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Sleep Hygiene for Optimizing Recovery in Athletes: Review and Recommendations

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Abstract

For elite athletes who exercise at a high level, sleep is critical to overall health. Many studies have documented the effects of sleep deprivation in the general population, but few studies exist regarding specific effects in the athlete. This review summarizes the effects of sleep deprivation and sleep extension on athletic performance, including reaction time, accuracy, strength and endurance, and cognitive function. There are clear negative effects of sleep deprivation on performance, including reaction time, accuracy, vigor, submaximal strength, and endurance. Cognitive functions such as judgment and decision-making also suffer. Sleep extension can positively affect reaction times, mood, sprint times, tennis serve accuracy, swim turns, kick stroke efficiency, and increased free throw and 3-point accuracy. Banking sleep (sleep extension prior to night of intentional sleep deprivation before sporting event) is a new concept that may also improve performance. For sports medicine providers, the negative effects of sleep deprivation cannot be overstated to athletes. To battle sleep deprivation, athletes may seek supplements with potentially serious side effects; improving sleep quality however is simple and effective, benefiting not only athlete health but also athletic performance.

Keywords

sleep deprivation; athletes; sleep hygiene; exercise; athletic performance; sleep extension

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Conflict of Interest

Authors declare that they have no conflict of interest.

Introduction

Sleep is an essential body function that frequently does not get sufficient attention. Traditionally, diet and exercise have been viewed as the two cornerstones to health and longevity. The authors consider however the three pillars of health to include diet, exercise, and sleep, and argue that ignoring one causes the other two to suffer. We feel people who are sleep deprived may perform poorly in peak exercise and may crave unhealthy foods that can promote weight gain. Similarly, we propose dietary indiscretions can yield poor sleep and may impair athletic performance. We believe optimizing all three pillars is critically important to overall health and recovery, and is a better strategy than resorting to supplements and energy drinks that athletes (and the general population) may turn to when fatigued and lacking adequate sleep.

Many different sleep disorders exist, and often people remain undiagnosed and untreated. Sleep apnea is a common condition that affects at least 10 % of the adult US population [1]. Although typically considered a disease of obese men, lean individuals including elite athletes may suffer from this problem [2]. Similarly, insomnia is a common condition that can be treated effectively if the problem is recognized and appropriately addressed. Even in people without sleep disorders, insufficient sleep duration has negative health effects that can impact all aspects of an individual's well-being. Elite athletes can suffer from these conditions and may be unaware of them unless specifically evaluated. Although further discussion of these disorders is beyond the scope of this paper, certain sleep symptoms, e. g., having difficulty falling asleep or maintaining sleep, may indicate a sleep disorder and should prompt both athlete and clinician to seek further evaluation.

In this review, we provide a novel comprehensive review summarizing both the detrimental effects of sleep deprivation in athletes and benefits of sleep extension on athletic performance. Prior studies have documented the effects of sleep deprivation in the general population [3–5], but few studies exist regarding specific effects in the athlete [5–7], including key aspects such as reaction time, accuracy, strength and endurance, and cognitive function. Furthermore, there is a paucity of research on benefits of sleep extension in the athlete and gaps still exist in the literature. We review the available literature on these key areas and provide clinical commentary and recommendations to equip clinicians with the most up-to-date knowledge for primary and secondary care. For sports medicine providers, the negative effects of sleep deprivation cannot be overstated to athletes and knowledge of proper sleep hygiene is critical for general practitioners to promote athlete health and performance. We give recommendations for practitioners who treat athletes and provide clinical commentary on associated topics including circadian rhythm, exercise timing, and mitigating jet lag, all relevant subjects in athletes who travel frequently and cross several time zones. Lastly, we provide both traditional sleep hygiene strategies and alternative "tips and tricks" for athletes to improve quality of sleep, and when to seek medical attention if they suspect a sleep disorder.

