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Review

Optimizing sleep to maximize performance: implications and recommendations for elite athletes

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Despite a growing body of literature demonstrating a positive relationship between sleep and optimal performance, athletes often have low sleep quality and quantity. Insufficient sleep among athletes may be due to scheduling constraints and the low priority of sleep relative to other training demands, as well as a lack of awareness of the role of sleep in optimizing athletic performance. Domains of athletic performance (e.g., speed and endurance), neurocognitive function (e.g., attention and memory), and physical health (e.g., illness and injury risk, and weight maintenance) have all been shown to be negatively affected by insufficient sleep or experimentally modeled sleep restriction. However, healthy adults are notoriously poor at self-assessing the magnitude of the impact of sleep loss, underscoring the need for increased awareness of the importance of sleep among both elite athletes and practitioners managing their care. Strategies to optimize sleep quality and quantity in athletes include approaches for expanding total sleep duration, improving sleep environment, and identifying potential sleep disorders.

In recent years, increased attention has been paid to the essential role of sleep in health and well-being. However, like numerous other important health-related behaviors, many athletes still experience inadequate sleep (Samuels, 2009; Silva et al., 2012). Compared with non-athletes, athletes tend to sleep less (6.5–6.7 h per night) and the quality of their sleep is lower (Fietze et al., 2009; Mah et al., 2011; Leeder et al., 2012; Hausswirth et al., 2014; Sargent et al., 2014). Limited additional research suggests that some athletes, in particular National Football League (NFL) players, have higher rates of obstructive sleep apnea/sleep disordered breathing, a sleep disorder that reduces night time sleep quality and often results in high levels of daytime sleepiness (George et al., 2003; Albuquerque et al., 2010).

We now know the consequences of inadequate sleep are especially important for athletes given the relationship between sleep and athletic performance.

Athletes face a unique set of constraints in their efforts to sleep well. Training schedules, available practice times, lengthy travel to competitions, jet lag, and pre-competition anxiety can all impact the quality and quantity of sleep prior to performance (Mah et al., 2011; Sargent et al., 2014; Juliff et al., 2015). Several studies have documented a competitive advantage for West Coast–based teams in evening games, ostensibly due to the impact of circadian misalignment (Jehue et al., 1993; Smith et al., 2013). Circadian rhythms can also result in variations in peak performance based on the time of day and typical training schedules, both of which can have an effect on performance in competitions (Drust et al., 2005).

Among athletes, sleep may be deprioritized relative to other training needs. A pervasive attitude in our modern culture has been that the ability to tolerate insufficient sleep is a strength and is perceived as a badge of honor (e.g., Adler, 2009). More recently, however, several high profile athletes have identified the importance of sleep as a means to improve performance (Schultz, 2014). However, it is likely that these recent public statements remain the exception rather than the rule when it comes to prioritizing the importance of sleep among athletes on a night-to-night basis.

Further, an individual's ability to self-assess their level of sleep impairment is poor (Van Dongen et al., 2003), making it difficult for athletes to gauge the impact of potential insufficient sleep on performance. Research has shown that objective performance becomes impaired in a dose-dependent manner (greater sleep loss equates to greater performance impairment); however, subjective assessments show a leveling of perceived sleepiness (impairment) that persists as sleep loss accumulates (Van Dongen et al., 2003). A useful comparison for the impact of sleep loss equates the degree of impairment to the effects of alcohol. Strikingly, performance impairments equivalent to those of 0.05% blood alcohol content (BAC) are found after only 17–19 h of wakefulness, and 28 h of wakefulness is equivalent to 0.10% BAC (Williamson & Feyer, 2000).

The goal of this article is to increase awareness of the importance of sleep for maximum athletic performance, as well as to provide strategies for athletes to optimize their own sleep patterns. This review is organized into three sections: (1) the impact of sleep on athletic and neurocognitive performance, (2) the relationship between sleep and physical health, and (3) strategies to optimize sleep in athletes.

Methods

A literature search on empirical articles published before October 2015 on sleep and performance in athletes was conducted on Web of Science. Initial search terms were ["sleep quality" OR "sleep duration"] OR ["sleep deprivation" OR "sleep restriction" OR "sleep extension"] AND ["athletics" OR "athletes"] AND "athletic performance." A more expanded search for individual domains of performance (e.g., endurance, speed) was also conducted. All articles that contained quantitative assessment of performance and a standardized assessment of sleep (including both objective measures and validated self-report questionnaires assessing duration or quality) were included. Targeted literature searches were then conducted in neurocognitive domains and physical health/injury risk, with a focus on outcome measures of particular relevance to athletes and athletic performance (e.g., risk of illness, executive functioning, attention-related performance).

