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Jet lag: an underestimated factor in reduced physical performance in athletes

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ABSTRACT:

Introduction and purpose: Jet lag is a common issue affecting most athletes traveling across at least 2 time zones, particularly when traveling eastward. Observational studies on over 114,000 game matches have established that traveling teams had a statistically significant higher rate of game losses. Jet lag manifests not only in a decline in athletes' physical performance but also affects cognitive abilities, attention span, and subjective feelings of fatigue. Melatonin can be a very important supplement in helping to regulate the circadian rhythm. Other recommended methods include phototherapy, appropriate meal timing, and sedative medications.
This paper aims to gather the latest clinical research assessing athletes' predisposition to jet lag symptoms, large-scale retrospective observational studies evaluating this phenomenon, and discusses the functioning of the circadian rhythm, methods for alleviating jet lag symptoms, and its manifestations.

Materials and methods: This article comprises a literature review based on publications from PubMed, ClinicalKey, and Google Scholar utilizing the key phrase: Jet lag and Athletes, melatonin, 'PSQI', Actigraphy and 'Circadian rhythm disruption'. During the literature review, the authors initially selected 68 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, 32 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 which concern the theoretical aspect of jet lag and circadian rhythm regulation. All articles were originally written in English.

The state of knowledge: Jet lag has been identified as a factor impairing the physical performance of professional athletes. The amount of research allowing for its recognition in athletes is sufficient. However, there is a lack of studies on methods for managing jet lag.

Current recommendations are based on low-quality studies with small sample sizes. Additionally, there is a lack of diagnostic methods specifically designed for athletes experiencing acute sleep deprivation.
Conclusions: In the above review, we established that jet lag is prevalent among athletes traveling to competitions and significantly impairs their physical and cognitive performance. Despite comprehensive sleep quality questionnaires, there is a lack of tools tailored to athletes' specific needs. Clinical and observational studies confirm reduced performance and an increased number of losses in teams traveling long distances. Recommended methods to mitigate jet lag include melatonin, light therapy, meal timing, and sedative medications, but these have limited reliability due to insufficient research on small athlete groups. More extensive studies are needed to develop stronger evidence-based recommendations.

Key words: Jet lag, Athletic performance, Sleep deprivation, Melatonin, Ciricadian rhythm

1. Introduction

The improper quantity and quality of sleep is a recognized and proven factor that impairs physical performance in athletes. Acute sleep deprivation, occurring among other instances during time zone changes, can negatively affect physical performance in parameters such as high-intensity intermittent exercise, skill control, speed, aerobic capacity, and endurance [1]. In addition to physical parameters, sleep deprivation can also deteriorate cognitive functions and mood, which includes slower reaction times and weaker verbal and visual memory. As a result, there is an increased risk of resorting to stimulants to stay awake, which is not a proper solution and further deteriorates health [2]. Long-term sleep deficits can also lead to an increased risk of developing depression. Studies indicate that disrupting the 24-hour cycles of activity and rest is correlated with key features of mood disorders. Young individuals with mood disorders often experience greater irregularities in sleep and wake rhythms, leading to less mood stability and a higher risk of developing depression [3,4].

Our previous work addressed the overall impact of sleep deprivation on the reduction of physical performance in athletes. We identified several main causes leading to the deterioration of sleep quality in professional athletes, among which jet lag plays a key role [5].

Jet lag has already been identified in several research papers as a significant factor impairing physical performance according to athletes, sports coaches, and physicians. However, it is still a neglected factor [6]. In this publication, we aim to present the extent of the problem of jet lag's impact on the physical performance of athletes and summarize publications containing recommendations for improving sleep comfort during travel to distant time zones.

2. Background

2.1 Circadian Rhythm

The circadian rhythm is the body's internal 24-hour cycle that synchronizes biological and behavioral processes with the surrounding environment. It is regulated by molecular processes occurring in the brain, which are reset daily by the light-dark cycle. The circadian rhythm is controlled by a center located in the suprachiasmatic nucleus (SCN) in the hypothalamus.

