

Mini Review

How Sleep Deprivation and Optimization May Impact Health and Performance

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ABSTRACT

Adequate sleep is crucial for health and well-being. Research shows that 1 in 3 Americans reportedly sleep less than the recommended guidelines and over 70 million experience some type of chronic sleep issue. Sleep deprivation has been shown to impact health negatively; however, more and more current research is emerging supporting the link between inadequate sleep and a range of various disorders, such as obesity, diabetes, cardiovascular disease, hypertension, arrhythmias, mood disorders, dementia, neurodegeneration, and more. Beyond general health, sleep deprivation has been shown to have a negative impact on athletic performance, including deficits in accuracy, reaction times, and cardiovascular endurance. The purpose of this mini-review is to investigate the key variables that most significantly contribute to sleep deprivation in athletes while covering strategies that may optimize one's health by adjusting sleep-based factors.

Keywords: Athlete, Health, Performance, Rapid eye movement, Sleep

INTRODUCTION

Adequate sleep is crucial for health and well-being. However, research shows that 1 in 3 Americans reportedly sleeps less than the recommended guidelines.¹ Over 70 million people experience some type of chronic sleep issue.² Not only does sleep optimization severely impact health markers but it has also been shown to improve athletic performance significantly.³

Here are some key facts about sleep:

- An average night's sleep consists of 4–6 sleep cycles.⁴
- Each 90-minute cycle comprises non-rapid eye movement (NREM) and rapid eye movement (REM) phases.⁵
- Sleep significantly impacts our circadian rhythm (internal clock).⁶
- Your body temperature drops by 1–2 degrees during sleep.⁷
- Sleep deprivation is associated with increased inflammation and weakened immunity.⁸
- Sleep optimization has been shown to improve accuracy, reaction times, and sports performance.⁹

The following review explores the research on how sleep optimization and deprivation influence health and sports performance. Factors such as sleep times, frequency, duration, and tracking capabilities are examined.¹⁰

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CIRCADIAN RHYTHM

A live organism's biological internal clock is thought to be the basis for several physiological and behavioral patterns and cycles known as biological rhythms.¹¹ Humans have benefited from the knowledge of these patterns in various ways, one of which is understanding our sleep cycles better.¹²⁻²⁰ One of the most common terms, "Circadian Rhythm," refers to a person's sleep cycle throughout the course of a typical 24-hour day, originating from the Latin words "circa," which means "around," and "dies," meaning "day" or as we have come to understand it, a 24 hour period.¹² The circadian rhythm, also known as one's biological clock, is an innate timing and order of events that are determined by different stimuli (in this case, day and night) to produce various changes in our physiology. These changes are brought about by various physiological mechanisms that stimulate wakefulness, sleepiness, and alertness. A regular and constant sleep-wake cycle is established by the brain's suprachiasmatic nucleus, which also controls the release of the sleep-inducing hormone melatonin.¹³

Although the "Circadian Rhythm" is the most well-known, scientists use two other related biorhythms to explain a human's series of physiological cycles. Ultradian Rhythms - ("ultra" means greater), also known as short-term biorhythms, vary from 20 min to several hours and occur within a 24-hour cycle indicating activities such as heart rate and pulse, blood circulation, arousal, and REM sleep cycles.^{20,21} Infradian rhythms, which are derived from the Latin term *infra*, which means "lower" or "below," refer to physiological events that occur less often than every 24 hour, such as the menstrual cycle or pregnancy.²²

Ultradian rhythms are of particular importance as they are believed to reflect the cycles of Non-Rapid Eye Movement ("NREM") and Rapid Eye Movement ("REM") sleep. These micro sleep cycles occur 4-6 times per night, lasting up to 90 min each, within an individual's overall sleep-wake cycle.

