating levels of melatonin, causing a delay in sleep onset [20].

Additionally, there is potential for sleep loss and neurocognitive and physiological performance to be compromised [9, 21–23]. Emerging research suggests that there are differences in sleep duration and quality between athletes and healthy controls. In contrast to non-athletes, athletes are often exposed to conditions that can interfere with sleep duration and quality, such as jet lag, unfamiliar sleeping environments, evening training, and/or competition and underlying fatigue [24].

In this sense, sleep monitoring has become a common practice in sport, and, in athletes, it may be useful to identify those who may need an intervention in terms of sleep disorders. Consequently, it is necessary to identify atypical patterns in the sleep and wakefulness of athletes and provide adequate sleep hygiene strategies to avoid disturbances in sleep duration and quality. Efficient and noninvasive methods and equipment, such as actigraphy and other alternatives to polysomnography, can provide detailed information about sleep and wakefulness during the sporting season.

Although there is high availability of information regarding the duration and quality of sleep in different age groups in the general population, information available in the scientific literature about sleep in athletes is still scarce. However, sleep is currently recognized as one of the essential components in the recovery from fatigue and, consequently, in the performance of athletes. Thus, it is essential that athletes, coaches, and clinicians understand the factors that can affect sleep, as well as realizing the usefulness of methods and equipment for assessing the duration and quality of sleep, as this process can result in better health and performance for the athlete.

2. The importance of sleep

Sleep is an essential component for athletes' recovery from fatigue, due especially to its physiological and psychological restorative effects [25]. In fact, it seems important that athletes learn to manage their sleeping and waking times, given the influence on circadian rhythm, since alterations in the biological clock may affect not only the duration and quality of sleep, but, mainly, sports performance [17].

Athletes and coaches recognize the importance of sleep as one of the most important strategies for recovering from fatigue and improving an athlete's performance [2]. However, during the competitive period, it is common for athletes to follow strict training and competition schedules, which, associated with intense training loads and the physical and emotional demands of competitions, may interfere and reduce the duration and quality of their sleep [26] and, consequently, decrease the fatigue recovery process [27]. This potential imbalance can actually occur when training and competitions are held close to bedtime [28]. Furthermore, exercise, when performed close to bedtime, may alter circadian rhythms [29] and sleep patterns (e.g., reducing sleep duration) [28, 30]. In fact, it seems important that athletes learn to manage their sleeping and waking times, given the influence on circadian rhythm, since alterations in the biological clock may affect not only the duration and quality of sleep, but, mainly, sports performance [2].

In the general population, less than 8 h of sleep per night may be associated with alterations in cognitive performance, mood, and wakefulness, as well as with increases in daytime sleepiness episodes [31]. This theme extends to younger athletes, who are expected to have a greater physiological need for sleep (8–10 h per night) compared with adults (7–9 h per night) and who often experience delays in sleep onset and awakening [32, 33]. Similarly, compared with adult athletes, young athletes have different daily commitments, such as school and social activities (including time spent online during the night), which can further alter sleep habits and/or wakefulness [34]. As an example, in an epidemiological study [35], significant reductions in neurocognitive performance (assessed through visual tests of memory and speed of response to a given visual stimulus) were observed in 7150 young athletes from different sports, who had a sleep duration of less than 5 h per night.

However, despite the high availability of information regarding the duration and quality of sleep in different age groups in the general population, in the scientific literature, the information available regarding the duration and quality of sleep in athletes is still scarce [36]. In fact, this seems contradictory given that sleep is currently recognized as one of the essential components in athletes' recovery [25]. Thus, there is a need to investigate, through sensitive and noninvasive methods, the monitoring of sleep patterns and wakefulness in athletes, in order to promote better sleep hygiene and, consequently, better recovery and performance.

3. Sleep, injuries, and performance

The current training and competition demands are topics with the greatest interest and discussion in the fields of sports science and sports medicine. This theme is commonly associated with the problem of sports injuries that affect athletes. In this sense, it is essential that clubs create ideal conditions for the training and development of athletes, integrating strategies and best practices for the prevention, treatment, and rehabilitation of injuries in an integrated perspective for athletes' health and performance.

