Health Problems of Civilization
eISSN: 2354-0265, ISSN: 2353-6942

REVIEW PAPER

ARTYKUŁ PRZEGLĄDOWY

SLEEP DEFICIENCY AND ITS IMPACT ON ATHLETE PERFORMANCE

NIEDOBÓR SNU I JEGO WPŁYW NA WYDAJNOŚĆ FIZYCZNĄ SPORTOWCÓW

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Tokarski MP, Banasiak AA, Sadłowski B, Bieganek P, Łukaszewicz S, Pawłowski P, et al. Sleep deficiency and its impact on athlete performance. Health Prob Civil. https://doi.org/10.5114/hpc.2024.140525

Tables: 1

Figures: 0

References: 43

Submitted: 2024 May 13

Accepted: 2024 Jun 11

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Summary

Based on the analysis of sleep deprivation among athletes and its impact on performance, we can conclude that insufficient sleep quantity and quality poses significant challenges to athlete performance. Research findings consistently highlight the detrimental effects of sleep loss on various aspects of athletic performance including endurance, reaction time, cognitive function, risk of injury, and perceived fatigue. Despite growing awareness, athletes often underestimate the importance of proper sleep hygiene due to demanding training and preparation for

competitions. Recommendations aimed at improving the quality of sleep among athletes include supplementing melatonin, tryptophan and their precursor products in the diet, balanced recovery periods and the inclusion of naps throughout the day. The use of sleep monitoring technology and the implementation of personalized sleep optimization strategies give hope that the diagnosis of sleep deficiency in athletes might be more extensive in the future. There are still topics that require further research, such as improving diagnostic methods for sleep deficiency and the topic of chrononutrition, i.e., optimizing the hours of food consumption in order to obtain higher-quality sleep.

Keywords: jet lag, sleep deprivation, melatonin, circadian rhythm, sports

Streszczenie

Na podstawie analizy problemu braku snu wśród sportowców i jego wpływu na wydajność fizyczną możemy stwierdzić, że niewystarczająca ilość jak i jakość snu stwarza poważne wyzwania dla wyników sportowców. Wyniki badań konsekwentnie podkreślają szkodliwy wpływ utraty snu na różne aspekty osiągnięć sportowych, w tym wytrzymałość podczas obciążenia wysiłkiem, czas reakcji, funkcje poznawcze, ryzyko kontuzji i poziom odczuwanego zmęczenia. Pomimo rosnącej świadomości, sportowcy często nie doceniają znaczenia prawidłowej higieny snu ze względu na wymagające treningi i przygotowania do zawodów. Zalecenia mające na celu poprawę jakości snu wśród sportowców obejmują uzupełnianie w diecie melatoniny, tryptofanu i ich prekursorów oraz zrównoważone okresy odpoczynku i uwzględnienie drzemek w ciągu dnia. Wykorzystanie technologii monitorowania snu i wdrażanie spersonalizowanych strategii optymalizacji snu daje nadzieję, że w przyszłości diagnostyka niedoborów snu u sportowców może być szersza. Wciąż pozostają tematy wymagające dalszych badań, jak np. doskonalenie metod diagnostycznych niedoborów snu

oraz tematyka chrononutricji, czyli optymalizacji godzin spożywania pokarmów w celu uzyskania wyższej jakości snu.

Słowa kluczowe: jet lag, deprywacja snu, melatonina, rytm dobowy, sport

Introduction

Sleep has a significant role in maintaining overall health throughout the entire span of one's life. From childhood onward, it shapes the proper development of our brain, cognitive functions, and procedural memory, influencing the development of our physical abilities [1]. However, a considerable number of people experience insufficient duration and/or quality of sleep. Athletes are particularly susceptible to sleep deprivation, wherein despite the growing awareness of the essential role of sleep in performance enhancement, prioritizing proper sleep hygiene is often overlooked due to the rigorous nature of their training regimens. Inadequate sleep quantity significantly impacts performance deterioration, mood destabilization, and cognitive impairment [2,3], thereby correlating with decreased physical endurance. Its prevalence in the population of athletes, depending on the method and the study group, is found in 28 to 73% of respondents. Each hour of lost sleep is associated with a 0.4% decrease in performance. The reasons for this situation are related to extensive overtraining of athletes preparing intensively for competitions, as well as excessive caffeine consumption, the influence of blue light, long journeys between time zones, and jet lag. Sleep deficiency in athletes (defined as less than 6 hours of uninterrupted sleep in a given day) leads to a decrease in the physical performance of athletes and increases the risk of injury compared to athletes who are considered to sleep well, i.e., about 8.3 hours a day, and who control additional factors influencing sleep quality such as diet, training time, and maintaining the correct circadian rhythm.

