Sleep in Sports: A Short Summary of Alterations in Sleep/Wake Patterns and the Effects of Sleep Loss and Jet-Lag

Schlaf im Sport: Eine kurze Zusammenfassung über Veränderungen im Schlafverhalten und den Einfluss von Schlafmangel und Jet-Lag

Summary

- This review article aims to summarise general aspects regarding sleep and sports. It is generally assumed that sleep is a basic requirement for physiological and psychological recovery, whereas it appears that sleep of elite athletes is highly influenced by training stimuli and external as well as internal factors.
- Studies about sleep deprivation and restricted sleep indicate the importance for cognitive functions as well as mood and behavioural aspects. Effects on performance parameters are not reported as consistently. In contrast to sleep restriction, extending sleep for several nights might lead to improvements in performance, mood, and alertness.
- In terms of intercontinental travel, jet-lag might be an issue for elite athletes. Although a few studies indicate that effects on athletic performance might not be present, sleep, mood, and some physiological measures are affected due to shift in time zones.
- Simple strategies can be applied to enhance adaptation to the destination and diminish jet-lag symptoms.

Zusammenfassung

- Studien über Schlafentzug und verkürzten Schlaf verdeutlichen die Bedeutung für cognitive Funktionen sowie stimmungs- und verhaltensbezogene Aspekte. Effekte auf Leistungsparameter liefern allerdings kein einheitliches Bild. Im Gegensatz zu Schlafrestriktion kann eine verlängerte Schlafdauer über einige Nächte zu Verbesserungen der Leistung, Stimmung und Aufmerksamkeit beitragen.
- Einige einfache Strategien können eingesetzt werden, um die Anpassung an den Zielort zu fördern und Jet-Lag-Symptome zu verringern.

KEY WORDS: Recovery, Sleep Loss, Jet-Lag, Performance

SCHLÜSSELWÖRTER: Erholung, Schlafmangel, Jet-Lag, Leistung

Introduction

Sleep is attributed an important role in recovering from daytime events, saving energy, functioning of the immune system and memory consolidation (3, 29). The alteration of sleep and wakefulness is organised by homeostatic control and the endogenous circadian rhythm which interact with each other (38). The circadian rhythm is driven by the biological clock which operates about 24h. It is keeping track of the time of day (i.e., according to the light-dark cycle) and determines the optimal time for sleep (7). The sleep homeostatic control aims to balance the time spent awake and time spent asleep by building up sleep pressure during periods of wakefulness and dissipating this pressure during sleep periods. Thus, the structure of sleep and the amount of sleepiness depend on the duration of the wake period as well as on the biological time of day (7). Sleep length, quality, and the circadian timing are considered key factors in terms of the overall recuperative outcome of sleep (35).

Typical instruments for the assessment of sleep are polysomnography (PSG), actigraphy and questionnaires which are briefly summarised in Table 1. PSG requires the attendance in a sleep laboratory and as recordings are expensive, it does not allow for long-term monitoring. Therefore, actigraphy has been widely accepted in sleep research because of its invasiveness and unobtrusiveness, as well as its reasonable validity and reliability compared to PSG (34). Wrist activity monitors and armbands can easily be applied in natural settings which offer the opportunity to monitor certain training cycles among athletes without disturbing sleep patterns (21, 22). Furthermore, it is important to obtain subjective perceptions and sleep habits. Still, it should be considered that personality characteristics and mood as well as memory biases might affect self-reported sleep ratings (20). The combination of both methods appears useful in athletic contexts. They can be implemented to examine changes in sleep parameters, and the perception thereof which can be affected by training stimuli and other external factors (22).
Postscript and scientists assume a mutual relationship between exercise and the nightly sleep (5, 35). Recent reviews provide expedient details about physiological aspects of the function of sleep (11), as well as nutritional interventions to enhance sleep (18). In addition to these publications, this section focusses on findings that refer to changes in sleep in different contexts among athletes. As the absence of sleep or relative sleep restriction underline the role of sleep, relevant effects for athletic settings are reviewed afterwards. Since travel to international competitions may result in a shift in time zone, one section deals with the impact of jet-lag on athletes. Previous publications mainly deal with mechanisms of jet-lag and management strategies, but an overview of empirical findings among (elite) athletes is still lacking. Considering the nature of overview articles in this journal, this review aims to provide a brief summary of the most important aspects regarding sleep in front of a sport scientific background.