Sleep can influence the risk of injury and illness. In a study of 122 athletes, it was observed that the risk of injury increased by 65% when athletes slept less than 8 h per night [37]. In another more recent study, it was possible to observe that 23 athletes with reduced sleep durations (<8 h) demonstrated a high association with the increase in musculoskeletal injuries. However, evidence in the literature is still very limited about this association. It is also important to note that sports injury is an emergent complex phenomenon, and the risk factors of injury comprise nonlinear associations between various factors such as the biomechanics, training and

competitions workloads, as well as psychological and physiological characteristics. For example, according to Laux et al. [38] results, the highest risk for injury appears to occur from a synchronized growth in training and competitions workloads and loss in total sleep time; nonetheless, prospective randomized trials determining that decreased sleep quality leads an injury could require a more decisive response. Research on this topic may provide important information for coaches and practitioners in identifying potential strategies to maintain and improve athlete well-being.

Effects of inadequate sleep duration and quality on performance are likely to be seen specifically in competitive athletes, because of their high-performance demands being more likely to show the harmful effects of suboptimal sleep. Research studies have found negative results of sleep deficiency on athletic performance and well-being, specifically relative to time to exhaustion, muscle strength, and mood state [39, 40]. In a study of a sleep banking (i.e., sleep extension) for college basketball players (n = 11, 18–22 age), sleep duration was augmented by 110.9 ± 79.7 min ($p < 0.001$), together with significant increases in daytime sleepiness, reaction time, sprinting time, accuracy, fatigue, tension, depression, irritation, confusion, and mood disturbance [41]. In other study of cyclist's athletes and triathletes [42], an improved endurance performance was shown after three nights of sleep banking (~8.4 h sleep each night) compared with usual sleep (~6.8 h sleep each night), suggesting that endurance athletes' sleep must be >8 h each night to improve performance.

Considering the importance of examining sleep habits and wakefulness in athletes, the impact of training and competition schedules and loads on sleep indices has recently been explored [43–45]. In these studies, it was observed that sleep habits (i.e., the duration and quality of sleep) can be affected by schedule variations and by training and competition loads, especially when sessions are held at night, close to bedtime.

It should also be noted that the sleep habits and wakefulness of athletes may depend on the type of sport practiced [26]. For instance, Lastella et al. [26] investigated sleep/wake behavior of elite athletes, including young female and male athletes, and compared differences between athletes from individual (cycling, mountain bike, racewalking, swimming, and triathlon) and team sports (Australian football, basketball, soccer, and rugby union). Sleep/wake behaviors of elite athletes (n = 124) were well below the recommended 8 h of sleep per night, with shorter sleep duration existing in individual sports. These outcomes suggest that the amount of sleep the athletes obtain depends also on their sport.

That said, and although the duration and quality of an athlete's sleep may be associated with the schedules and loads of training and competition, it is also important to consider other factors that can influence sleep indices and wakefulness, namely age, sex, and chronotype [46]. For example, sex was identified as a risk factor for lifetime sleep problems in elite French athletes, with a greater incidence of sleep problems in female athletes [47]. Age has been shown to relate to the prevalence of poor sleep quality, with athletes >25 years of age reporting greater Pittsburgh Sleep Quality Index (PSQI) scores compared with ages <20 [48]; early fatherhood and/or motherhood could be a causal factor [49]. The age of the athletes was also classified as a risk factor for sleep disturbance previous to a competition; however, habitual sleep quality was not [50]. These findings may indicate that athletes who normally report good sleep quality are not necessarily resilient against sleep disturbance during, for instance, a major competition.

4. Measuring sleep

To detect and control sleep disorders, it is important to monitor sleep habits and perceptions of sleep through subjective and objective measures [51].

In general, the main recommendations on sleep monitoring point to polysomnography, which uses surface electrodes to monitor physiological parameters such as brain, muscle, cardiac, and respiratory activity [52]. Polysomnography is particularly useful for investigating sleep pathologies, including sleep-disordered breathing [53] and sleep disorders caused by concussion [54]. However, polysomnography is an expensive technique and requires specialized laboratory equipment, so its use in athletes in the real context is impractical [55].