Aim of the work

In this review article we analyze the effects of sleep deprivation on athletes and compile recommendations aimed at improving sleep quality, thus translating into enhanced physical performance and improved athlete achievement.

Methods

This article comprises a literature review based on publications from PubMed (287 results), ClinicalKey (154 results), Taylor & Francis (185 results), and Wiley Online Library (142 results), utilizing the key phrase: 'Sleep deprivation in athletes'. Additional keywords used during the search were 'melatonin,' 'PSQI', and 'chrononutrition'. During the literature review, the authors initially selected 76 articles for review, which were found to meet the eligibility criteria and be consistent with the topic of the study. Ultimately, after a thorough analysis of the works, 43 were used. The articles used in the analysis of the research problem come from the years 2019-2024. There are several articles from earlier years – 2014, 2010, 2009, and 2001 – which concern the theoretical aspect of sleep deficiency. All articles were originally written in English.

During the selection of articles for the review, the authors took into account works that were originally written in English and concerned the impact of the quality and/or quantity of sleep on the performance of athletes and the factors that worsen and improve the quality of sleep. The group taken into account includes professional and amateur athletes of both sexes, of various ages, and from various sports disciplines. We used randomized controlled trials, observational studies, meta-analyses, and review articles published in peer-reviewed scientific journals. Article exclusion criteria included publications on the impact of sleep deprivation on

individuals unrelated to physical activity, case studies, letters to the editor, and expert commentary, as well as publications in languages other than Polish and English.

The authors analyzed the papers selected for review for their quality and clarity using the following tools: CONSORT, STROBE, and PRISMA for relevant articles. All articles received a medium or high rating. Among the statistical analysis methods, 7 studies used ANOVA, 6 the independent t-tests, 3 the Chi-square tests, 3 the generalized linear models, 3 the paired t-tests and 1 used the U-test.

Literature review results

Theoretical aspect

Sleep is defined as a natural, reversible state characterized by reduced awareness and responsiveness to external stimuli. During sleep, individuals typically experience altered levels of consciousness and diminished sensory perception, allowing for restorative processes to occur within the body and brain [4]. Sleep is structured into four consecutive phases. The first three are non-rapid-eye movements (NREM), while the fourth and final phase is rapid eye movements (REM). One cycle lasts approximately 90 minutes. To speak about effective sleep, we should undergo at least 4-5 of these cycles, which result in the need for about 7-9 hours of uninterrupted sleep per day for it to be considered sufficient. Adhering to such a pattern will yield positive effects on the body, such as maintaining cardiovascular health, regulating hormones, strengthening the immune system, and improving mood and cognitive performance, which is crucial for athletes' performance, as we will discuss further. In addition to sleep quantity, other factors such as temperature, noise and sleeping surface play a significant role in its effective progression. The use of sedatives such as alcohol, antihistamines and

benzodiazepines can aid in sedation but they are associated with side effects, including excessive daytime sleepiness and increased risk of injury [5]. The REM phase of sleep plays a crucial role in sleep quality and overall physiological restoration. The reduction of REM sleep duration, whether due to sleep restriction or deprivation, can have significant implications for both cognitive and physical performance. Moreover disturbances in REM sleep can lead to fragmentation of NREM sleep and impaired sleep continuity. Understanding the importance of REM sleep in maintaining optimal sleep quality is essential for athletes aiming to enhance their performance [6].