Materials and Methods

The study was conducted in accordance with recognized ethical standards and national/international laws and met the standards of the journal's ethical standards document [8]. A PubMed/Medline literature search was performed for research articles from 1980 through 2018 using MeSH keywords "Sleep Deprivation," "Athletes," "Sleep Hygiene," "Exercise," "Athletic Performance" and additional search terms "sleep extension," "sleep quality," "jet lag syndrome, "circadian rhythm," without restrictions for language, sex or age. Additionally, references of articles meeting search criteria were manually scanned for relevance. Studies not involving athletes, trained or recreationally active young/healthy subjects were excluded, as were studies where sleep was not the primary outcome measure, and animal studies. Seventy-nine studies were retrieved and screened, of which 40 relevant studies are reviewed. Extracted articles were very heterogeneous, which prevented data pooling; most are either small studies of ≤ 20 subjects or small cohorts therefore a descriptive review is presented. Sleep deprivation parameters widely varied, from reducing sleep by 2.5 h per night to several days of total sleep deprivation. Sleep extension interventions had more consistency, with most studies extending sleep by 2 h vs. some studies utilizing a midday nap. Athletes studied encompassed those in endurance events, strength sports as well as mixed physiology sports, and included male and female participants. ►Fig. 1 outlines the PRISMA search strategy to categorize research into Sleep Deprivation (18 studies, see ►Table 1), Sleep Extension (11 studies, see ►Table 2), Circadian Effects (2 studies) and Jet Lag (9 studies) and are presented below.

Sleep deprivation in elite athletes

Elite athletes are known to get less total sleep than non-athletes [9, 10]. This pattern is pervasive throughout multiple sport disciplines studied, whether individual vs. team sport or strength vs. endurance sport (e. g., canoeing, diving, rowing, speed skating, endurance cyclists [9, 10]). Olympic athletes frequently get less than the traditional 8 h recommendation and are reported to sleep 6.5–6.8 h [9, 10]. Furthermore, when they do obtain an adequate sleep time of at least 8 h, they may have longer sleep latency (increase in the time it takes to fall asleep) and lower sleep efficiency (lower quality of sleep) than non-athletes, resulting in reduced sleep quantity as well as quality [10].

There can be several reasons for this situation. Athletes often have rigorous and strict training schedules, travel obligations and time zone changes. Athletes may downplay the importance of sleep, considering it less important compared to other aspects of their mandatory training. The ever-growing prevalence of smartphones and other electronic devices can further disrupt sleep [11, 12]; professional and amateur athletes communicate frequently via social media, post messages, comment on their event/match. These activities are commonly done at night after practice/games, preventing good sleep hygiene. Furthermore, blue-light emissions from screens disrupt the body's natural melatonin production which helps regulate one's circadian rhythms, and can affect next-morning alertness [11]. Lastly, although athletes may focus on a good night's sleep the night before a competition, stress and anxiety before the upcoming match may impair healthy sleep [12].

Focusing on healthy sleep throughout training is thus important, not just the night before competition when sleep may be the most difficult.

Negative effects of sleep deprivation

Most adults require 7–9 h of sleep per night [13]; some postulate athletes may need more due to the typical intensive exercise regimen. Inadequate sleep duration in the general population has been associated with a myriad of negative health effects including neurocognitive, metabolic, immunologic and cardiovascular dysfunction [14]. People who are sleep deprived may have impaired brain function that could affect judgment and/or decision-making during athletic performance [15]. From a metabolic standpoint, sleep deprivation has been associated with obesity and diabetes [16]. Sleep-deprived individuals may crave unhealthy foods and show impairments in glucose sensitivity, which may impair glycogen repletion and potentially affect appetite, food intake, and protein synthesis [17]. Impaired sleep also negatively affects growth hormone and cortisol secretion [18]. Sleep deprivation increases pro-inflammatory cytokines, which impairs immune system function, impedes muscle recovery and repair from damage, leads to autonomic nervous system imbalance (simulating overtraining symptoms), results in slower/less accurate cognitive performance, and alters pain perception [19–21]. From an athlete's standpoint, all these metabolic pathways affected by poor sleep are very important and relevant to athletic performance.