On the other hand, actigraphy uses accelerometers placed in portable devices to record movements that, analyzed using algorithms, estimate the quality and duration of sleep [56]. Actigraphy is less expensive, noninvasive, and can be used in training and competition routines, ideally requiring two consecutive weeks of monitoring [57]. Thus, actigraphy emerges as the most accessible method to objectively monitor the sleep of athletes during the night [55]. Overall, wrist-worn accelerometers allow estimation of total sleep time (the total amount of sleep obtained during a sleep period), time in bed (the amount of time spent in bed attempting to sleep between bedtime and get-up time), wake up time (time at which a athlete got out of bed and stopped attempting to sleep), sleep onset time (transition from wakefulness into sleep), wake after sleep onset (number of min awake after sleep onset), latency (the period of time between bedtime and sleep onset time), and sleep efficiency (percentage of time in bed that was spent asleep) [55]. However, it is imperative to highlight that activity monitors tend to underestimate sleep in people who exhibit high levels of movement during light sleep [58]. In fact, some works showed that (elite) athletes obtain less sleep than the general population [59, 60] and present larger movement and fragmentation during sleep [61, 62]. Thus, and given the sleep characteristics of (elite) athletes, it is important to determine how well activity monitors are sensitive to recognize moments of sleep and vigilance in this type of population. This raises a potential issue with the use of activity monitors for measuring sleep in (elite) athletes.

Questionnaires and in particular "sleep diaries" are also used to record the start and end times for all sleep periods (i.e., night sleep and daily naps) [57]. Nevertheless, subjective reports (e.g., PSQI) might deviate from objective measures [63], especially with regard to mood and memory biases, while personality characteristics may also affect self-reported sleep ratings [64]. Indeed, some discrepancies have been detected when comparing subjective parameters with objective measures [65].

Additionally, and considering the ability of monitoring (objectively or subjectively) sleep duration and quality obtained by an (elite) athlete as a useful tool for evaluating recovery from training and competition [55], it is crucial to highlight the importance of individualized monitoring.

Although it is conventional to focus monitoring on group mean responses following a particular training intervention or competition, sport settings frequently produce diverse results with high and low responders being often lost in the averaged data reports [66, 67]. As a consequence, an increased attention for individualization of monitoring in sport settings has growth to a variety of athlete-monitoring approaches, allowing coaches to better manage fatigue and planning training prescription on an individual basis [68].

Nevertheless, research examining the sleep of athletes has typically averaged data across several nights, providing a mean estimate of usual sleep [26, 48, 61]. While such approaches are useful to allow basic insight into sleep (to better understand fatigue and recovery in athletes), they lack the sophistication to provide understanding of how sleep may vary across multiple nights at the individual level [69–71]. Moreover, individual variability can reflect differences within individuals over time [72], with high intra-individual variability in the athletes' sleep indicating

the need for individualized sleep education strategies and interventions to promote appropriate sleep [69].

Although identifying the optimal amount of sleep on an individual basis may be difficult [73], young and adult athletes who exhibit average sleep of less than 8 or 7 h, respectively, likely warrant additional assessment to classify their sleep difficulties. Hence, those athletes that reveal deleterious effects of inadequate total sleep time should be stimulated to use sleep hygiene strategies to increase sleep during night and vigilance during the day [74]. Longitudinal monitoring of training and match load, sleep, fatigue (e.g., through heart rate variability), stress, and mood may not only help identify individuals at risk, but also monitor improvements in sleep, well-being, and performance after interventions [75].

Overall, it might be important to include sleep monitoring in (elite) athletes encompassing individual responses, in addition to group means [69]. Also, special attention should be given to the sleep behavior of (elite) athletes (e.g., total sleep time) during periods of congested fixtures, such as international competitions, since sleep deficits can impair performance [17], as already mention above (point 3).

5. Sleep hygiene

The implementation of strategies that promote sleep quality should be a priority for athletes. In fact, during sleep, fundamental physiological and psychological processes take place for the recovery from fatigue, so the optimization of sleep hygiene strategies increasingly assumes an important role in the routines and planning of those dedicated to improving sport performance.

A recent study [76] evaluated the effect of education on sleep hygiene in athletes. It was found that sleep hygiene education had a considerable positive impact on sleep indices. Educational programs on sleep hygiene in athletes provided a significant improvement in sleep duration and quality and reduced daytime sleepiness. Furthermore, research into the effects of sleep hygiene education on athletes, especially young people, is quite limited [31].