To diagnose sleep disorders in athletes, subjective and objective measurements are utilized. Subjective methods include the Pittsburgh Sleep Quality Index (PSQI), Athens Insomnia Scale (AIS), Insomnia Severity Index (ISI), Mini-Sleep Questionnaire (MSQ), Jenkins Sleep Scale (JSS), Lees Sleep Evaluation Questionnaire (LSEQ), and Epworth Sleepiness Scale. These questionnaires inquire about the patient's sleep habits and experiences, including bedtime, sleep onset latency, total sleep time, and factors contributing to awakenings such as feelings of warmth or cold, nocturia, nocturnal pain, or nightmares. While these questionnaires demonstrate reasonable efficacy in diagnosing sleep problems, they have limitations associated with imprecise questioning, which may not always accurately highlight the underlying sleep issue, necessitating further enhancement. Among them, the Pittsburgh Sleep Quality Index (PSQI) is the most widely used, with a score greater than 5 indicating poor sleep quality [7]. In objective sleep assessment, we use polysomnography (PSG), electroencephalography (EEG), cyclic alternating pattern (CAP), and actigraphy. The authors note that these methods have their limitations as they may not always accurately assess sleep quality and suggest that future research should involve combining different types of measurements [8].

Chronic sleep problems or insufficient sleep duration will entail negative consequences in terms of cognitive functioning, but also carry negative implications for our emotions. There is a strong causal relationship between sleep and brain emotional function. Studies indicate that lack of sleep can lead to emotional disturbances, while sleep can provide benefits in terms of emotional regulation [9]. Another consequence of sleep deprivation is its impact on metabolism. There are distinct connections between sleep rhythm and metabolism. Sleep disorders and disruption of the circadian rhythm are clearly associated with the development of metabolic disorders [10]. The mentioned causes are just part of the key disorders that accompany sleep deprivation. However, they form the basis for the issues that athletes face during years of training, during which they often overlook the role of sleep in their journey toward achieving better physical performance and enhancing achievements.

Epidemiology

In a study by Monma et al. [11] on a group of 86 elite judo players, the occurrence of poor sleep quality, assessed as a score >5.5 on the PSQI scale, was found in 40.7% of the athletes. In another study by Hoshikawa et al. [12] conducted on a group of 817 Japanese athletes, 28% of the respondents reported low sleep quality (PSQI >5.5). A systematic review by Buboltz Jr et al. [13] of different groups of elite athletes (n=710) assessing subjective sleep quality using the PSQI scale showed that one third to one half of the athletes have poor sleep quality. The average value of the result >5 for the entire group of respondents was 47%. The average score achieved on the PSQI scale was 7 (SD: 4). The largest group of people reporting poor sleep quality, occurring in as many as 70% of the respondents, were Paralympic athletes (Table 1).

Table 1. Percentage of athletes with a PSQI score >5 considered to have low-quality sleep

Study	Sport	Participants	Prevalence	M±SD
Monma et al. [11]	Judo	86	35 (40.7%)	5.3±2.1
Hoshikawa et al. [12]	Multi-sport	449 (male)	111 (24.7%)	4.2±2.1
		368 (female)	118 (32.1%)	4.7±2.2
Gupta et al. [13]	Gymnastics, team sports, bobsleigh multi-sports (Paralympic)	710	47%	7±4

Notes: M±SD – mean global score/standard deviation.

A meta-analysis examining the effects of sleep loss on the performance of 227 athletes suggests that sleep loss has a negative impact on exercise performance. The results indicate a significant decrease in the percentage change in performance (%Δ), which averaged -7.56%, with a 95% confidence interval from -11.9 to -3.13, which was statistically significant (p=0.001, I2=98.1%). This effect was significant for all exercise categories. Subgroup analyses indicated that the pre-exercise sleep loss pattern, such as sleep deprivation, early sleep restriction, and late sleep restriction, is a significant factor, with consistent negative effects observed only with sleep deprivation and late sleep restriction protocols. Athletes can expect to experience approximately a 0.4% decline in performance for each hour spent awake following sleep loss [14].

An observational study aimed at determining the subjective and objective sleep quality of athletes was conducted on a group of 175 professional athletes from various disciplines, using a combination of subjective (self-reports) and objective (wrist activity monitors) methods. The study showed that the average self-assessed sleep needed to feel rested was 8.3 hours, while the average actual sleep duration was 6.7 hours. Only 3% of athletes obtained enough sleep to meet their self-assessed need, and 71% of athletes had a sleep deficit of one hour or more. The most sleep was obtained by athletes who fell asleep between 22:00 and 22:30 hours (7.2 hours)

or woke up between 09:00 and 09:30 hours (7.6 hours). Athletes involved in team sports (6.9 hours) obtained more sleep than athletes involved in individual sports (6.4 hours) [15].