Results

Effects of sleep loss on athletic performance

There are multiple overlapping areas of performance that are substantially affected by inadequate sleep, including speed, endurance, strength, attention, executive function, and learning. This section reviews these findings, broadly categorized into the domains of physical and neurocognitive performance.

Physical performance

Treadmill tests have been used to assess the impact of experimental sleep loss on speed and endurance. Two studies found that shorter distances were covered during timed tests following one night of total sleep deprivation (Oliver et al., 2009; Skein et al., 2011), with one documenting participants reporting similar effort on both rested and sleep-deprived trials (despite impaired performance) (Oliver et al., 2009). This finding complements the observation that increased compensatory effort is needed under conditions of sleep loss in order to "remain behaviorally effective" (Goel et al., 2009). Thus, sleep loss appears to reduce athletic performance despite equivalent applied effort and may relate to observed reductions in glycogen stores in muscles *even prior to performance* following just one night of total sleep deprivation (Skein et al., 2011). One night of sleep loss has also been shown to reduce time to exhaustion and increase resting oxygen uptake and resting carbon dioxide production (Azboy & Kaygisiz, 2009). Even a single night of partial sleep loss has been shown to increase heart rate and oxygen consumption, as well as higher lactate levels during a cycling test (Mougin et al., 1990). Together, these findings demonstrate that sleep loss has a direct physiologic effect that translates into reduced speed and endurance.

Studies examining strength/lifting performance impairments following sleep restriction report mixed results. One study of 10 collegiate male weightlifters observed no significant difference in lifting performance after a night of total sleep deprivation, despite increases in negative affect, fatigue, and sleepiness (Blumert et al., 2007), while another found that anaerobic performance (power) was not significantly affected after one night of sleep loss (Taheri & Arabameri, 2012). A third weightlifting study found that sleep restriction over 3 days was associated with a lower maximum weight lifted in tasks that required the largest muscle groups (Reilly & Piercy, 1994). These studies are small and have used several strategies to assess power. More research is needed to better understand how inadequate sleep may affect this performance domain.

Even mild sleep restriction can affect accuracy in athletic performance. In a study of tennis players, reducing sleep duration to 5 h for a single night impaired serving accuracy from an average of 53–37% (Reyner & Horne, 2013). Sleep loss also has been shown to impair dart throwing accuracy following a night of sleep restricted to 4–5 h when compared with a full night's sleep (Edwards & Waterhouse, 2009). This study also demonstrated decrements in throwing accuracy as a function of chronobiological factors (i.e., time of day) (Edwards & Waterhouse, 2009).

While the studies described above document the negative impact of inadequate sleep on athletic performance, there are limited data assessing the impact of extending sleep on performance—either via increasing nocturnal sleep duration or use of daytime naps. Two studies have demonstrated the beneficial effects of *increasing* sleep duration. In one study, college men's basketball players were encouraged to obtain as much nocturnal sleep as possible and were able to increase objectively measured average sleep durations from an average of 6.6 h/night to 8.5 h/night (Mah et al., 2011). Compared with baseline, performance following the 5- to 7-week sleep extension period reflected a 5% increase in speed, 9% increase in free throw accuracy, 9% improved free-throw percentage, and 9.2% increase in three-point field goal percentages (Mah et al., 2011). Another study found that expanding sleep duration by an estimated 2 h per night improved the serving accuracy of college tennis players from 36% to 41% (Schwartz & Simon, 2015). The available data on the impact of daytime naps are mixed. One small study (n = 10 men) found that a 30-min nap following a night of partial sleep restriction improved alertness and sprint times, among other domains (Waterhouse et al., 2007). Another larger observational study of ultra-endurance cyclers found that sleep time during the an 600-km race (e.g., nap periods) had no impact on race time, although the duration of performance in this study may be longer than the competition periods faced by most athletes (Knechtle et al., 2012). While these studies are preliminary in nature, overall, they provide encouraging data that improving sleep can be an effective performance enhancement strategy.