As mentioned before, there are several factors that can influence the duration and quality of sleep in athletes. Calendars congested with competitions and regular trips, competitions of great physical and emotional demand that take place at night, or constant changes in the morning time to wake up because of training and travel are examples of common factors that can negatively influence the duration and quality of sleep in athletes.

In this context, the management of light exposure emerges as fundamental, as this factor has a significant impact on sleep. Exposure to light influences the production of melatonin, so managing the times of exposure to artificial light throughout the day can be used as a sleep management and hygiene strategy. Additionally, in competitions that take place at night, athletes are exposed to immense artificial light: lighting in sports facilities, the projectors used by the media in interviews at the end of competitions, light from busses, airports, and planes.

On the other hand, social contexts may also be decisive. In recent studies carried out with female soccer players in Portugal, who usually start training very late, close to bedtime, due to their daily commitments (e.g., work, studies) that have to be reconciled with the training and match schedules, it was found that the athletes showed a reduction in total sleep time and length of time to fall asleep on training days performed at night, compared with training days performed during the day or on rest days (i.e., days without exercise) [28, 44]. It was pointed out that one of the additional explanations for the observed results could have been in the athletes'

exposure to the light emitted in the stadium. In fact, these data are little studied in sport, but during the training days, the athletes were exposed to >1200 lux and 5600 K, with the bright polychromatic light ≥1000 lux, which could be enough to stimulate wakefulness effects during sleep [77]. However, it should be borne in mind that, currently, one of the main sources of exposure to light results from the use of electronic devices (especially smartphones and tablets) and that their use around bedtime is possibly the factor that most influences the sleep latency of athletes.

Thus, the term sleep hygiene, which refers to the recommendations, strategies, behaviors, and conditions developed to promote quality and duration of sleep, has been appearing more and more often in the list of sports planning tasks for athletes [25]. It is important to be aware that, unlike other possible recovery strategies used in sport (e.g., cryotherapy, massage, nutrition, nutritional supplementation), sleep has particularities that are not always controlled by the athlete themselves. Thus, bearing in mind the importance that sleep can have on sports performance, this is a subject that deserves the greatest attention of all those dedicated to promoting health and performance in athletes.

6. Conclusions

Athletes, coaches, and supporting staff should adopt a scientific approach to both designing and monitoring training programs. Appropriate health and load monitoring is crucial for determining whether a player is adapting to a training program and minimizing the risk of developing nonfunctional overreaching, illness, or injury. To gain understanding of the training and match demands and their effects on the player, several potential markers are available. However, very few of them have strong scientific evidence supporting their use. Moreover, it is important to note that athletes, from different types of sports, normally obtain inadequate sleep duration and quality. From an athletic point of view, reductions in performance, decision-making ability, learning, and cognition can occur alongside reductions in immune function and an increased susceptibility to injury gain.

In this respect, monitoring sleep in athletes can be useful for early detection and intervention before significant performance and health decrements are observed. Noninvasive and time-efficient methods/equipment such as wearable actigraphy monitors can provide detailed information about positive and negative adaptions over short and long periods throughout the competitive season. In addition, each athlete can perform the recordings at home and/or training facilities, adopting a "real world scenario" to grant high ecological validity to the research and/or practical interventions. The accumulated knowledge regarding the importance of sleep has sleep monitoring to become a popular strategy among (elite) athletes, coaches, and supporting staff. However, given the complexity of analyzing sleep patterns and the limited availability of athletes to participate in sleep studies, those indicators are yet poorly documented.

Overall, factors related to training and competition can alter sleep patterns in athletes. Therefore, topics such as: (1) sleep patterns and disorders among athletes; (2) sleep and optimal functioning among athletes; (3) screening, tracking, and assessment of athletes' sleep; and (4) interventions (i.e., sleep hygiene) to improve sleep must be further investigated.

Conflict of interest

The authors declare no conflict of interest.

Author details

Júlio Costa[1*], Pedro Figueiredo[1,2], Fábio Y. Nakamura[3] and João Brito[1]

1 Portugal Football School, Portuguese Football Federation (FPF), Oeiras, Portugal

2 CIDEFES, Universidade Lusófona, Lisboa, Portugal

3 Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD), University of Maia (ISMAI), Maia, Portugal

*Address all correspondence to: jahdc@hotmail.com

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