Causes of insufficient amount of sleep among athletes

Caffeine consumption

In studies with actigraphy and EEG usage, caffeine has a negative impact on sleep quality in aspects such as sleep onset latency, wake time after sleep onset, sleep efficiency, and duration. In research involving athletes, this transferred into an unfavorable effect on sleep quality and its regeneration following physical exertion. Despite caffeine being associated with diminished sleep quality, there are studies indicating that caffeine has a positive influence on individuals engaging in sports who consume it directly during training: it shortens reaction time and reduces the onset of fatigue during exertion. The timing of caffeine intake plays a core impact on its profit balance. Consuming caffeine in the morning does not yield as significant consequences as consuming it in the late afternoon (after 4:00 PM), where its consumption at this time significantly affects sleep onset latency. This is due to the half-life of caffeine, which ranges from 4 to 6 hours. Unfortunately, athletes are often incapable of adjusting their training schedules accordingly, by limiting their ability to restrict caffeine intake in the afternoon hours [16].

Jet lag

Athletes traveling to distant time zones for competitions often experience acute sleeplessness resulting from the need to adjust to a different time zone. Symptoms include

general fatigue, sleep disturbances, loss of concentration, motivation, appetite, and headaches. This tends to performance issues. The effect is mostly observed when the time zone shift exceeds 3 hours. Research has shown that athletes who want to minimize the effect of jet lag after plane travel need a 24 hour adaptive period for each time zone crossed prior to the competition [17].

Time of performing competition

The time schedule of competitions in a different time zone is an essential factor influencing performance after travel. Athletes traveling east for earlier afternoon competitions may fail to achieve optimal results as their local time is closer to morning hours. Similarly, athletes traveling west may experience a disadvantage in late afternoon competitions as their local time approaches bedtime. They may benefit from gradually shifting their circadian clock prior to competitions when an unfavorable travel schedule is anticipated [17,18].

Blue light

Exposure to blue light inhibits the secretion of melatonin. Blue light sources include screens of electronic devices, e.g., phones, tablets, and television. The research suggests that exposure to blue light may decrease the quality and duration of sleep, leading to reduced performance and impaired post-exercise recovery [19]. However, the authors emphasize that researchers do not present a unequivocal negative stance on the impact of blue light, as there are studies indicating it may bring benefits among people who are physically active for a long time. Further studies are required before drawing conclusions. It is important to note that there

are studies on the impact of blue light, which suggest that exposure to blue light has a positive effect on cognitive abilities, alertness, and reaction time [20].

Meal composition time

A diet with high amount of fat input may contribute to a shortened sleep duration [21]. Additionally, research indicates that consuming solid meals may lead to a delay in sleep onset of up to 3 hours compared to consuming liquid meals, which is explained by the stimulation of the vagus nerve by food in the gastric antrum [22].

Altitude

A sudden change in altitude above sea level negatively impacts sleep quality. It leads to increased nocturnal awakenings, shortened deep sleep phase, decreased oxygen saturation, and increased periodic breathing. These factors result in poorer sleep efficiency. Athletes whose discipline takes place at high altitudes must first acclimatize to the altitude at which they are located. Otherwise, they will be more susceptible to symptoms of overtraining and will have reduced exercise tolerance [23].

Alcohol consumption

Research explicitly indicates that alcohol consumption not only does not aid in falling asleep, but also significantly impairs sleep quality, making it categorically inadvisable as a sleep aid, especially during the competition preparation period [24].

Effects of sleep deprivation in athletes

Increased risk of injury

The study by Matthew et al. [25] revealed that the amount of nocturnal sleep is associated with the risk of injuries among young athletes. This association was observed even after accounting for other factors that may influence injury indicators, such as academic year or the amount of time spent in sports training. Additionally, it was noted that with increasing age, the risk of injury rises, which is correlated with the growing pressure stemming from the increasing difficulty level of competitions as well as the intensifying overtraining of athletes. This finding is not surprising, considering previous research indicating that even moderate sleep deprivation can lead to a deterioration in psychomotor functions.

Respiratory motor output and endurance

Reduced sleep duration may decrease respiratory efficiency despite the maintenance of normal respiratory muscle strength. This situation is attributed to the disruption of cortical control over the respiratory reflex, diminished diaphragmatic motor potential, increased perception of dyspnea, and reduced motivation to engage in physical exertion under conditions of fatigue [26].