Sleep deprivation specifically in athletes has also been studied. ►Table 1 summarizes effects of reduced sleep on athletic performance. Studies span multiple sports: power and endurance, team and individual, male and female. The measured physical effects of sleep deprivation include decreased running performance, decreased muscle glycogen concentration and reduced submaximal strength, isokinetic peak torque, minute ventilation, distance covered, sprint times, tennis serve accuracy, soccer kicking skills, and time to exhaustion. Cognitive effects included decreased psychomotor functions, mood, and vigor (a subjective feeling of energy and enthusiasm), and increased reaction time and confusion. Predictably, studies showed impairments with 24–36 h of sleep deprivation (and one studied 64 consecutive hours of sleep deprivation) [10, 22–27], however many showed negative effects with just 2–4 h less sleep per night [28–32]. Gross motor functions such as brief bouts of strength and anaerobic power were relatively preserved in some studies [25, 26, 28, 33, 34], but affected in others [25, 34–36]. Arguably more important in elite sports than physical functioning, cognitive functions including reaction time, judgment and decision-making significantly suffered [33, 36, 38]. This can be a crucial area in elite sports, where highly trained athletes are often considered similar regarding their physical ability, and high-level cognitive function may therefore play the pivotal role in competition outcome.

Positive effects of sleep extension

Adequate sleep has clear benefits to health. Increasing sleep duration among people who are sleep deprived is shown to improve multiple measurements of function. For example, if the natural circadian rhythm is disrupted, cortisol levels rise and individuals may go into a catabolic state [39]. Athletes may turn to illicit substances such as anabolic steroids and growth hormones to stop catabolism and improve recovery. However if athletes restore

natural sleep patterns, the very anabolic hormones they are seeking recover to healthy levels naturally [40]. There are cognitive performance improvements with increased sleep as well [41]. Therefore, athletes who sleep adequately prior to competition are likely to benefit from the standpoint of peak performance.

Although there is an abundance of sleep extension research in the general population, there is a paucity of studies in athletes and its potential ergogenic effects. ►Table 2 summarizes how better sleep can improve cognitive and physical performance. Restoration of sleep and sleep extension in athletes improves sprint times [42, 43], tennis serve accuracy [44], swim turn and kick stroke efficiency [45], swim sprint [45], basketball shooting accuracy [42] (free throw and 3-point accuracy), half-court and full-court sprints [42], and time to exhaustion [46]. Cognitive performance tasks also improved, ranging from reaction times, psychomotor vigilance tasks, alertness, vigor, and mood [42, 43, 45–50]. Unsurprisingly, improving sleep resulted in decreased fatigue and sleepiness [42–45, 47, 48, 50, 51], but more important is that these presumably healthy athletes reported sleep deprivation symptoms of fatigue and sleepiness in the first place.

Newer studies demonstrate how including a simple sleep hygiene/sleep optimization education program for athletes can improve sleep time and sleep efficiency [51, 52]. Even if an athlete cannot get an adequate night's sleep, a nap the following day may be beneficial [43, 47–49]. Perhaps more valuable, if an athlete expects to have impaired sleep (e. g., long travel day before a major competition), the new concept of "banking sleep" (intentional sleep extension prior to a night of sleep deprivation) in a pilot study did improve motor performance [46].

Given that sleep extension research in athletes is still in the early stages, future research is needed to detail further performance benefits of increasing sleep in athletes. However, based on the available research, most studies agree on increasing sleep by 2 h for athletes (with a goal of up to 9 h in elite athletes) [42–45, 50]. Nine hours may seem excessive to some, but given the absolute importance of sleep to overall well-being as well as performance, the three pillars of health cannot be overstated. Especially for elite athletes, sleep should be emphasized and included as a top priority (as important as their exercise routine and diet).

Circadian aspects

The body's natural clock has a profound effect on most biological functions. The body clock, or circadian rhythm, is an important factor in optimizing sleep duration [53, 54]. People can sleep poorly if they attempt to sleep when they are out of their circadian phase; this situation commonly occurs in individuals with jet lag or who frequently cross time zones [54]. Similarly, circadian factors may have a role in the peak performance of athletes. In one study, the outcomes of NFL football games were compared in East Coast teams playing on the West Coast versus West Coast teams playing on the East Coast [53]. The study factored in the point spread, a calculation based on the known factors that may influence outcomes of games (e. g., better teams, home field advantage, team injury reports, etc.). For afternoon games, no difference in outcome was observed (athletes performed similarly in a 1 p.m. vs. 4 p.m. Eastern time game regardless of game location in the US). For evening games however, East Coast teams consistently performed poorly on the West

Coast (and did not beat the point spread). Putting this into perspective, for East Coast athletes playing a West Coast night game, the game may end at close to 2:00 a.m. from the standpoint of their body clock. This disadvantage was consistent across 40 years of NFL games, suggesting a major impact of circadian factors above and beyond traditionally recognized sources of variance.