Melatonin, secreted by the pineal gland primarily at night, helps synchronize our biological clock, signaling when it is time to sleep. This allows us to adjust our physiological functions to the appropriate times of the day. Additionally, melatonin plays a crucial role in the process of sleep induction, where an increase in melatonin levels in the evening helps prepare the body for sleep by lowering body temperature and inducing feelings of sleepiness. Due to these properties, melatonin may have therapeutic applications in restoring proper sleep rhythms in individuals affected by jet lag [7]. Another significant hormone in the regulation of the circadian rhythm is cortisol, secreted by the adrenal glands. Cortisol reaches its peak at the end of the sleep period and plays a crucial role in the transition from the sleep phase to the wake phase [8].

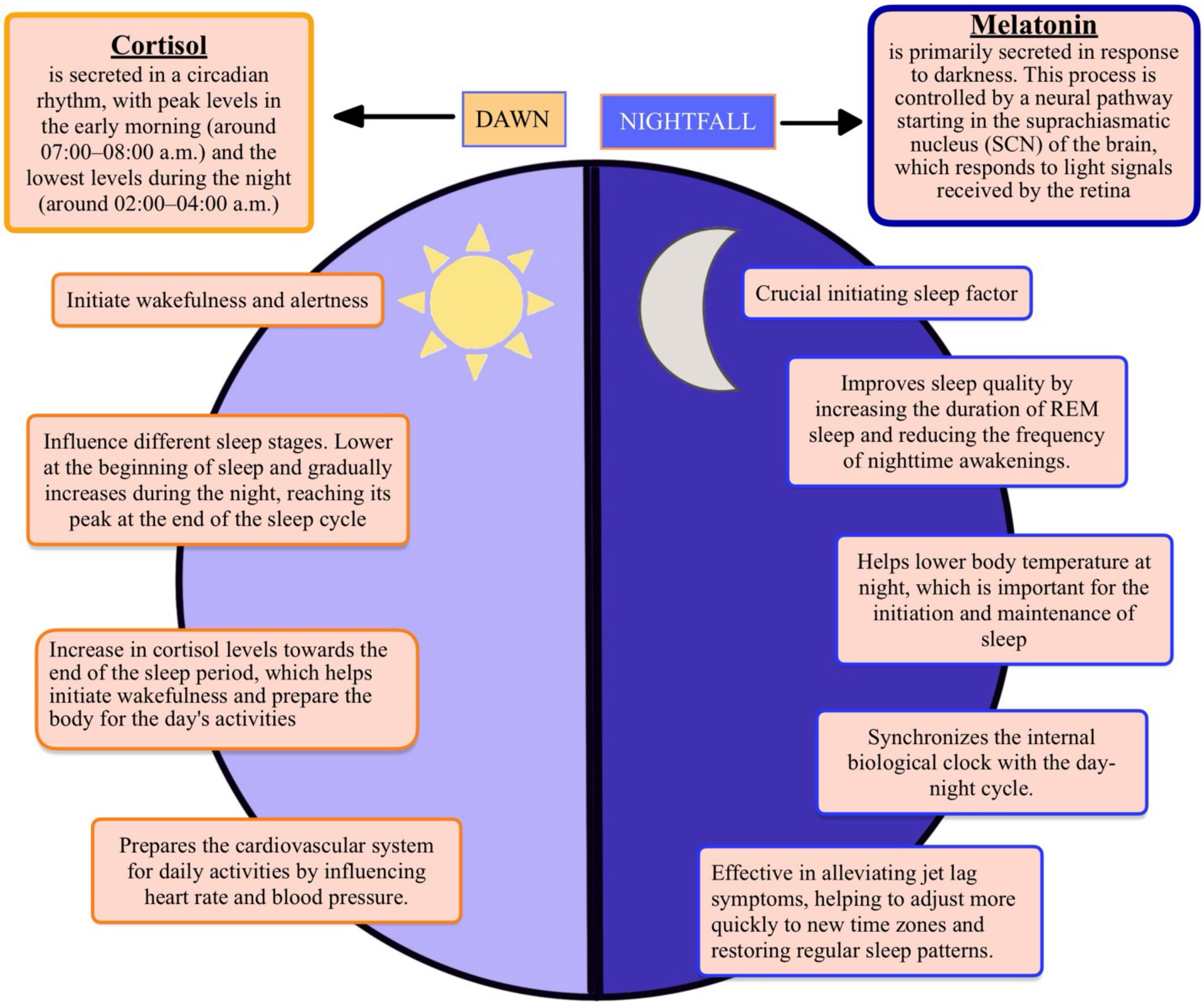


Figure 1: Regulation and impact of the circadian rhythm on sleep and wakefulness [7,8]

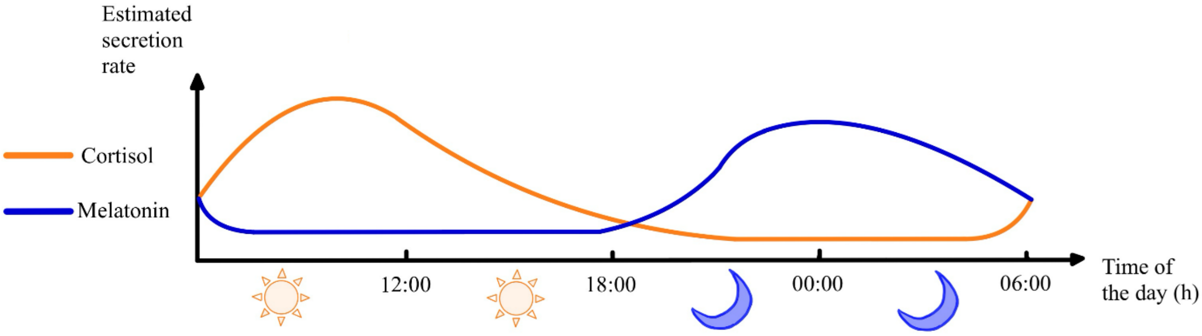


Figure 2: Estimated secretion rate of hormones regulating the circadian rhythm [7,8]

2.2 What is Jet Lag?

Jet lag, also known as rapid time zone change syndrome, occurs when a person travels across multiple time zones. This results in transient sleep problems. The circadian rhythm remains adjusted to the original time zone for a while, which can cause sleep disturbances and daytime fatigue. The negative effects of jet lag are more pronounced when traveling eastward compared to westward. This is due to the need to advance the internal biological clock [9]. Athletes, as a professional group that frequently travels, are particularly susceptible to the effects of jet lag, which has a proven direct impact on the decline in physical performance due to disruptions in daily functioning, general malaise, and gastrointestinal disturbances during the first few days of travel. Its negative impact has been demonstrated in athletes traveling across at least 2 time zones, with symptoms typically persisting for 1 day per crossed time zone [10].

2.3 Monitoring Sleep Quality

To assess sleep quality, both subjective and objective evaluation methods can be utilized. Among subjective methods, the most important questionnaire is the Pittsburgh Sleep Quality Index (PSQI), which examines our sleep experiences. A score above 5 points on this scale indicates poor sleep quality in the assessed individual [11]. A meta-analysis conducted by João Gustavo Claudino et al. [12], comparing 30 instruments used to assess sleep quality, demonstrated that the best questionnaires for this purpose are the Likert rating scale, the Liverpool Jet-Lag Questionnaire, and RESTQ. Their advantages include low cost and a broad range of sleep parameters in various contexts. However, a limitation remains that these questionnaires are not tailored to the conditions faced by athletes. Among the objective methods for assessing sleep quality, actigraphy and polysomnography (PSG) are prominent, with PSG being considered the gold standard for monitoring sleep quality. Unfortunately, this comes at a high cost and involves discomfort due to the nature of the examination [13].

