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Overview Article

The Potential Impact of Heat on Athletes' Sleep at the Paris 2024 Olympics and Paralympics Games

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Sleep Sci

Abstract

In 2024, Paris will host the Olympic (during July and August) and Paralympic (during September) Summer Games. Despite temperatures often exceeding 40°C in Paris in July, the International Olympic Committee (IOC) has indicated that there will be no installation of air conditioning in the athletes' rooms. High ambient temperatures can impair the quantity and quality of sleep and, consequently, impair athletic performance. In this overview, we present the rationale behind and explain the process of how a warm environment is unfavorable to the sleep of Olympic and Paralympic athletes, as well as offer practical recommendations on how to mitigate the effects of environment heat for a restful and effective night's sleep during the Paris 2024 Olympics and Paralympics Games.

Keywords
- sleep
- athletes
- para-athletes
- Olympic
- Paralympic
- heat acclimation

Introduction

For athletes and para-athletes worldwide, participation in the Olympic and Paralympic Games represents the pinnacle of their sporting careers, offering the opportunity to achieve optimal results in their respective sport modalities. In most sports, these Games constitute the most significant occurrence in an athlete's professional journey.

Physical training is an unquestionable factor for athletic performance. Equally important, rest and recovery are essential components to achieve significant results and, consequently, sporting success.[1] Among the possibilities for recovery strategies, sleep can be a crucial factor in restoring the body from the central and peripheral fatigue inherent to physical training. Traditionally, sleep is defined as a reversible behavioral state in which the individual shows relative immobility and an increased threshold for response to external stimuli.[2]

While high-quality sleep positively influences athletic performance, lack of sleep (in terms of both quality and quantity) has indisputable detrimental effects resulting in various negative consequences. For instance, compromised

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ability, as evidenced by a study involving male team sports athletes deprived of sleep who demonstrated a reduction in both average and total sprint times.[3] Another study showed a drop in serve accuracy of up to 53% in male and female tennis players deprived of sleep compared with performance after a regular night of sleep.[4] Male runners and volleyball players demonstrated a lower exhaustion threshold after sleep deprivation,[5] and their reaction time was negatively impacted with sleep deprivation.[6] Additionally, there is a higher risk of musculoskeletal injuries[7] and immunosuppression associated with sleep deprivation.[8]

A plenty of intrinsic and extrinsic situations can negatively impact athletes' sleep. For example, the intensity and timing of training sessions can significantly affect sleep. High-intensity workouts, especially when conducted in the evening, can lead to delayed sleep onset and reduced sleep duration.[9] Additionally, athletes can face significant mental and emotional demands, such as pressure to perform, fear of injury, and media scrutiny, and these stressors can cause anxiety and hyperarousal, making it difficult for athletes to fall and stay asleep.[10] The bidirectional relationship between stress and sleep means that stress can impair sleep quality, which, in turn, can exacerbate stress and affect overall performance.[10]

As an example of an extrinsic factor, one can cite environmental temperature, which significantly impacts athletes' sleep quality. Variations in ambient temperature, particularly when athletes are exposed to either excessively hot or cold conditions, can interfere with the body's thermoregulation during sleep.[11] This disruption can lead to reduced sleep efficiency, increased wakefulness, and overall poorer sleep quality, which, in turn, affect athletic performance and recovery.

In the context of the country and host city for the 2024 Olympic and Paralympic Games, environmental temperature can be a significant extrinsic factor that impacts athletes' sleep quality. In this overview, we present the rationale behind and explain the process of how a warm environment is unfavorable to the sleep of Olympic and Paralympic athletes, as well as offer practical recommendations on how to mitigate the effects of environment heat for a restful and effective night's sleep during Paris 2024 Olympics and Paralympics Games.

Accommodations, Ambient Temperature, and Sleep

In 2024, Paris will host the upcoming Summer Games in July and August (Olympic Games) and September (Paralympic Games). In these months, it will be summer in Europe, with temperatures generally showing long-term warming trends for both annual and seasonal averages. In 2023, the warmest summer by a significant margin was recorded, with a 1.4° C increase above the average.[12] The 2024 Games will be primarily held in Paris and its surrounding areas, although some events will take place farther from the capital, including soccer at various southern locations and sailing competitions in the waters of the Mediterranean along the coast of Marseille.

Some evidence show that high temperatures during the European summer are responsible for negative impact on health status, including death. For example, Ballester et al.[13] estimated the mortality burden associated with the record-breaking temperatures registered in the 2022 summer in Europe. The authors estimated 61,672 heat-related deaths in Europe between May 30 and September 4, 2022, with women being the most affected. Italy, Spain, Germany, and France (host country of the Olympic and Paralympic Games) had the highest heat-related mortality numbers. Specifically, France had the highest number of heat-related deaths among people aged 0 to 64 years (age range of most athletes). Therefore, the high temperatures in Europe during the Olympic and Paralympic Games should be a cause for concern to athletes, coaches, and sports managers.