In summary, athletic performance deteriorates with even mild sleep loss (sleeping 4–5 h compared with 7–8 h) across a number of domains including speed, endurance, and performance accuracy. While these performance metrics are interrelated, the consistency of significant findings suggest that adequate sleep plays an integral role in peak physiological performance. More recent data also suggest that extending (increasing) total sleep time can significantly improve performance on these metrics.

Neurocognitive performance

Peak athletic performance, particularly during competition, requires optimal neurocognitive functioning. Insufficient sleep has been shown in multiple studies to erode neurocognitive function in several domains central to athletic performance, including attention, executive functioning, and learning.

Attention. Numerous studies show that sleep loss negatively impacts attention (Dinges et al., 1997; Vgontzas et al., 2004). There is also mounting evidence that "catching up" on sleep following chronic sleep restriction does not immediately restore full performance (Belenky et al., 2003). This finding is particularly important for athletes, who may undergo a period of mild sleep restriction during intense pre-competition training with the false expectation that they can "catch up" on sleep in the night or two before a big event and erase any performance deficits. While there are inter-individual differences in susceptibility to the effects of sleep loss, with some individuals being more resilient to the effects of sleep loss than others (Van Dongen et al., 2004), to date there is no accurate way to identify vulnerable individuals outside of laboratory testing, and, as described earlier, self perception of sleep-related impairment is poor (Van Dongen et al., 2003).

Executive function. Arguably, executive function is the most important domain for athletic performance during competition. Executive functioning encompasses the higher level thinking required to apply strategy, make decisions, and manage attention. Sleep loss erodes executive functioning, particularly on tasks requiring flexible thinking and learning (Goel et al., 2009). Inhibitory control, or the ability to refrain making impulsive or risky decisions, is also critical to athletic performance and is negatively affected by even one night of sleep loss (Harrison & Horne, 2000; Killgore et al., 2006; Killgore et al., 2011; Anderson & Platten, 2011; Rossa et al., 2014). These studies collectively suggest that insufficient sleep may have a significant negative impact on athletes' ability to make a game time decision, read, and react to an opposing defense or implement a specific competition strategy.

Learning. The ability to learn new skills is also essential to high-level athletic performance. Sleep fosters increased consolidation of memories and allows for faster and better performance on learned tasks requiring physical execution. One landmark study demonstrated that a night of sleep results in a 20% increase in motor speed without the loss of accuracy, compared to a similar amount of time awake (without incurring sleep loss) (Walker et al., 2002). There is also evidence that sleep and dreaming is critical to off-line memory re-processing/consolidation (Stickgold et al., 2001) and visual discrimination (Stickgold et al., 2000). For a full review of sleep-dependent learning findings, the reader is referred to the review by Walker and Stickgold (2004). The relationship between learning and sleep is of particular relevance to collegiate athletes, who are faced with meeting multiple academic and athletic demands. See Curcio et al. (2006) for a review of sleep loss, learning capacity, and academic performance.

Effects of sleep loss on physical health

Maintaining and optimizing physical health is essential for peak athletic performance. From a most basic level, the ability to stay healthy and avoid illness and injury is critical for athletes' ability to perform. This includes maintaining an ideal body mass and the ability to tolerate the discomfort of physical training. These aspects of physical health directly relevant to athletic performance are nested within a much broader literature documenting links between sufficient sleep and risk for diabetes, cardiovascular diseases, and mortality among others (Ayas et al., 2003; Gangwisch et al., 2007; Grandner et al., 2010).

Injury risk

There is accumulating evidence that insufficient sleep increases risk of injury. Adolescents sleeping less than 8 h/night were found to be 1.7 times more likely to experience a significant injury than those who slept more than 8 h (Milewski et al., 2014). The impact of inadequate sleep on reaction time and cognitive abilities (see performance section above) is likely to contribute to this increased injury risk. Data drawn from other fields (e.g., insufficient sleep and motor vehicle accidents and medical errors) also show striking increases in risk of accidents and injury with sleep loss (Lyznicki et al., 1998; Barger et al., 2005; Centers for Disease Control & Prevention, 2015). Young adults, the prime age for most athletes, have been shown to be at even greater risk for sleepiness-related errors or accidents (under simulated conditions) compared with older adults (Cappuccio et al., 2010; Filtness et al., 2012).