Within the circadian sleep-wake cycle, there are two stages which consist of four shorter phases, 3 of which are NREM and 1 REM. Each phase has a specific objective, and the duration of each phase will vary as the night goes on.²³ During phase 1 of NREM, the body begins to wind down; muscle activity declines, and eye movement begins to slow - some refer to this as "light sleep." During phase 2, memory consolidation occurs, and the body is prepared for deep sleep with reductions in heart rate, breathing, and body temperature. Phase 3 (known as slow wave sleep) is associated with low-frequency brain waves known as delta waves. As your eye movement and muscle activity completely cease, waking someone in this phase becomes extremely hard. This is the deepest NREM sleep phase known for tissue repair and immune system strengthening. Stage 2 is the REM

cycle - the final stage of sleep. The brain activity and rapid eye movements begin to increase, and the breathing rate becomes irregular. This cycle is associated with dreaming and can range from 10 min to an hour.²⁴ Experiencing the appropriate sleep cycles daily plays a major role in our memory, emotions, cognition, and overall brain function and development.^{25,26}

Working on sleep hygiene can help maintain a healthy circadian rhythm, which may be beneficial to the quality and duration of sleep, and, thus, one's health and performance. In fact, a recent 2020 research trial found participants who adhered to a consistent sleep and wake time experienced better regular sleep timing and circadian rhythm alignment.¹⁶ The circadian rhythm, however, can be interrupted and become "out of sync," so to speak. And, yes, this can potentially cause various health problems, such as metabolic syndrome, cardiovascular disease, hormonal issues, depression, bipolar, insomnia, and more.¹³⁻¹⁵ A 2017 meta-analysis found that night shift workers had a higher associated risk of depression compared to daytime workers,¹⁷ and a 2021 study of 369 participants found that the use of electronic devices 2 hour before bed, lack of exercise, and coffee after 4 pm were all associated with poorer sleep quality.¹⁹

Tips for maintaining a healthy sleep-wake circadian rhythm cycle:

- Establish consistent sleep-wake times^{16,17}
- Immediate sunlight exposure upon waking up¹⁸
- Avoid artificial electronic bright lights at night¹⁹
- Maintain a healthy diet^{19,27}
- Daily exercise^{19,28}
- Avoid excess amounts of caffeine and/or stimulants after 4 pm¹⁹

HEALTH

Sleep deprivation has been shown to impact health markers negatively; however, more and more current research is emerging supporting the link between inadequate sleep and a range of various disorders, such as obesity, diabetes, cardiovascular disease, hypertension, arrhythmias, mood disorders, dementia, neurodegeneration, and more.²⁹ A 2015 literature review looked at the short and long-term consequences of sleep deprivation, showing short-term consequences such as an increased stress response; pain; depression; anxiety, and deficits in memory, performance, and cognition.³⁰ Furthermore, long-term consequences include cardiovascular disease, hypertension, weight gain, metabolic syndrome, gastrointestinal disorders, and even an increased risk of certain cancers.³⁰

PERFORMANCE

Beyond general health, sleep deprivation has been shown to have a negative impact on athletic performance, including

deficits in accuracy, reaction times, and cardiovascular endurance.³ Not only do we see an association between high sleep quality and greater muscle strength, but a 2018 systematic review of 17 studies report that inadequate sleep impairs maximal muscle strength in various compound movements.³¹ Furthermore, a 2011 study measured the effects of sleep extension on collegiate basketball players' performance and athletic potential. Following a 5-7 week period of increased time in bed (10 hour), participants displayed an increase in sprint times, improved shooting accuracy, decreased reaction times, increased vigor, and decreased fatigue.

HOW MUCH IS ENOUGH?