**Sleep of Athletes in Different Settings**

Practitioners and scientists assume a mutual relationship between exercise and the nightly sleep (5, 35). Recent reviews provide expedient details about physiological aspects of the function of sleep (11), as well as nutritional interventions to enhance sleep (18). In addition to these publications, this section focusses on findings that refer to changes in sleep in different contexts among athletes. As the absence of sleep or relative sleep restriction underline the role of sleep, relevant effects for athletic settings are reviewed afterwards. Since travel to international competitions may result in a shift in time zone, one section deals with the impact of jet-lag on athletes. Previous publications mainly deal with mechanisms of jet-lag and management strategies, but an overview of empirical findings among (elite) athletes is still lacking. Considering the nature of overview articles in this journal, this review aims to provide a brief summary of the most important aspects regarding sleep in front of a sport scientific background.

**Effects of Sleep Loss and Restricted Sleep**

Imposing participants to a complete sleep deprivation or partial sleep restriction is a common approach to investigate the role of sleep on recovery and performance. Over the past decades numerous studies have been executed with partially contradicto- 

**Table 1**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>AIMS/POSSIBLE INTERVENTIONS</th>
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<tbody>
<tr>
<td>Sleep assessment</td>
<td>Polysomnography: Medical examinations, recording sleep stages &amp; cycles, clinical research questions</td>
</tr>
<tr>
<td></td>
<td>Actigraphy: Long-term monitoring of sleep habits, application in home environment, analysing changes in sleep patterns in response to external and internal variances</td>
</tr>
<tr>
<td></td>
<td>Sleep log: Subjective perception &amp; appraisal, subjective changes in sleep patterns</td>
</tr>
<tr>
<td>Sleep problems</td>
<td>Difficulty initiating sleep: Implementing bedtime routines or rituals, avoiding activating or stimulating activities before bedtime (e.g., watching exciting movies), keeping a regular sleep schedule, refraining from caffeinated beverages and alcohol in the evening, implementing relaxation techniques (e.g., controlled breathing, autogenous training)</td>
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As a matter of course, sleep/wake patterns do not emerge identically every night. Especially athletes have to deal with changing conditions (e.g., due to training and competition schedules or non-sport related obligations). While there are already some theoretical publications and review articles, studies about sleep in sport settings have not been reviewed and summarised yet. Therefore, the following section briefly summarises findings about changes in sleep in different contexts among athletes. As the absence of sleep or relative sleep restriction underline the role of sleep, relevant effects for athletic settings are reviewed afterwards. Since travel to international competitions may result in a shift in time zone, one section deals with the impact of jet-lag on athletes. Previous publications mainly deal with mechanisms of jet-lag and management strategies, but an overview of empirical findings among (elite) athletes is still lacking. Considering the nature of overview articles in this journal, this review aims to provide a brief summary of the most important aspects regarding sleep in front of a sport scientific background.
of neuronal activity accumulate during wakefulness. This process prevents the effective clearance of toxic waste and impedes regular neuronal performance. Consequently, cumulative sleep loss causes an oxidant imbalance and cell death (9). Generally, these findings should be treated with caution, as the studies vary significantly regarding study design and small sample sizes without elite athletes and almost exclusively male participants. Nevertheless, this underlines the importance of sufficient sleep.

**Effects of Jet-Lag**

Among elite athletes, travelling around the world is a necessity in order to participate in international competitions. However, it is assumed that travelling over three and more time zones will lead to jet-lag which is classified as a circadian rhythm sleep disorder with external conditions conflicting with the internal pacemaker (13). Common symptoms are difficulties with sleeping at the correct time, transient fatigue during the day, lack of concentration, decreased motivation, gastrointestinal disturbances and loss of appetite, feelings of disorientation as well as an impaired mental and physical performance (33). While jet-lag tends to be similar in men and women, symptoms are usually worse after eastward rather than westward flights (26). Lee and Galvez (26) reported that westward travels (i.e., causing a phase delay) lead to a symptom peak in the first three days, while eastward travels (i.e., leading to a phase advance) cause more severe and persistent symptoms.