Illness susceptibility

Maintaining a state of physical well-being is essential for optimal athletic performance, and increasing evidence suggests that sleep is protective against illness risk. Among the most powerful evidence for this comes from a study conducted by Cohen et al. (2009). In this study, participants tracked their sleep and then were inoculated with a dose of active cold virus (Cohen et al., 2009). Individuals sleeping less than 7 h/night prior to the inoculation were three times more likely to develop a cold after a direct application of cold virus than those sleeping 8 h or more (Cohen et al., 2009). A follow-up study by this research team found a significant increase in risk of developing a cold with less than 6 h of sleep per night (Prather et al., 2015) compared with sleeping 7 or more hours. Observational data from adolescents also showed that longer sleepers reported fewer illnesses than shorter sleepers (Orzech et al., 2014). Sleep also helps support a healthy adaptive immune response to vaccinations (Benedict et al., 2012; Prather et al., 2012), another effective method of reducing illness risk.

Weight maintenance

Maintaining an ideal body mass can help optimize performance and, in some sports, determines if an athlete is able to compete in a particular weight class (e.g., rowing or wrestling). There is a wealth of data showing a relationship between sleep duration and body mass index (BMI), with short sleep durations in particular associated with higher BMIs. These associations have been observed in epidemiological studies both cross-sectionally (Taheri et al., 2004) and prospectively (Chaput et al., 2008). Further, short sleep durations are associated with changes in metabolic hormones related to appetite and food consumption in both epidemiological (Taheri et al., 2004) and experimental sleep restriction (Spiegel et al., 2004; Simpson et al., 2010) studies. These changes in hormone patterns can help explain changes in food intake patterns that follow sleep restriction, with a shift towards increased carbohydrates and snacks (Nedeltcheva et al., 2009), increased portion sizes (Hogenkamp et al., 2013), and a decreased ability to process glucose (Schmid et al., 2011). There are also limited data suggesting that poor sleep quality (either observed or reduced through experimental manipulation) is associated with reduced glucose metabolism (Stamatakis & Punjabi, 2010; Byberg et al., 2012), suggesting that sleep quality, as well as quantity, may be important for optimal health maintenance. Together, these data demonstrate that obtaining adequate sleep can be an important behavioral strategy for developing and maintaining an ideal weight and body composition for athletic performance.

Pain tolerance

Increased pain tolerance can allow athletes to train more intensely, compete with greater focus, and engage more fully in rehabilitation after injury. Sleep is intimately involved in pain regulation, with one study finding an 8% decrease in pain threshold tolerance after a single night of total sleep deprivation (Onen et al., 2001), and others showing small but significant increases (5–10%) in spontaneously reported generalized pain after both total and partial sleep restriction (Haack et al., 2007, 2009). Interestingly, one study of mildly sleepy but otherwise healthy adults (reflective of inadequate habitual sleep duration) found that extending sleep opportunities for four nights increased pain tolerance by 20% (Roehrs et al., 1989).

Table 1. Recommendations for Improving Sleep in Athletes

Obtain adequate total sleep duration
Strategy 1: Track sleep for 2 weeks using a self-report sleep diary (example: http://yoursleep.aasmnet.org/pdf/sleepdiary.pdf). Gradually increase sleep duration by 15 min every few nights, until athlete feels well rested and alert during the day. Consider increasing nighttime sleep by 30–60 min/night; this is particularly important if average sleep duration is <7 h/night
Strategy 2: Consider implementing regular naps, beginning on weekends or off-days if needed. Allow adequate time to return to full alertness after daytime naps
Maintain healthy sleep habits
Strategy 1: Develop a good sleep environment: the ideal room is cool, dark, and comfortable. Avoid having/using electronics or personal devices in bedroom
Strategy 2: Avoid alerting factors in the evening. Reduce ambient light exposure in late evening hours as possible, limit electronic device use at least 1 h prior to bedtime, allow for a 30–60 min relaxing wind-down period before bed. Ideally, consume no caffeine after lunch; limit alcohol use in late evening
Minimizing impact of travel
Strategy 1: Factor-in time needed to adjust to new time zone; as a rule of thumb, the body can adjust to 1 h of time zone difference each day. Consider starting to shift body clock prior to departure or during flight; personalized travel planners (available online) may be helpful
Strategy 2: Reduce impact of non-jet lag travel effects: dehydration, acoustic stress, low physical activity, changes in food/drinking patterns
Identify/address possible sleep disorders
Strategy 1: Consider referral to sleep clinic if athlete has difficulty sleeping or is experiencing high levels of daytime sleepiness despite adequate opportunity
Strategy 2: Athletes with insomnia but limited access to a sleep clinic may benefit from online treatment with cognitive behavioral therapy for insomnia (CBTI)
Assess impact of improved sleep on athletic performance
Consider conducting pre- and post-assessment of a relevant performance metric for the athlete (e.g., sprint times) after implementation of sleep improvement strategies. Conduct post-assessment after 2–4 weeks of improved sleep to best assess the effects of behavioral changes