Of note, nonphotic stimuli such as exercise also have the capacity to cause a “phase shift” in individuals; in other words, exercise can stimulate changes in the body’s circadian rhythm. In a study investigating exposure to morning, afternoon, evening, or nocturnal exercise, 1 h of evening exercise elicited a 30 min later phase shift to time of melatonin onset in healthy young men, effectively advancing or “phase shifting” their circadian rhythm [55]. This finding is supported and further elaborated upon in a very recent study [56] involving both young and older men and women. One hour of treadmill exercise was done on 3 consecutive days at 8 different day and night clock times. It was found that evening exercise (7–10 p.m.) induced a phase delay (later rhythm), and that morning or early afternoon exercise (7 a.m. and 1–4 p.m.) induced phase advance (earlier rhythm) as measured by 6-sulphatoxy melatonin, and the melatonin response was comparable to expectations for exposure to bright light of equal duration. For the athlete who has early morning races or night games, experiences altered training schedules or travels in different time zones, these findings have important potential implications and may potentially help to alleviate the effects of jet lag (see below).

Mitigating jet lag

The more east-west time zones crossed, the more difficult it may be to adapt. One study showed specifically traveling west to east on a long-haul flight had worse effects on sleep and subjective fatigue, motivation, and feelings of jet lag [57]. Sprint performance was also affected, especially in the first 72 h after landing [57]. Another study showed that not only long duration (up to 30h) but short (up to 6.5 h) duration east-west flights compromised sleep, increased fatigue and decreased vigor [58]. For the longer-haul flights, subjective fatigue and jet lag were significantly higher, wake-up time was earlier, and subjective vigor lower compared to the shorter flights (interestingly, these parameters were affected more than overall sleep) [58]. As a rough guide, jet lag symptoms may last for about one day per time zone crossed when traveling eastward, and a half-day per time zone crossed when traveling westward [59, 60]. Taking this adjustment period into account when making travel plans could be helpful.

Jet lag with north-south flights is not as well understood. One may not technically change time zones, but there may be a change in the ratio of light to darkness as one moves away from and toward the equator [61]. The sun is a powerful regulator of circadian rhythms, therefore when in a new time zone, a simple option would be to get as much sun exposure during daylight hours and to avoid being indoors if possible [62]. This is especially important in the morning to reset the body’s clock to the sun’s new rise and set times. For athletes seeking an individualized travel plan, online calculators can create light exposure schedules based on calculations from departure and destination location and flight length (The Sleep Foundation website provides general recommendations [63], but many

commercial websites have jet lag calculators). Resetting your watch and phone's clock to the destination time while in flight can help with the adjustment, too. The "first-night effect" (discomfort in a new atmosphere) is a well-known travel phenomenon that can disrupt sleep as your body adjusts to a new sleep environment [62]. Bringing objects from the home sleep/wake environment (pillows, blankets, photos, favorite coffee mug) can ease the transition [63]. Some individuals turn to sleep aids such as supplements and medications. However, their side effects can be significant, and it is unknown if they actually reset the body clock [64].

Finally, melatonin is a body hormone that regulates sleep. It is suppressed by bright sun in the morning, and increases in production at night, resulting in sleepiness [65]. Blue light from computer and phone screens also disrupt melatonin release [11]. Athletes may try melatonin supplements, but supplements are not FDA-regulated. They have variable potency, may have side effects, and may contain contaminants resulting in a positive drug test. Therefore, exposure to natural sun outdoors early in the morning and avoiding artificial bright light at night (including phones and computers) may be the best strategy [62].

Sleep hygiene strategies

Athletes are often forced to adhere to strict competition and travel schedules, and must maintain rigorous training that may interfere with their ability to obtain quality sleep. Although making sleep a priority is an important recommendation, some individuals have difficulty initiating and maintaining sleep. These athletes may benefit from improved sleep hygiene. Healthy sleep can be trained and improved upon by utilizing regular routines and creating an optimal environment for sleep. ►Table 3 lists healthy sleep hygiene examples from our academic medical center's patient educational reference [66]. Typical recommendations include waking up at the same time each day, establishing the same evening routine before bed, and avoiding stimulants and distractions. ►Table 4 lists additional options that have been suggested, such as getting natural light, avoiding blue light, stress reduction and meditation, and food (including melatonin depending on circadian issues) recommendations [67]. Athletes may not be able to adopt all sleep hygiene recommendations but should attempt to integrate as many as possible to maximize this vital body function.