Short-term sleep deprivation leads to several negative physiological consequences, such as increased blood pressure, activation of the sympathetic nervous system, impaired glucose regulation, and heightened inflammation. Epidemiological studies also indicate that self-reported sleep duration is linked to long-term health outcomes. Both excessive sleep (>8 h/day) and insufficient sleep (<7 h/day) are associated with a slightly higher risk of overall mortality, cardiovascular diseases, and the development of symptomatic diabetes.³²

Shortened sleep duration has been linked to weight gain and increased body fat, especially in younger individuals. However, this effect appears to diminish with age. It is important to note that while chronic sleep deprivation continues to be associated with weight gain over time, the relationship weakens with age. This decline in the impact of sleep deprivation may be due to other age-related factors that contribute to the natural rise in adiposity as people get older.³³

The effects of sleep deprivation are particularly pronounced in sports that require speed, tactical strategy, and technical skill, with extended periods of sleep deprivation causing the most significant decline in performance.³⁴ Sleep plays a critical role in recovery and adaptation between exercise sessions, and mounting evidence indicates that both increased sleep duration and enhanced sleep quality are linked to better performance and greater success in competitive settings. Moreover, adequate sleep may help reduce the risk of injury and illness in athletes, thereby optimizing overall health and potentially boosting performance through increased training participation.³

A general recommendation of 7–9 hours of sleep is considered ideal for adults to support overall health and well-being.³⁵ However, it is important to note that this recommendation applies primarily to sleep duration and sleep quality should also be considered. In addition, as mentioned earlier, some studies suggest that elite athletes may benefit from longer

sleep, with recommendations of up to 10 hours per night to optimize performance and athletic outcomes.³⁶

HOW DOES SLEEP OR TRAINING SCHEDULE AFFECT OUTCOMES?

Disruptions to a sleep schedule, whether caused by time zone changes or life-related factors, are associated with decreased performance outcomes.³⁷ Training sessions or competitions held during extremely early or late hours can disrupt circadian and homeostatic rhythms. Adjusting the training schedule to allow for better sleep duration can significantly improve various aspects of athletic performance.³⁸ Furthermore, a 2011 study found that aerobic exercise performed in the morning resulted in significantly more time spent in both light and deep sleep, as well as the highest frequency of sleep cycles, compared to exercise conducted in the afternoon or evening.³⁹ In addition, a follow-up study in 2014 confirmed similar findings regarding the positive effects of morning exercise on sleep. It also reported a reduction in systolic blood pressure among participants who exercised in the morning, compared to those who exercised in the afternoon or evening.⁴⁰ Research on shift work and chronic disruptions to sleep schedules consistently shows that alterations to the circadian rhythm have negative effects on both physical and psychological health outcomes in both men and women. Compared to men working regular, non-variable work schedules, those on variable shifts experience higher rates of heavy drinking, job stress, and emotional issues. Female shift workers report even more significant challenges, including increased use of sleeping pills, tranquilizers, and alcohol, as well as lower social support, higher job stress, and more emotional difficulties.⁴¹ Later sleep times and greater variability in sleep patterns are most strongly correlated with poor health outcomes. While providing specific recommendations can be challenging due to the complexities of managing variable schedules and individual lifestyles, it can be concluded that earlier bedtimes, more consistent wake times, and a stable sleep schedule are associated with more reliably positive health outcomes. Consistency in sleep timing plays a key role in optimizing physical and psychological well-being.^{42,43}

CAN YOU ADAPT TO POOR SLEEP?

In an era where adaptability is often considered a hallmark of human resilience, one might question whether this principle extends to sleep. A 2021 study found that 71% of elite athletes self-reported insufficient sleep.¹ Achieving optimal sleep duration and maintaining a consistent sleep schedule remains a challenge for many. While occasional late nights or deviations from a regular sleep pattern may appear inconsequential, the concept of “catching up on sleep” is often oversimplified.