Strategies to optimize sleep in athletes

This section reviews approaches to improving sleep duration and sleep quality and suggests countermeasures to offset the negative impact of insufficient sleep and jet lag. Recommendations for identification and referrals for treatment of potential sleep disorders are also discussed (Table 1). It is important to consider that "sleep symptoms" are a common symptom of overtraining syndrome (Mackinnon, 2000); as such, the presence of sleep disturbances should also prompt a review of overtraining symptoms among at-risk athletes and addressed as appropriate.

Improving total sleep duration

The amount of sleep needed varies based on age, physical activity, and a range of other individual factors; however, most adults need between 7 and 9 h of sleep per night (Hirshkowitz et al., 2015). The most recent consensus statement of the American Academy of Sleep Medicine and Sleep Research Society states that adults should sleep 7 or more hours per night and that sleeping more than 9 h/night may be appropriate for young adults (Watson et al., 2015). While not yet tested empirically, it has been suggested that athletes need comparably more sleep than non-athletes to ensure adequate physiological and psychological recovery from training (Bird, 2013). Other proponents of increased sleep time in athletes suggest that athletes should obtain 80 h of sleep total per week, including nightly sleep duration and naps (Samuels, 2009). While sleeping an average of 11.4 h per 24 h period (the equivalent of 80 h/week) may not be necessary or even feasible for most athletes, there are data supporting the idea that athletes may benefit from more than an "average" amount of sleep for recovery from athletic training as well as to maintain peak performance (Mah et al., 2011).

As a first step to optimizing sleep, we recommend that athletes track their sleep patterns for 2 weeks, using either a basic self-report diary or a personal sleep monitor. It should be cautioned that personal sleep monitors may have limited accuracy, particularly those that assess sleep while placed on the bed and not worn on the body. If sleep duration is below 7 h/night on average, athletes should be encouraged to engage in a "behavioral experiment" in which they test the effects of extending their sleep duration (initially by 30–60 min/night) on a desired performance metric (e.g., sprint times) before and after a 2- to 4-week period of increased sleep. Athletes already sleeping greater than 7 h may also benefit from a trial of increased sleep duration. Strategies to increase sleep duration include increasing nighttime sleep duration and implementing (or increasing) daytime naps. To date, there are no available data on the relative benefit of increasing total sleep duration (e.g., nighttime sleep duration plus naps) relative to nighttime sleep duration alone, or when it may be optimal to add sleep time to receive maximum athletic performance benefit. Guiding principles suggest adding sleep time when feasible based on scheduling limitations, and also at times of day in which the athlete will be able to sleep more easily (e.g., moving bedtime earlier for a "morning person" or waking later for a person with night owl tendencies). Strategies for implementing naps are described in the napping section below. It should be noted that while protecting/increasing sleep opportunity can be beneficial for increasing sleep duration, "trying to sleep," or exerting effort to sleep once in bed, may create sleep problems and result in decreased total sleep time. This is particularly important for athletes who have insomnia or other difficulties in sleeping (Broomfield & Espie, 2005).

Improving sleep quality/healthy sleep habits

Healthy sleep habits can help athletes develop the highest quality sleep possible and obtain the most restorative benefit from their sleep. These habits fall into two main categories: sleep environment factors and pre-sleep behaviors.

Sleep environment. The ideal sleeping environment is cool, dark, quiet, and comfortable (like "sleeping in a cave"). Sleeping in conditions that are too warm or light can disrupt the body clock and lighten sleep (Lack et al., 2008; Dijk & Archer, 2009). Ambient noise can also disrupt sleep through full or partial arousals from sleep. A comfortable sleep environment is also essential with respect to both physical comfort (e.g., appropriate mattress firmness) and also feeling safe and secure in the bedroom. The majority of strategies to improve athletes' sleep environments rely on practical solutions: use of a room fan to cool temperatures; an eye mask or light-blocking window shades to reduce light; and earplugs, fan, white noise machine, or white noise "app" to block or reduce disruptive noise. Comfort with the sleep environment may require a new mattress or a mattress topper or adjustments to roommate arrangements.