3. Prevalence of jet lag among professional athletes

3.1 Clinical trials

We have gathered 5 studies evaluating the direct impact of jet lag on professional athletes, which examined not only subjective symptoms of jet lag but also focused on physiological changes such as alterations in blood pressure and hormone secretion profiles.

Doherty et al. assessed the impact of long-distance eastward travel on 7 elite athletes. Measurements were taken using actigraphy and sleep diaries for 5 days before the journey, during the journey, and 5 days after the journey. Actigraphy showed a significant reduction in time spent in bed, total sleep time, and sleep efficiency, particularly during the first 48 hours of travel [13]. Lemmer et al. evaluated the impact of time zone changes on the diurnal profile of blood pressure and heart rate in athletes, as well as the subjective symptoms of jet lag. Nineteen athletes crossed 8 time zones eastward or 6 time zones westward. Jet lag symptoms were present on average until the 5th-6th day after westward travel and until the 7th day after eastward travel. Average post-travel blood pressure values increased, with SBP and DBP at 128.8±3.9 and 72.6±4.1 mmHg, respectively. Disruptions in the diurnal profile of melatonin and cortisol secretion were also observed. Other deviations noted in the study results included decreased grip strength [14]. Heidi et al. aimed to compare short-distance and long-distance travel in a group of 11 wheelchair basketball players using actigraphy and subjective assessments. During the competition, subjective fatigue and jet lag ratings were higher for the LONG group compared to the SHORT group (ES = 0.73; ±0.77 for fatigue and ES = 0.57; ±0.60 for jet lag)[15].Fowler et al. conducted a study to assess the impact of a 24-hour westward journey across 11 time zones on subjective jet lag symptoms, sleep quality, and the risk of upper respiratory tract infections (URTI). The study found that long-distance travel significantly affected subjective feelings of jet lag and exacerbated URTI symptoms [16]. A study by Waterhouse et al. aimed to determine the factors influencing jet lag and how it manifests in athletes traveling from the UK to Australia. They crossed a total of 10 time zones eastward. The study highlighted various determinants of jet lag and suggested strategies to minimize its impact. Key predictors of jet lag included age, previous travel experience, and the way the biological clock adjusted to the new time zone. The findings emphasize the importance of strategic planning and personal habits in mitigating the effects of jet lag, particularly for individuals requiring optimal performance in new time zones [17].

Table 1: Summary of clinical trials evaluating the impact of jet lag on professional athletes [14-18].

Study	Sample size	Investigation	Journey and Measurements	Results
Doherty et al. [14]	n=7 (M[1] n=3 F[2] n=4) Elite athletes	Assess the impact of long haul eastward travel on	•21.5 h of total time travel •crossing 7 time zones east •Actigraphy and sleep dairy	•A reduction in total sleep time post-travel compared to pre-travel. •Delayed sleep onset and increased sleep fragmentation. •These sleep disturbances can potentially affect athletic performance due to the critical role of sleep in physical recovery and cognitive function.
Lemmer et al. [15]	n=19 Elite athletes	Assess the impact of crossing time zones on: BP, HR, symptoms of jet lag, training performance and body temperature	• WEST (Frankfurt – Atlanta): Flight duration 9 hours 50 minutes • EAST (Munich – Osaka): Flight duration 12 hours	• Jet Lag Symptoms: Symptoms lasted up to 5-6 days after WEST flight and up to 7 days after EAST flight. • Training Performance: Worst performance occurred during the first 4 days after WEST flight. • BP[3] and HR[4] Profiles: Both blood pressure and heart rate were disrupted on the first day post-flight. •Cortisol, Melatonin was disrupted 24-hour profiles
Heidi et al. [16]	n=11 Wheelchair basketball players.	investigate the impact of short-and long-distance (international travel on sleep and well-being in national	• LONG: Up to 30.2 hours • SHORT: Up to 6.5 hours	•Fatigue and Jet Lag: During the competition, subjective ratings of fatigue and jet lag were higher for the LONG group compared to the SHORT group (ES = 0.73; ±0.77 for fatigue and ES = 0.57; ±0.60 for jet lag). •Vigor: Subjective ratings of vigor were lower for the LONG group (ES = 1.94; ±0.72). •Wake-up Time: Wake-up time was earlier for the LONG group (ES = 0.57; ±0.60).
Fowler et al. [17]	n=18	Assess impact of a long-distance travel on subjective jet lag	•Flight 1: Sydney, Australia to Abu Dhabi, UAE (15.5	•Subjective jet lag symptoms peaked on day 2 post-travel and remained elevated until day 8. Sleep: Sleep and wake times were earlier on day 2,