A 2004 study from the University of Pennsylvania and Harvard Medical School looked at the neurobehavioral and sleep cumulative physiological cost of dose-response sleep restriction. 48 healthy participants between the ages of 21–38 were divided into groups and restricted to either 0, 4, 6, or 8 hours of sleep per night for 14 days straight (the group restricted to no sleep only went for three days due to safety concerns). Cognitive performance deficits were tested through a Psychomotor Vigilance Test (PVT), which screened for fatigue, alertness, and circadian misalignment.⁴⁴ As anticipated, the cohort that experienced total sleep deprivation for three consecutive days demonstrated a significant decline in performance on the PVT compared to their baseline. However, a noteworthy finding was that participants in the 4-hour and 6-hour sleep groups also exhibited a progressive decline in cognitive function, as evidenced by increasing PVT reaction times. After 14 days of restricted sleep (4 h/night), participants' PVT scores deteriorated to levels comparable to those observed in the zero-sleep cohort after just 3 days of total sleep deprivation. In addition, the 6-h group, after 14 days, scored around the same as the zero-sleep group after 1½ days of no sleep. What is seen in this study is a linear increase in cognitive decline as sleep restriction is increased – no plateau or adaptation effect occurs. However, when the participants were subjectively asked how they felt, they did, in fact, report they were feeling better, highlighting an interesting psychological mechanism, which is very relevant for coaches and trainers to be aware of, as physiological and cognitive abilities may be declining (sports performance). Yet, the athlete may not even be aware of it. Although a longer study, beyond 14 days, would be useful, these data in itself are very interesting and suggest that we can, in fact, not adapt to poor sleep; it just accumulates, causing more and more cognitive deficits.⁴⁵

HOW TO TRACK IT?

Wearable sleep-tracking devices have been scrutinized for their accuracy when compared to the gold standard of polysomnography.⁴⁵ However, an optimal approach to sleep monitoring may involve integrating subjective perception with secondary validation from wearable technology.⁴⁶ Over time, the continuous collection of sleep data – combined with its correlation to training performance – can help identify trends, mitigating factors, and lifestyle influences. This individualized analysis can then be leveraged to develop personalized sleep best practices.

KEY RECOMMENDATIONS FOR OPTIMIZING SLEEP

1. Track Sleep Subjectively and Objectively – Combine subjective self-assessment (“how you feel”) with objective data from wearable devices to improve long-

term sleep quality monitoring.

2. Analyze Trends and Lifestyle Factors – Use sleep data alongside performance metrics and lifestyle habits to develop an awareness of how daily routines impact sleep quality and overall performance.
3. Optimize Habit Formation and Training Modulation – Leverage sleep awareness to establish effective sleep habits and adjust training intensity based on subjective and objective markers of readiness.
4. Prioritize Consistency in Sleep Schedule – Aim for a regular sleep-wake cycle, with a consistent wake time being the most critical. Target 7–9 hours of sleep per night; if this is not feasible, maintain consistency in sleep duration.
5. Limit Stimulant Consumption – Avoid caffeine and other stimulants after 4 PM to prevent disruptions in sleep quality.
6. Implement a Structured Sleep Routine – If external commitments (e.g., work, family) challenge sleep consistency, set both a bedtime and wake-up alarm to enforce accountability.
7. Engage in Morning Movement and Daily Exercise – Incorporate physical activity early in the day to support circadian rhythm regulation and overall sleep health.
8. Reduce Light and Screen Exposure Before Bed – Minimize exposure to bright lights and electronic devices in the evening to facilitate natural melatonin production.
9. Maintain Healthy Pre-Bed Nutrition – Adopt balanced eating habits, avoiding large meals or highly stimulating foods close to bedtime.

By implementing these evidence-based strategies, individuals can enhance sleep quality, optimize recovery, and improve overall performance.

CONCLUSION

Optimizing sleep is essential for both health and performance. Poor sleep is linked to metabolic dysfunction, impaired glucose regulation, and increased inflammation, all of which negatively impact recovery, body composition, and long-term health outcomes. Conversely, high-quality sleep enhances physiological adaptation, improves cognitive and motor function, and supports peak athletic performance.

Given the profound effects of sleep on metabolic health and performance, prioritizing evidence-based sleep strategies – such as maintaining consistent sleep schedules, managing light exposure, and optimizing sleep duration – should be a fundamental component of any health and training plan.

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