Despite temperatures often exceeding 40°C in Paris during summer, the International Olympic Committee (IOC) announced that there will be no installation of air conditioning in the athletes' rooms.[14] The decision by the organizers of the Paris 2024 Olympic Games not to incorporate air conditioning systems in the Athletes' Village was justified to reduce the carbon footprint associated with the event.[14] The President of the IOC and the director of the Olympic and Paralympic Villages argue that installation of air conditioning is unnecessary due to the efficient isolation of the buildings, contributing to maintaining an acceptable internal temperature. Confidence in these and other measures to be adopted (availability of fans) aims to reduce the internal temperature by up to 6 degrees compared with the external environment.[14] Although the IOC's regard for the environment is commendable, we would like to raise some concerns regarding the comfort of athletes and potential harm to sporting performance.

Athletes often struggle with inadequate sleep, and various factors have been proposed to understand why elite athletes might face sleep challenges. A total of 53% of athletes reported sleep complaints, with the most prevalent being insufficient sleep or waking up tired (32%), followed by snoring (21%) and insomnia (19.2%), indicating that 36% of all athletes had a sleep disorder, with a more pronounced reduction in sleep quality observed in men compared with women.[15] A recent review study[16] identified the following sleep parameters of Olympic athletes: total sleep time (TST), sleep onset latency (SOL), sleep efficiency (SE), awakenings after sleep onset (WASO), quality of sleep, daytime sleepiness, and chronotype. The key findings reveal that Olympic athletes average a total sleep time (TST) of 6 hours and 10 minutes, with a sleep efficiency (SE) of 84%. Sleep onset latency (SOL) is $\sim$ 28 minutes, and wake after sleep onset (WASO) lasts for around 49 minutes. The prevailing chronotype among athletes is largely indifferent. Additionally, more than half of the athletes experience subpar sleep quality and report various sleep-related complaints.

The likelihood of poor sleep among Paralympic athletes is potentially higher due to the intricate nature of certain types of impairments. Indeed, past clinical studies have demonstrated that individuals with disabilities are more prone to experiencing sleep disturbances compared with those

without impairments.[17] A series of studies[18–20] showed that Paralympic athletes have low sleep quality, insomnia, and excessive daytime sleepiness, a situation that might influence negatively the sports performance. A recent review[21] demonstrated that Paralympic athletes have a low amount (7.06 hour) of sleep with poor quality and high sleep latency (28.05 minute), and 57.2% have daytime sleepiness, with the majority belonging to the indifferent chronotype (53.5%), confirming that sleep-related issues are prevalent in Paralympic athletes, characterized by suboptimal sleep quality and duration, along with elevated instances of daytime sleepiness.

Considering that the sleep circadian cycle is closely related to the central body temperature, it is crucial to have a comfortable environment to induce and maintain sleep.[22] Thermal environment, combined with other factors such as health and emotional states and bed conditions, is one of the main causes of sleep disorders[23] and should not be neglected.[22] In this context, some guidelines specify criteria for room temperature. The World Health Organization recommends a minimum room temperature of 18°C.[24] The Chartered Institution of Building Services Engineers (CIBSE) guide suggests 23 to 25°C in the summer.[25] The European standard (EN15251) establishes a maximum temperature of 26°C in habitable spaces (including bedrooms).[26]

What are the Potential Impacts of a Warm Environment on the Quantity and Quality of Athlete Sleep?

Various physiological and psychological aspects contribute to differences in thermal perception. Athletes age, sex, body composition and fitness, metabolic rate, and physiological adaptation due to temperature acclimation and habituation of different climatic zones, seasonal adaptation, and circadian/diurnal rhythm encompass both the physical characteristics of individuals and their subjective experiences in different thermal environments.[27]

►**Fig. 1** summarizes how a warm environment can impact the athlete's sleep and the main consequences of insufficient sleep. The human body has a natural cooling cycle during sleep, and when the ambient temperature is too high, it can be more challenging for the body to cool down. This can interfere with sleep stages, especially slow-wave sleep, which is responsible for physical recovery.[28] Elevated ambient temperatures in living spaces can cause physical discomfort, leading to difficulties in finding a comfortable sleeping position.[23] This can result in restless nights and frequent sleep interruptions. Moreover, increased sweating is observed during slow-wave sleep compared with other sleep stages, with excessive sweating being uncomfortable enough to cause nighttime awakenings, disrupting continuous sleep.[29]

A heat wave during the Olympic and Paralympic Games could greatly endanger athletes' sleep. Last summer highlighted this issue when the Cerberus heat wave pushed temperatures in southern Europe to 43°C during the day. However, at night, based on projections from the previous year, organizers expect that nighttime temperatures will not exceed 26°C, even in a heat wave.[30]

Unfavorable environmental conditions with increased temperatures pose a challenge for all athletes, with Paralympic athletes potentially being more significantly impacted than Olympic athletes,[31] due to reduced thermoregulatory