	Professional rugby players.	symptoms, sleep quality, well-being, and upper respiratory tract infection (URTI) symptoms	hours, 12085 km). •Flight 2: Abu Dhabi to London, UK (7.3 hours, 5478 km). •The players crossed 11 time zones.	improving by day 5. Total sleep time increased by day 8.
				•URTI symptoms increased on day 6 post-travel, with no significant changes in muscle strength, ROM, or pain.
				•Well-being: No significant changes in overall well-being, though fatigue was highest on day 2 and reduced by day 8..
Water-house et al [18]	n=85 (M n=54, F n= 31) •Elite athletes •Coaches •	Identify determinants of jet lag and its symptoms among travelers,	The travelers crossed 10 time zones, flying eastward from the United Kingdom to Australia.	•Participants who left the United Kingdom in the evening slept significantly more on the first flight compared to those who left in the morning (medians of 5.5 hours vs. 1.5 hours, p = 0.0002).
				•Age: Increasing age and a later arrival time in Australia were associated with less jet lag and fatigue.
				•Previous Experience: Experience of travel to Australia was linked to an earlier time of getting to sleep.

[1]- Male [2]- Female [3]-Blood Pressure [4]- Heart rate

3.2 Observational Studies

The second aspect involves observational studies that retrospectively assess whether athletes traveling across multiple time zones have significantly lower chances of winning a match. The studies we included analyzed a total of over 114,000 games, of which 8,562 met the criteria for jet lag for one of the teams according to the conditions established by the researchers. Leota et al. conducted an observational study on a total of 22,962 matches, comparing the results of home teams with visiting teams traveling across a number of time zones sufficient to cause jet lag, evaluating its potential impact on match outcomes. The study considered both eastward and westward travel. The results suggest that the direction of travel and the number of crossed time zones can significantly affect team performance [18]. Glinski et al. conducted a similar study, observing a total of 48,309 NBA games, of which 675 met the criteria for jet lag among players. They assessed the athletes' ability to perform free throws.

Teams affected by jet lag were those crossing at least 3 time zones. Teams experiencing jet lag had slightly lower free throw accuracy (74.6%) compared to their performance in non-jet lag games (75.4%), which was statistically significant (p = 0.02). The negative impact of jet lag was mainly observed during east-to-west travel, where free throw accuracy dropped to 74.6% compared to 75.5% in other games (p = 0.04). No statistically significant differences were found for west-to-east travel [19]. Song et al., in a 20-year observational study analyzing a total of 46,535 Major League Baseball (MLB) games, evaluated the performance of players who crossed at least 2 time zones. Jet lag significantly impacted the win percentage, particularly during eastward travel. Eastward travel had a significant effect on the home team's win percentage (p < 0.05), reducing their home-field advantage [20].