Evaluation of disordered sleep

Athletes with difficulty falling or maintaining sleep prior to a competition may say it's "just stress" but in fact have a sleep disorder. Athletes with daytime sleepiness may claim to "just be tired" from a hard workout, but have a true sleep disorder. Sleep disorders are difficult to self-diagnose, as individuals often do not know if they are snoring or have disrupted sleep. And even if an athlete believes he or she may have a sleep problem, the athlete may not want to speak up about it for fear of the repercussions (being benched, substituted, having stigma of "not as good" as other athletes). To raise awareness and encourage athletes to seek treatment, professional athlete Shaquille O'Neal once participated in a video with Harvard Medical School to increase understanding about sleep apnea and the negative effects he experienced as an athlete [2].

Conclusion

Sleep serves an absolutely vital physiological function and is arguably the single most important factor in exercise recovery. Many athletes and coaches prioritize exercise and seek to obtain the highest quality fitness. However, quality sleep should be part of the foundation of an elite athlete's routine. Building this vital function into an athlete's training program must be emphasized. Athletes can train themselves to improve their sleep if they have deficits, which by all measures should translate into improved performance. Therefore, the old saying "you snooze, you lose" should actually read to athletes, "you snooze (more), you win."

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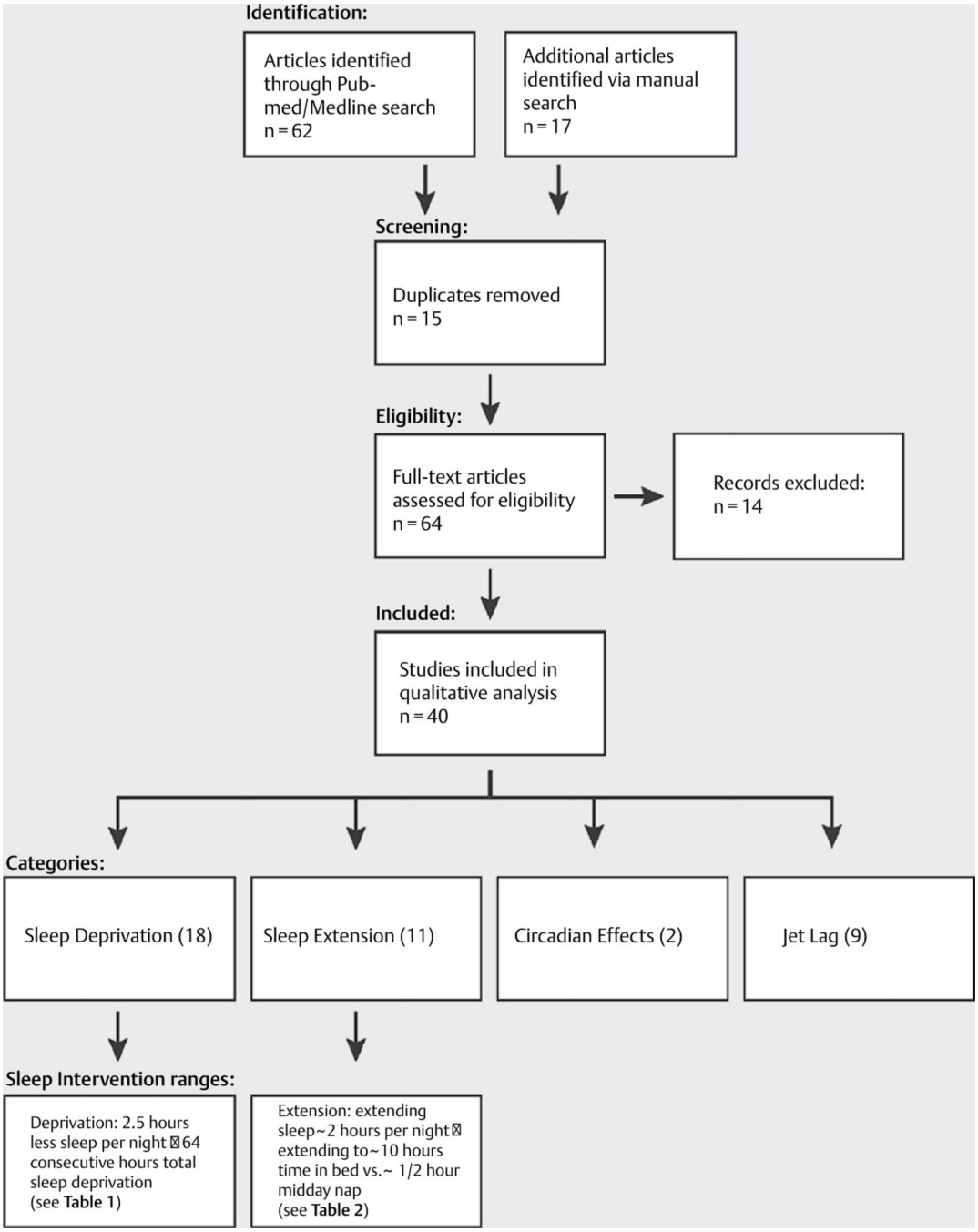