Muscle strength of the lower limbs

In a study by Rault et al. [27] conducted on 67 physical education students (38 women and 29 men) subjected to a single 24-hour sleep deprivation, a statistically significant decrease in the strength of knee extensors was observed in the experimental group compared to the control group. The reduction in knee extensor strength was significant in both women ($F=14.36$, $p<0.001$, $\eta^2=0.29$) and men ($F=8.22$, $p=0.008$, $\eta^2=0.23$). Changes in knee flexor muscle strength after 24 hours of sleep deprivation were not statistically significant for either the right leg ($F=1.71$, $p=0.196$, $\eta^2=0.03$) or the left leg ($F=0.45$, $p=0.50$, $\eta^2=0.01$). Additionally, it was found that sleep deprivation had a greater negative effect on people with a left lower extremity dominance [27].

Inhibited impulse control

In research by Lin et al. [28] conducted on professional table tennis players compared with athletes not associated with this sport (n=36), sleep deprivation has been shown to significantly slow reaction time. Professional table tennis players exhibited better reaction times than amateurs, which can be attributed to the automatization of this reflex and the reduced involvement of higher top-down cognitive processing as observed in amateurs. This suggests that sleep deprivation primarily affects advanced cognitive processes and less so our automatic impulses, which are dependent on lower brain centers.

Musculoskeletal pains

It was found that a significant 43.8% of professional athletes from Senegal (n=320) who suffered sleep deprivation experienced Musculoskeletal Pain (MSP). The most common locations of these pains are, respectively: hips and thighs (14.6%), back (13.5%), and wrists (10.1%). Among the studied sports disciplines, basketball players are the most exposed to experiencing MSP. It has also been proven that a longer recovery time combined with improved sleep quality significantly reduces the frequency of MSP occurrences [29]. A randomized crossover trial conducted on a group of physically active men (n=10) assessed the impact of sleep deprivation on the concentration of markers of muscle damage, the concentration of inflammatory cytokines, and the ability of muscle regeneration. The study consisted of two phases. In the first phase (sleep), the subjects slept for 8 hours for each of three nights. In the second phase (deprivation), they were deprived of sleep for 48 hours. During each phase, they were previously treated with the EEIMD (Exercise-Induced Muscle Damage) protocol. The research results showed increased concentrations of some inflammatory cytokines, such as IL-6, and creatine kinase in people subjected to sleep deprivation. However, sleep deprivation has not been shown to increase the time needed for muscle regeneration. Therefore, it would be necessary to check whether chronic sleep deficiency and the resulting increase in inflammatory parameters and indicators of muscle damage may contribute to the chronic muscle pain observed in the previous study [30].

Impaired cognitive performance and stress vulnerability

Athletes with insufficient sleep who went on to experience sport-related concussion (SRC) exhibited worse cognitive performance at baseline, particularly in attention and

processing speed (APS) measures, compared to those who did not sustain an SRC. This suggests that impaired cognitive function, combined with insufficient sleep, may elevate the risk of SRC occurrence. Additionally, it has been proved that chronic sleep deprivation leads to increased susceptibility to stress and elevates the risk of cardiovascular diseases [31].

Recommendations for good sleep hygiene

Melatonin supplementation

Melatonin is a hormone that physiologically coordinates our circadian rhythm. Secreted by the pituitary gland, it increases the feeling of drowsiness. Its supplementation by people who have trouble sleeping has become a common standard. Athletes can benefit from melatonin supplementation. Especially if we are talking about people who often travel to distant destinations, because it helps compensate for jet lag. An additional benefit of using melatonin is its proven anti-inflammatory and antioxidant effects, which may be important for athletes who expose their body to overload. Melatonin has very low toxicity. We normally administrate it in the doses of 1.3 and 5 mg, while the use of a dose of even 1 g per day was not associated with any side effects [32]. Results of a double-blind study by Pires et al. [33] in men (n=6) taking melatonin in low doses (0.3-1 mg) or a placebo in a total of nine sessions at 6:00 p.m., 8:00 p.m., and 9:00 p.m. with a 4-7 day interval between sessions showed significant improvements in sleep quality and duration. Low doses of melatonin (0.3-1 mg) administered at 6:00 p.m. and 8:00 p.m. had a significant effect on shortening the time to fall asleep. This effect was lesser for melatonin administered at 9:00 p.m. However, it has not been proved that the dose size had an impact on the stronger effect – groups who took 0.3 and 1 mg apparently had effects that shortened the time to fall asleep [33]. The use of melatonin is therefore very

beneficial, even though its effect on falling asleep is small, but taking it is practically not associated with any side effects and does not have addictive properties.