Table 2: Summary of observational studies evaluating the impact of jet lag on sports performance

Study	**Sample size**	**Investigation**	**Competitions Taken into Consideration**	**Results**
Leota et al. [19]	•10411 home teams •9583 away teams	Examining the impact of jet lag on team performance in league matches, considering the direction of travel (eastward and westward) and the number of time zones crossed.	• Home teams: ‣619 games with westward jet lag ‣451 games with eastward jet lag •Away teams: ‣928 games with westward jet lag ‣970 games with eastward jet lag	• Home teams experiencing eastward jet lag had an average winning percentage of 54.55% (SD=0.50), which was marginally lower than 58.05% (SD=0.49) for home teams without jet lag (t=-1.955, p=0.051).
				• Eastward jet lag affected performance, but the effects were not statistically significant compared to westward jet lag
Glinski et al. [20]	48,309 NBA games	determine the impact of jet lag on free-throw shooting performance in the NBA. The researchers aimed to	675 met the criteria for a team being affected by jet lag.	• Teams affected by jet lag had a slightly lower free-throw success rate (74.6%) compared to their performance in non-jet-lagged games (75.4%), which was statistically significant (p = 0.02).

		investigate whether traveling across time zones		• The negative impact of jet lag was mainly observed when traveling from east to west, where the free-throw success rate dropped to 74.6% compared to 75.5% in other games ($p = 0.04$).
Song et al. [21]	46,535 games. Major League Baseball games	Examine the effects of jet lag on specific performance metrics in MLB, focusing on the differences between eastward and westward travel	4,919 games with teams having at least 2h of jet lag.	•Eastward travel significantly reduced the home team's slugging percentage ($P < 0.05$). •The home team's winning percentage was significantly affected by eastward travel ($P < 0.05$), reducing their home-field advantage. •Jet lag impacted both home and away teams' defensive performance, particularly in the number of home runs allowed.