►**Fig. 1.**
PRISMA Flow Diagram Search Strategy.

►**Table 1**

Negative Effects of Sleep Deprivation.

Study	Population/Activity	Sleep Deprivation	Effect
Reilly and Deykin 1983 [38]	Exercise trained men	2.5 h total sleep/night over 3 nights	Multiple psychomotor functions negatively affected. Gross motor function (strength, lung power, endurance running) unaffected
Takeuchi et al 1985 [26]	40 m dash; leg extension exercise	64 h sleep deprivation	No effect on 40 m dash, isometric strength, or peak torque; authors conclude brief anaerobic performance may be maintained with sleep deprivation
Reilly and Hales 1988 [33]	Women	2.5 h total sleep/night over 3 nights	Similar findings in women as Reilly 1983 study; more notable negative effects on reaction time than gross motor function
Sinnerton & Reilly 1992 [28]	Swimmers	2.5 h less sleep /night over 4 nights	No effect on gross motor function (back & grip strength, lung function) or swimming performance. Depression, tension, confusion, fatigue, anger all increased, vigor decreased
Reilly and Piercy 1994 [34]	Weightlifting; bench press, leg press, deadlift, bicep curl	3 h total sleep/night over 3 nights	Significant decrease in submaximal lifts on all tasks, and decrease in max bench press, leg press, deadlift
Bulbulian et al. 1996 [35]	Exercise-trained men; isokinetic knee extension & knee flexion exercise	30 h sleep deprivation (1 night of no sleep)	Isokinetic peak torque significantly impaired
Souissi et al. 2003 [25]	Cycling; max, peak, & mean power	24 h & 36 h sleep deprivation	Anaerobic power (max, peak, mean) unaffected at 24 h but decreased at 36 h of no sleep
Blumert et al. 2007 [23]	Collegiate weightlifters; snatch, clean, jerk, front squat	24 h sleep deprivation	Mood suffered; increased confusion, fatigue total mood disturbance, less vigor, however no difference in snatch, clean, jerk, front squat, total volume or training intensity
Souissi et al. 2008 [29]	Male students majoring in physical education; Wingate test	4 h delayed bedtime vs. earlier rising time, with 4 h sleep deprivation (either at beginning or end of night)	4 h sleep deprivation at end of night affects peak, mean, & max power more than sleep deprivation at beginning of night; authors conclude early rising more detrimental than late bedtime
Azboy and Kaygisiz 2009 [22]	Male runners and volleyball players; incremental ergometer exercise test	One night (25–30 h) sleep deprivation	Decreased exercise minute ventilation and faster time to exhaustion; seen more in volleyball than runners
Oliver et al. 2009 [27]	Recreationally active healthy males; 30 min treadmill run at 60 % VO_2max	24 h sleep deprivation	Less total running distance covered (6 037 vs. 6 224 m); authors suggested reduced performance due to increased rate of perceived exertion
Skein et al. 2011 [24]	Male team-sport athletes; 15 m sprint times, double leg bounds, max knee extension	30 h sleep deprivation	Decreases mean and total sprint times, altered sprint pacing strategies, decreased muscle glycogen, decreased peak force, increased perceptual strain
Taheri and Arabameri 2011 [36]	Male collegiate athletes; Wingate test & reaction time task	24 h sleep deprivation	Decreased reaction time; no difference in anaerobic power (peak & mean)
Reyner and Horne 2013 [30]	Semi-professional tennis players; tennis serve accuracy	5 h total sleep/night, tested with and without caffeine following day	Tennis serve accuracy decreased after sleep deprivation; caffeine had no beneficial effect
Souissi et al. 2013 [31]	Judo athletes; maximal voluntary contraction, grip strength, and Wingate tests before and after judo competition	4 h sleep deprivation either at the beginning or end of the night	Sleep deprivation at the end of the night decreased muscle strength and power on following day, more so in the afternoon than morning; authors conclude early rising more detrimental than late bedtime