Pre sleep behaviors. An athlete's daytime routine can also impact their nighttime sleep. The main areas to consider are substances, light, and schedule.

Substance use: Athletes should be encouraged to end caffeine use (outside of strategic use for performance—see below) after lunchtime given its long half-life (3–7 h for most adults) (Fredholm et al., 1999). Alcohol consumption should also be avoided or limited for 3–4 h prior to sleep onset. While the initial effects of alcohol are sedating and are sometimes thought to be helpful for sleep, as alcohol is processed by the body it can have a significant disruptive effect on sleep (Roehrs & Roth, 2001). Use of other substances (e.g., nicotine, Adderall) with stimulant effects is also cautioned in the evening hours; the exact timing of the suggested cut-off point depends on the half-life of the individual substance. While there is increasing evidence for the use of herbal substances or nutraceuticals to improve athletic performance and recovery (e.g., Bell et al., 2015), to date, there is limited available empirical support for use of these substances to improve sleep in athletes or the general population (Halson, 2014; Yurcheshen et al., 2015).

Exposure to light during the daytime can also impact sleep quality and quantity. Exposure to bright light in the late evening can have an alerting effect and may result in difficulty falling asleep at the desired time through reducing or delaying the release of melatonin (a natural sleep regulating hormone) (Duffy & Czeisler, 2009). To avoid this, lights should be lowered and use of personal devices with LED screens should be avoided for several hours prior to bedtime. Data suggest that even 1–2 h of tablet use before bed can impact melatonin release (Figueiro et al., 2011). Seeking bright light exposure in the morning, however, is recommended as it can increase alertness and help set or maintain the desired biological sleep/wake rhythm (Duffy & Czeisler, 2009; Wood et al., 2013).

Establishing a sleep/wake routine: Maintaining a regular sleep schedule helps to optimize circadian (biological) effects on sleep/wake cycles (Manber & Carney, 2015). Contrary to what is commonly believed, the most effective way to stabilize a circadian rhythm is by anchoring the wake time, rather than the bedtime. As it is often difficult for athletes with early morning competition or travel schedules to maintain a regular sleep schedule, trade-offs with respect to the amount of sleep maintained must be balanced with implementing a regular schedule. Finally, as higher levels of cortical arousal can interfere/delay sleep onset, athletes who have difficulty sleeping should additionally build in a 30- to 60-min wind down routine before bed in order to transition into a more relaxed brain state before bedtime (Manber & Carney, 2015). The content of the wind down is flexible, but the individual should be engaging in relaxing, pleasant, non-productive activities (e.g., reading, taking a bath, stretching).

Countermeasures: In an ideal world, athletes will approach key performances fully rested; however, this is often not feasible. In these situations, "countermeasures" can help buffer the negative effects of insufficient sleep. The main countermeasure approaches are naps and caffeine.

Naps. While the majority of the sleep period should occur at night in order to best align with the normal circadian rhythm, daytime naps can increase overall sleep duration. They also provide a short-term general performance boost under conditions of sleep restriction (Brooks & Lack, 2006). A caution is that longer naps (e.g., greater than 30 min) may lead to a period of lingering "sleep inertia," or grogginess, and impaired performance after waking (Brooks & Lack, 2006). The timing of naps is also important to consider, as it may be relatively easier for the athlete to fall asleep at different times of the day; additionally, naps taken late in the day may have a negative impact on nighttime sleep (Borbely, 1982). Athletes may more easily be able to initiate sleep during daytime hours by taking advantage of circadian alerting rhythms, which generally demonstrate a slight afternoon "dip" (making sleep initiation easier) (Borbely, 1982). For a more extensive description of impacts of nap length, time of day, and age on general performance and well-being, please refer to the review by Milner and Cote (2009). Effects of naps on physical performance mixed, but to date few have examined the impact of naps when controlling for nighttime sleep duration (Waterhouse et al., 2007; Knechtle et al., 2012; Petit et al., 2014). Thus, the available data suggest that naps may be a useful way to increase habitual sleep duration, general performance, and feelings of alertness, more so than as a day-of-performance improvement strategy.