Despite these general symptoms, empirical evidence regarding the effects of air travel and jet-lag on athletic performance is somewhat limited up to this point. Only few studies have been conducted with elite athletes (5, 16, 28, 30). After travelling six time zones westwards, as well as travelling eight time zones eastwards, male Olympic gymnastics athletes showed perceptual jet-lag symptoms and effects on the cardiovascular system, whereas reduced training and coordination performances were only present after the westward travel (28). It was concluded that athletes should arrive at least two weeks in advance to overcome jet-lag before commencing competitions after travelling six time zones (28). Among female and male collegiate swimmers, negative physiological, perceptual, and affective changes did not occur during heavy training, neither upon travelling four time zones from east to west nor from west to east (30). Even following a 16h-delayed time shift there was no significant impairment on sprinting performance among elite skeleton athletes (4). On the other hand, these athletes perceived themselves as jet-lagged for up to seven days after travel and salivary cortisol was reported to display a typical time course response to the change in time zone. This points to the estimation of one day needed for each time zone crossed to readjust (4). Additionally, a recent study with elite football players has shown that sleep was impaired upon travelling westward with a 4h-delayed time shift for the first two nights (16). Perceptual measures of jet-lag and recovery did not reveal significant differences between baseline and any time point during the 10-day tour (16). However, following 24h simulated international air travel with simulated time zone shifts, reductions in sleep duration, sprint performances as well as exacerbated mood states were reported for physically active male participants (14, 15).

Generally, this small number of studies seems to indicate that athletic performance is probably not directly affected by jet-lag following travel across several time zones but rather behavioural and perceptual factors. Nevertheless, more research is needed, and in anticipation of the upcoming Olympic Games 2016 in Rio de Janeiro, Brazil, efforts should be undertaken to counteract potential issues regarding the effect of time zone shift and eventual jet-lag symptoms. Regarding European athletes, the Games require westward travelling which might be endured easier due to a phase delay (i.e., -5h from UTC +2 during Central European Summer Time). A typical range for an organised circadian pattern is assumed between 23.5h to 26.5h which enables a 30min phase advance or 2.5h phase delay on any single day (6).

**Concluding Remarks**

This review highlights the importance of adequate sleep behaviour in athletic settings in order to achieve optimal recovery. Findings of changes in sleep in athletes and recent survey data of athletes’ sleep behaviour (10, 23, 27) suggest that sleep habits and sleep times, as well as the awareness about the importance of sleep have some need for improvements among athletes. They should be educated in terms of optimal sleep routines and dealing with sleep problems (before competitions) (10). For instance, it could be shown that sleep hygiene recommendations improved sleep quantity in tennis players (8). Table 1 gives an overview of relevant aspects and possible interventions in sport contexts.

Several psychological and physiological parameters might be impaired due to the lack of sleep, even when sleep duration is only reduced by some hours. In summary, results of different performance measures in response to sleep loss somehow reveal inconsistent evidence. In contrast, cognitive functions and mood states appear to be negatively affected quite consistently. This implicates that interventions should be primarily directed to mood-related or motivational aspects of athletes.

Time zone shifts following air travel might also lead to disturbed sleep patterns and cause jet-lag symptoms. Therefore, sufficient time should be considered for an optimal adjustment to the destination before starting the competition. Treatment strategies have been recently reviewed: The duration of jet-lag might be shortened when the sleep schedule is adapted one to two hours toward the destination time zone in the days preceding the departure (26). During the flight, caffeinated and alcoholic beverages should be avoided and plenty of fluids should be ingested to decrease the severity of jet-lag (26). Upon arrival, exercise might help to maintain the arousal level, while strategic napping might alleviate symptoms of jet-lag as well (26). In Rio de Janeiro, athletes might consider exposing to light and avoiding light following certain schedules, which depend on the direction of travel and the numbers of time zones crossed (13). Besides, the timing of the meal should be congruent to the destination’s time. This factor seems to be more important than the type of meal (26). Regarding drug supplementation, elite athletes should not consider antidotes to fatigue such as modafinil, methylphenidate and pemoline as well as melatonin, which is supposed to promote sleep (32). Therefore, adaptation strategies should be concentrated on behavioural aspects exclusively.

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**Conflict of Interest**

The authors have no conflict of interest.