Study	Population/Activity	Sleep Deprivation	Effect
Mejri et al. 2016 [32]	Male Taekwondo athletes; intermittent running recovery test (Yo-Yo)	4 h sleep deprivation at beginning of night vs end of night	Both types of sleep deprivation affects running performance (sleep deprivation at end of night moreso than beginning); lactate levels affected only with deprivation at end of night. Peak HR and rate of perceived exertion unaffected
Pallesen et al. 2017 [37]	Male junior soccer players; soccer skills including ball control, kicking, sprints with changes of direction	24 h sleep deprivation	There was a net negative effect of sleep deprivation on continuous kicking test; 30 meter sprint with directional change test showed steeper learning curve in the sleep-deprived condition; significantly higher subjectively perceived sleepiness in the sleep deprivation group; authors concluded attention tasks are highly sensitive to the negative effects of sleep deprivation

►**Table 2**

Postive Effects of Sleep Extension.

Study	Population/Activity	Sleep Extension	Effect
Gillberg et al. 1996 [48]	Healthy volunteers	Midday ½ h nap following night of sleep deprivation (4 h total sleep)	Nap after restricted sleep brought performance on psychomotor vigilance tasks back to baseline; alertness improved, sleepiness decreased
Kamdar et al. 2004 [50]	Healthy college students	Sleep as much as possible/night over 7 nights (~2 h more sleep/night, from ~7 to 9 h)	Reaction time improved; daytime alertness, vigor, mood improved; fatigue decreased
Hayashi et al. 2005 [49]	Healthy university students	Midday nap following sleep deprivation (1.5 h less total sleep)	Alertness and performance on psychomotor vigilance tasks improved after nap, moreso with stage 2 sleep vs. stage 1
Brooks and Lack 2006 [47]	Healthy young adults	Afternoon nap following night of sleep deprivation (5 h total sleep)	Nap improved cognitive performance tasks, sleepiness, fatigue, vigor, alertness
Waterhouse et al. 2007 [43]	Healthy males	Midday ½ h nap or sit quietly following night of sleep deprivation (4 h total sleep)	Reaction time accuracy improved, 2 m & 20 m sprint times improved; alertness & short-term memory improved; sleepiness decreased
Mah 2008 [45]	Men's and women's collegiate swimming teams	Increase to minimum 10 h in bed/night over 5–7 weeks (~2 h more sleep/night)	15 m sprint swim improved, faster reaction times off the blocks, improved turn times, increased kick strokes; daytime sleepiness decreased mood & vigor improved, fatigue decreased
Mah et al. 2011 [42]	Men's collegiate varsity basketball team	Increase to minimum 10 h in bed/night over 5–7 weeks (~2 h more sleep/night)	Half-court & full-court sprints improved, shooting accuracy improved (free throw and 3-point field goal percentage 9–9.2 %); vigor & mood improved; sleepiness & fatigue decreased
Schwartz and Simon 2015 [44]	Collegiate varsity tennis players	Increase to at least 9 h sleep/night over 1 week (~2 h more sleep/night)	Tennis serve accuracy improved (35.7 % to 41.8 %), sleepiness levels (Epworth & Stanford Scales) decreased
Arnal et al. 2016 [46]	Healthy men in 30's with normal BMI	Increase time in bed by 1.6 h (habitual vs. extended time in bed 8.2→9.8 h) prior to 1 night of total sleep deprivation	Time to exhaustion during motor performance tasks (sustained muscle contraction) increased with sleep extension compared to habitual sleep at baseline by 3.9 % (prior to sleep deprivation). After a night of total sleep deprivation, time to exhaustion in sleep extension group doubled (8.1 %) compared to habitual sleep. There were no differences in voluntary muscle activation; likely effect is partially due to reduced rate of perceived exertion
O'Donnell and Driller 2017 [52]	Elite female netball athletes	Sleep monitoring pre-post a sleep hygiene education session by a specialist in sleep research and athletic recovery	Sleep hygiene education (presentations on sleep physiology, sleep hygiene practical tips, importance of sleep for athletes, and athlete Q&A) resulted in significant improvement in total sleep time, wake variance and wake episode duration.
Van Ryswyk et al. 2017 [51]	Australian Football League male athletes	Education session explaining normal sleep needs, how to improve sleep duration and quality, ongoing feedback	After a 6-week sleep optimization program, there were increases in total sleep time, sleep efficiency, vigor scores, and decrease in fatigue levels