Tryptophan

Tryptophan, one of the amino acids, is a precursor of melatonin and serotonin. The amount of serotonin produced in the brain depends on tryptophan brain saturation, specifically the ratio of tryptophan to other large neutral amino acids (Trp-LNAA). Providing it in larger amounts causes an increase in the production of serotonin, which ultimately leads to an increase in endogenous melatonin. Tryptophan is an exogenous amino acid. Its main sources are animal products such as beef, lamb, and poultry. It is also found in eggs and milk. Plant sources of tryptophan include nuts, seeds, and whole grain products [34] A randomized controlled trial was conducted by Hudson et al. [35], in which the study group (n=57) took part in a 3-week study to assess the effects of natural and artificial sources of tryptophan on support for falling asleep. The first week was a baseline period in which participants kept sleep diaries with no supervision. During the second week, participants continued to keep sleep diaries but also ate their assigned food 30 minutes before going to bed. The third week involved only keeping sleep diaries, without eating the assigned foods, in which the subjects comparing the effectiveness of consuming 250 mg of tryptophan from a food containing tryptophan to its intake in the form of a supplement showed that both sources had a similar effect, improving the subjective assessment of sleep quality in subjects by 12.2 and 11.8%. Reduction in the number of night awakenings by 19.2% and 22.1% was observed. However, the benefits of taking tryptophan with food containing it were a more favorable pharmacokinetic distribution of tryptophan, and products containing it are also rich in vitamin B3. In the study in question, pumpkin seeds were a natural source of tryptophan [35]. In a study to assess the effect of α-lactalbumin

supplementation, a cow's milk protein with the highest concentration of tryptophan, a group of subjects (n=58) assessed the influence of a diet rich in α-lactalbumin on the increase in serum tryptophan concentration on two experimental days separated by a 4-week break. It was found to significantly increase the concentration of tryptophan in the form of Trp-LNAA by 48% when taken in protein preparations enriched with α-lactalbumin, which resulted in an improvement in the ability to function in stressful situations. Diet had a significant impact on the subjective feeling of depression. After the α-lactalbumin diet, depression levels decreased slightly after stress (from 15.62±5.7 to 14.86±5.2), while after the diet in the control sample, depression levels increased (from 15.19±5.7 to 16.19±5.7). There are no studies on the effect of tryptophan supplementation on improving sleep quality and physical performance in athletes. This may be a potential direction for further research [36].

Dietary habits facilitating falling asleep

Consuming carbohydrates with a high glycemic index increases plasma tryptophan concentrations, suggesting that a dinner containing products with a higher glycemic index may aid in sleep onset. Kiwifruit and cherries contain a large amount of melatonin, and kiwifruit is also a source of serotonin precursors. Incorporating these fruits, such as in post-workout shakes in the evening, is also an example of good eating habits that aid in maintaining proper sleep hygiene among athletes. The last important element is supplementation of B vitamins and magnesium. The correct concentration of these microelements has a beneficial effect on the concentration of serotonin and melatonin in plasma [37].

Balance between exercise and recovery time

An adequate period of regeneration after physical exercise is also necessary for proper sleep. Athletes require a detailed, comprehensive recovery plan that takes into account their individual needs. It should include proper hydration, nutrition, and psychological and physiotherapeutic support [38]. Education on how to properly deal with stress is also necessary. All these activities will have an ultimate beneficial effect in increasing the performance of athletes. Most athletes have been described as being sleep deprived and under too much stress. Hence, it is very important for persons involved in sports to personalize the approach to optimizing sleep to ensure the best results and to minimize the risk of training-related injuries [39].

Sleep-tracking technology

Currently, there are wrist-worn devices or finger versions which allow us to monitor our behavior during sleep, and draw conclusions about its quality. Data collected for at least 7 days (optimally for 2–3 weeks) allows for a preliminary diagnosis of sleep disorders or problems such as circadian rhythm disorders, travel fatigue, and insomnia. Additionally, if they include an automated assessment algorithm, they can help objectively determine the effects of jet lag and support effective strategies to minimize jet lag while traveling [40].