Caffeine. It is well known that strategic use of caffeine can improve athletic performance (for review, see Sökmen et al.,

2008) and that caffeine is helpful in minimizing the effects of sleep loss/sleep inertia on general performance (Van Dongen et al., 2001). The broader literature on the effects of caffeine on performance following sleep loss is complex, for example, suggesting that caffeine may buffer an individual against sleep-related impairments in risk taking (Killgore et al., 2011) but not decision making (Killgore et al., 2012). Few well-controlled studies examine the impact of caffeine on athletic performance following sleep loss. In one small study of tennis players, caffeine had no beneficial effect on serving accuracy in sleep-deprived participants (Reyner & Horne, 2013). Together, these studies suggest that caffeine may not universally counter performance deficits related to sleep loss.

Minimizing impact of travel on sleep

Jet lag occurs when there is a misalignment between an individual's internal sleep/wake rhythm and the new (local) time zone and can have a significant negative impact on both night-time sleep quality/quantity and daytime alertness. A rule of thumb is that it takes approximately 1 day to adjust to each time zone crossed. Athletes who need to maximize their performance upon arrival may consider either attempting to avoid synchronization to the local time zone if the new time none is out of phase with their normal performance rhythm (as hypothesized by Youngstedt & O'Connor, 1999) or beginning to transition their sleep wake schedule before traveling to minimize the effects of jet lag on performance upon arrival. Specifically timed light exposure, melatonin supplements, and other environmental cues, such as physical activity, can all minimize the impact of jet lag (Sack, 2010). Jet lag management programs (available online) can create an individual plan for travel based on destination and habitual sleep patterns. Additionally, air travel frequently results in dehydration, stress from noise and physical crowding, and changes in physical activity and eating/drinking patterns. Increasing fluid intake, use of earplugs and eye masks, and planned stretching breaks during flight can minimize these symptoms. While there is limited research on adjusting to jet lag specifically in athletes, several recent position papers describe how the effects of jetlag on athletic performance can be mitigated (Forbes-Robertson et al., 2012; Samuels, 2012).

Altitude: Sleeping at altitude or simulated altitude is a widely used training strategy for athletes (Kinsman et al., 2005), despite a lack of well-controlled studies supporting its utility (Lundby et al., 2012). In the general population, sleeping at altitude has been shown to negatively affect sleep architecture and quality (Latshang et al., 2013). There are little available data examining the relative trade-offs of impaired sleep vs potential performance gains obtained by training at altitude. This need for additional research is reflected in a recent review of sleep altitude training, which stated that the research is not sufficiently advanced to make specific recommendations for athletes at this time (Lundby et al., 2012).

Identifying/treating sleep disorders and other contributing disorders

If sleep difficulties or excessive daytime sleepiness are experienced even with sufficient time allowed for sleep, a sleep disorder may be present and a referral for further evaluation at a sleep disorder clinic is appropriate. Insomnia, obstructive sleep apnea, and circadian rhythm disorders (mismatches between internal body clock rhythms and desired sleep/wake schedules) are relatively common in adults and are treatable medical conditions. Contrary to public opinion, athletes experience disrupted or poor quality sleep at higher rates than non-athletes and may have higher rates of sleep disorders [particularly among professional football players (Samuels, 2009; George et al., 2003)]. For insomnia disorder, online treatments (e.g., cognitive behavioral therapy for insomnia) are also available if face-to-face treatment is inaccessible. In addition, mental health disorders, such as depression and anxiety, often have symptoms of disrupted sleep, so it is important to consider sleep disturbances within an overall assessment of athlete well-being and make referrals to appropriate mental health services as needed.

Perspectives

An increasing body of research documents the negative impact of sleep loss on human performance across a range of domains. While the literature on sleep patterns in athletes and the impact of insufficient sleep on athletic performance are in their nascency (Fullagar et al., 2015), there is a robust body of evidence documenting global performance impairments (e.g., on attention) and negative health effects following sleep loss, which can directly affect athletic performance potential. Increasing awareness of the broad range of consequences of inadequate sleep is one way to encourage elite athletes to prioritize obtaining optimal sleep. Drawing from the clinical sleep literature, additional strategies of increasing sleep duration/improving sleep quality and quantity and assessing impact on performance are essential, as is the identification/treatment of common sleep disorders. Implementing these effective strategies to optimize their own sleep patterns give athletes an additional tool in their arsenal to maximize athletic performance.

Key words: Athletic performance, cognitive function, sleep restriction, insufficient sleep.

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