4. Effects of long-distance air travel and jet lag

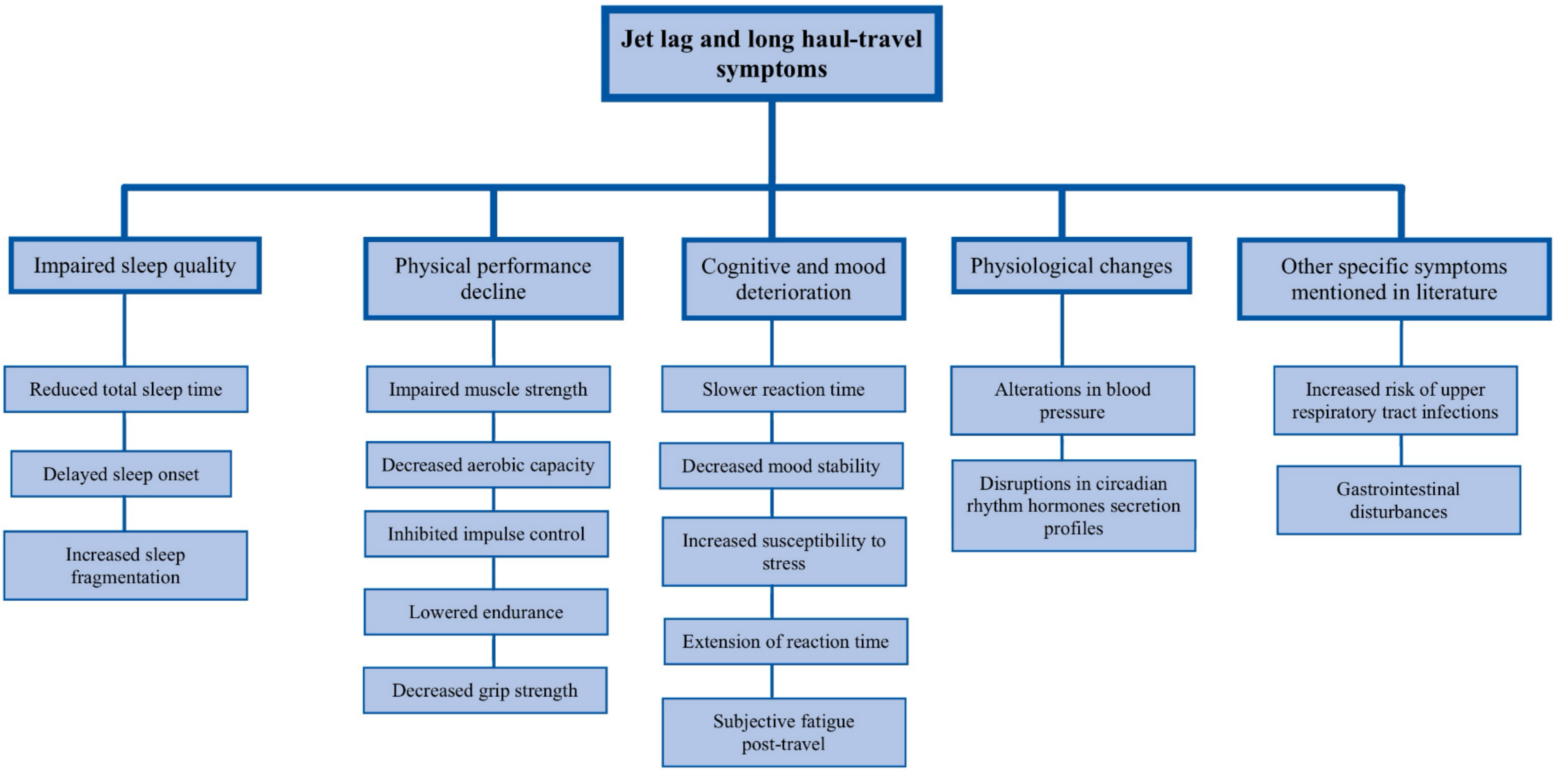
Jet lag has a significant impact on the deterioration of sleep quality in athletes. However, its negative effects are not limited to impaired sleep alone but also encompass several other adverse aspects that can ultimately lead to a decline in physical performance. Rossiter et al., in their systematic review, critically evaluated the evidence on the impact of long-distance travel on the psychomotor and physiological parameters of professional athletes traveling for more than 6 hours. The review demonstrated that elite athletes experience symptoms of jet lag for up to 7 days following long-distance travel, particularly when traveling eastward. However, it could not be conclusively determined whether this had an impact on diminished athletic performance. Due to the discrepancy in results from simple tests such as grip strength, where jet lag significantly affected strength reduction, this effect was not observed in more complex tests. The authors highlight the limited pool of studies investigating this phenomenon [22]. Zubac et al., in their review, highlighted the risk of dehydration occurring under the specific conditions present in an airplane during long-distance travel. During air travel, reduced oxygen pressure and low humidity lead to increased water loss, and fluid intake during the journey may sometimes be insufficient to compensate for this loss. Dehydration can negatively affect athletes' physical performance, but further studies are needed to assess the impact of this phenomenon [23]. The last aspect worth mentioning is the increased risk of infection associated with long-distance travel and being in a confined space, which heightens the risk of infectious diseases. In the past, there have been reports of the spread of infectious diseases among air travelers, such as influenza or norovirus infection [24]. A well-documented contemporary phenomenon is the transmission of the SARS-CoV-2 virus during long-distance flights, where the risk of virus transmission for a nearby seated person increased by 7.3 times [25]. In Figure 3, we summarize all the negative effects of jet lag that have been established during the literature review.