Daytime napping

A systematic review conducted by Sirohi et al. [41] examined the effect of napping in two groups of subjects. The review included 12 studies with a total of 67 male participants in

the partial sleep-deprived condition and 90 participants in the non-sleep-deprived condition. One group took a nap after 3-4 hours of nightly sleep deprivation, while the second group took a nap without interrupting sleep at night. The conclusions drawn from the conducted research suggest that daytime naps lasting between 20 to 90 minutes, taken between 1 p.m. and 4:30 p.m., may have a beneficial effect on athletic performance by reducing the feeling of exertion and fatigue, which translates into positive effects on various performance components, such as time to exhaustion (TTE) and agility tests. Additionally, sleep appears to play an important role in improving performance parameters such as reduced reaction time, increased attention, improved muscle strength, and reduced levels of sleepiness. Sports disciplines which gain benefits from a nap include endurance sports, obstacle courses, bench press, leg press, and vertical jump. The mechanism behind the beneficial effects of naps is not entirely clear; the general consensus points to a beneficial effect of napping during the day on athletic performance, which may have important implications for training and competitive practice [41].

Chrononutrition

Another phenomenon still under research is chrononutrition, which explores the relationship between the food we eat and the human circadian rhythm. An experimental study conducted by Tahara [42] on rodents proved that feeding time influenced the expression of Per1 and Per2 genes responsible for the control of the circadian rhythm. Scheduled feeding had a significant effect on the metabolism and body weight of the mice. Feeding during the active period (night) was less effective for gaining weight than feeding during the rest period (day). Additionally, it was found that feeding a high-fat diet during the day led to greater weight gain and metabolic disorders than feeding at night. A study conducted by Dote-Montero et al. [43] on a group of young adults (n=118) using surveys for 3 weeks to assess their eating times in

relation to their circadian rhythm found that an evening meal time, considered unhealthy, and a wide 24-hour eating window were not associated with the risk of weight gain and increased cardiovascular risk [43]. While researching this topic, the authors did not find any research examining the impact of chrononutrition on the performance of athletes, which is a potential path for the development of research on optimizing the physical performance of physically active people.

Discussion on the effectiveness of the intervention

During a review of articles presenting solutions to reducing sleep deprivation in athletes, we found potential solutions with varying levels of effectiveness, which we have outlined above. Daytime napping and balancing exercise and recovery time are highly effective in reducing the negative impact of sleep deprivation. Research suggests that sleep deficiency cannot be replaced by factors other than supplementing the amount of daily time devoted to sleep. The authors' attention was drawn to the issue of nutrition that improves sleep. As of this writing, there are a small number of studies on the use of tryptophan supplementation or its derivatives in daily nutrition and chrononutrition for improving sleep quality and the speed of falling asleep in the context of athletes and physically active people. Melatonin supplementation seems to be a good idea as one way to optimize the speed of falling asleep. It is characterized by a small improvement in falling asleep, but the fact that research emphasizes its negligible risk of side effects and is not an addictive substance means that it may be a good direction to improve the quality of sleep.

Conclusions

The review aimed to collect information on the effects of sleep deprivation and possible ways to mitigate this negative effect in a group of professional athletes and physically active individuals. The collected articles clearly indicate that sleep deficiency negatively impacts physical performance. It impairs concentration, increases the risk of injury during exercise, and limits the efficiency of the respiratory system by increasing the threshold for feeling shortness of breath in the central nervous system. It may also cause chronic muscle pain, affecting the comfort of everyday functioning.

The causes of sleep deprivation we have identified are extensive and include caffeine consumption, jet lag, race start time in a different time zone, exposure to blue light, food composition, altitude, and alcohol consumption, to name just a few. During the review, we identified two possible paths for further research on improving the quality of sleep in athletes. The first is to conduct further research on optimizing the circadian rhythm of athletes, checking what rest periods and naps during the day and their lengths will result in the most optimal improvement in sleep and how this will impact physical performance. The second direction for further research is the issue of optimizing the nutrition of athletes, focusing on the timing of meals and their composition, so that it does not limit the time needed to fall asleep and has a positive effect on sleep quality.

Disclosures and acknowledgements

The authors declare no conflicts of interest with respect to the research, authorship, and/or publication of this article.

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Artificial intelligence (Gemini Google Translate) was used only in the process of checking the grammatical and stylistic correctness when translating initially the text into English. The entire text of the manuscript was originally written by the authors.

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