►**Table 3**

Healthy Sleep Hyginne Recommendations.

Healthy Sleep Hygiene 'Top Ten' Recommendations (*source: UCSD Center for Pulmonary and Sleep Medicine patient information handout*)[66]
1. Don't go to bed until you are sleepy. If you aren't sleepy, get out of bed and do something else until you become sleepy.
2. Regular bedtime routines/rituals help you relax and prepare your body for bed (reading, warm bath, etc.).
3. Try to get up at the same time every morning (including weekends and holidays).
4. Try to get a full night's sleep every night, and avoid naps during day if possible (if you must nap, limit to 1 h and avoid nap after 3 p.m.).
5. Use the bed for sleep and intimacy only; not for any other activities such as TV, computer or phone use, etc.
6. Avoid caffeine if possible (if must use caffeine, avoid after lunch).
7. Avoid alcohol if possible (if must use alcohol, avoid right before bed).
8. Do not smoke cigarettes or use nicotine, ever.
9. Consider avoiding high-intensity exercise right before bed (extremely intense exercise may raise cortisol, which impairs sleep).
10. Make sure bedroom is quiet, as dark as possible, and a little on the cool side rather than warm (similar to a cave).

►**Table 4**

Additional Sleep Hyginne Recommendations.

Other 'Tips & Tricks' for Healthy Sleep Hygiene [67]
1. Avoid blue light emitted from screens at least 2 h before bed (smartphones, laptop, monitors). Blue light suppresses melatonin production that is needed to induce sleep. Avoid text messaging, social media, games, app use.
2. Get bright, natural light (the sun) upon awakening (the sun is ideal, but some suggest at least a 10,000 lux lamp if artificial)
3. Don't hit the snooze button. It does not improve sleep quality.
4. If you have difficulty waking up, some suggest a dawn-simulator alarm clock.
5. If you must use your computer at night, consider installing color-adjusting and blue-light reducing software or wear blue-light blocking glasses.
6. Meditation may be helpful. Brainwave entrainment (e. g., binaural beats) is considered experimental.
7. Higher carbohydrate (namely high glycemic index foods) at night may improve sleep, as well as high protein including tryptophan. High fat intake at night may disrupt sleep. Inadequate total caloric intake during the day may impair sleep at night.
8. Topical magnesium (e. g., salt bath, topical mineral oil) or oral magnesium may help if you are deficient.
9. Melatonin naturally occurring in foods (e. g., tart cherry juice, raspberries, goji berries, walnuts, almonds, tomatoes) may potentially improve sleep, but avoid artificial melatonin supplements.
10. Don't fall asleep to the TV. Sleep studies show you frequently wake up during the night and have poor quality sleep.
11. Herbal supplements are largely unknown with potential serious side effects, and may be on USADA-prohibited lists or result in positive banned substance test for athletes.
12. Consider reducing your fluid intake before bed so you don't get up to go to the bathroom (only if you maintain enough hydration during the day).
13. Cooling your body temperature may improve sleep. Some suggest keeping room between 60–70 degrees; however, keep hands and feet warm (socks and gloves may help during winter months).
14. Check your mattress - it may be too old (mattresses typically last a maximum of 9–10 years) and may have allergens.
15. Recovery from exercise should not only focus on muscle recovery. Reducing mental fatigue is just as important for healthy sleep. Reduce external stressors in your life.