Figure 3: Summary of Symptoms Associated with Jet Lag and Long-Haul Travel

5. Methods for alleviating jet lag symptoms

5.1 Melatonin Supplementation

In the reviewed literature, melatonin appears to play a very significant role in the



symptomatic treatment of jet lag effects. Administration of exogenous melatonin in the evening promotes phase shifting of sleep and facilitates falling asleep, which significantly helps alleviate jet lag symptoms. The use of melatonin in doses ranging from 0.5 to 5 mg is sufficient for this purpose [26]. Additional advantages of melatonin in the context of athletes include the lack of addictive effects and very low toxicity. While the use of 1.3 to 5 mg of melatonin is considered the standard dosage, studies have shown that taking doses as high as 1 g per day did not result in toxic effects [27]. Reported side effects of melatonin use include daytime sleepiness, dizziness, headaches, and loss of appetite. However, it is not entirely clear whether these are due to melatonin use itself or if they were symptoms of jet lag [26].

5.2 Light Exposure

A crucial therapeutic approach in alleviating the effects of jet lag may be appropriately timed light exposure and avoidance, aimed at facilitating the re-synchronization of the circadian rhythm. Recommendations for mitigating jet lag include evidence that exposure to bright light at specific times can help shift the circadian rhythm. For eastward travel, morning light exposure is recommended, whereas for westward travel, evening light exposure is advantageous. Avoidance of light at inappropriate times is equally important. For eastward travel, light exposure in the evening should be avoided, while for westward travel, morning light exposure should be avoided [28]. Combining light exposure with melatonin, tailored to the internal biological clock, may effectively shift circadian rhythms. For a time zone change of 3-6 hours, morning light exposure and afternoon melatonin administration are recommended. Upon arrival, it is advised to continue morning light exposure and take melatonin at the local time corresponding to the afternoon at the departure location [29].

5.3 Timing and Composition of Meals

Proper meal timing and composition can help minimize the symptoms of jet lag. Regular feeding and fasting cycles are crucial for peripheral clocks, such as the liver clock, which is sensitive to the timing and composition of meals. The Argonne Diet, which involves alternating between high-protein, low-carbohydrate meals and consuming a high-protein breakfast upon arrival, may reduce jet lag symptoms. Consuming carbohydrate-rich meals before bedtime can impact sleep quality by shortening the time it takes to fall asleep. However, meals high in carbohydrates consumed immediately before sleep may reduce the quality of deep sleep. Protein, particularly tryptophan, influences the production of serotonin and melatonin, which are essential for sleep regulation. Fat intake may increase the levels of free tryptophan in the blood, affecting melatonin production and sleep quality. A very low-carbohydrate, high-fat diet may increase the duration of deep sleep and all stages of non-REM sleep. To minimize jet lag, it is advisable to eat meals at consistent times and to consume meals rich in tryptophan, low-glycemic carbohydrates, and fats. It is important to avoid eating high-carbohydrate meals right before bedtime to prevent compromising the quality of deep sleep [30].

5.4 Sedative Medications

Sedative medications may serve as a second-line treatment due to their potential for dependence and side effects, and they are listed among potential pharmacological solutions. Due to their addictive potential and adverse effects, benzodiazepines are not considered a first-line treatment for athletes. Review authors also highlight the lack of studies assessing the effectiveness of such interventions in athletic populations, and the current data are very limited.

6. Conclusion

In the review, we have established that jet lag is a very common phenomenon among athletes traveling to sports competitions. While there are comprehensive questionnaires assessing subjective sleep quality, there is a lack of questionnaires tailored to the specific living conditions of athletes. The analyzed clinical studies leave no doubt about the reduced performance of athletes subjected to long-distance travel. Observational studies have shown that the number of matches lost by teams undertaking long journeys was statistically significant. Jet lag significantly impairs athletic performance through various mechanisms, such as reduced physical and cognitive performance, and deteriorated mood. Among the recommended methods for alleviating jet lag symptoms are the use of melatonin, light therapy, appropriate meal timing, and sedative medications. However, these studies emphasize their limitations due to the insufficient number of studies conducted on small groups of athletes. Consequently, these recommendations have limited reliability and require more detailed studies on larger populations to develop recommendations and algorithms with greater evidence strength.

Statement of the author's contribution

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