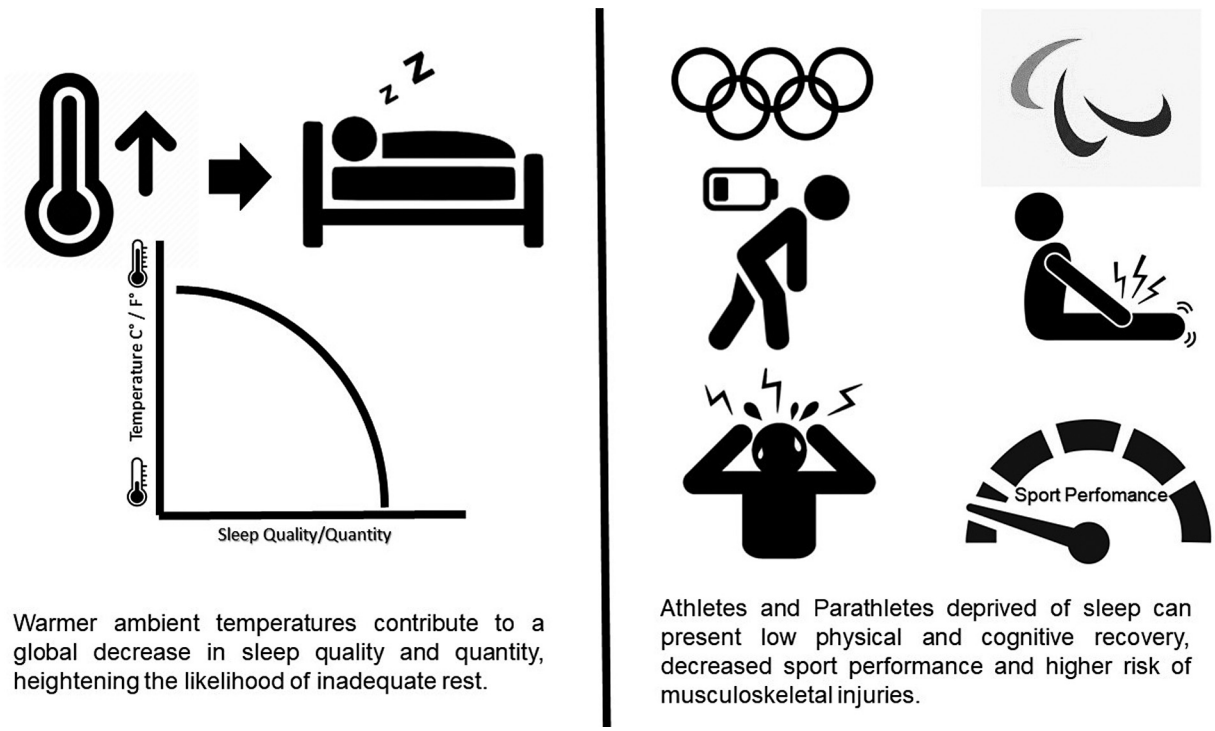

Fig. 1 Elevated ambient temperatures can exert notable influences on both the quantity and quality of sleep, subsequently impeding the body's ability to recover efficiently following training and competition.

capacity resulting from their impairments. Indeed, it is widely recognized that thermoregulation is impaired in athletes with spinal cord injury due to autonomic dysfunction.[32]

Athletes with amputations may experience a reduction in the ratio of body surface area to mass, resulting in increased metabolic heat production and impaired heat dissipation capacity.[33] Additionally, amputees may feel greater discomfort in the prosthetic socket in warm environments.[34] Athletes who have multiple sclerosis might experience reduced sweating ability and heightened heat intolerance overall[35]. Therefore, ensuring a sleep environment with thermal comfort is essential to promote good sleep quality and positively influence overall health and daytime performance.[36]

Another noteworthy point is that there is a clear connection between ambient temperature, skin microclimate, and core body temperature. At optimal ambient temperatures, typically between 19 and 21°C, the body regulates the skin's microclimate to remain within the range of 31 to 35°C. Deviations from this range can negatively impact sleep. A study by Harding, Franks, and Wisden demonstrated a reciprocal link between body cooling and sleep, suggesting that thermoregulatory behaviors before sleep can optimize sleep –particularly during the non-rapid eye movement (NREM) phase –through neural circuits. Therefore, the effect of ambient temperature on sleep quality is undeniable.

No Air Conditioning and the Likelihood of a Warm and Unfavorable Environment for Restful Sleep: What to Do?

Distal heat loss seems to be closely related to increased drowsiness and sleep induction through the rise of circulating melatonin coinciding with the decline in central temperature before sleep onset.[39] A study conducted by Lan et al.[40] pointed out that the application of localized conductive cooling to anatomical regions such as the back and/or neck during sleep reduced skin temperature by 1.5 to 2.0° C, resulting in improved thermal comfort and sleep quality. In summary, it was suggested that local cooling applied to body parts (back and head) in contact with the bed can effectively maintain sleep quality and improve nighttime thermal comfort in warm environments.

Specialized devices such as gloves or boots designed to cool hands and feet can play an important role in facilitating efficient sleep onset in humans when ambient temperatures are not ideal. Regions such as the palms of the hands, soles of the feet, surface of the ears, and certain facial regions consist of a dense network of arteriovenous anastomoses that function as the primary portal for heat transfer and play a crucial role in thermoregulation.[41]

Paradoxically, the strategy of exposure to bathing or immersion in hot water not immediately before but between 1 and 8 hours before sleep increases slow-wave sleep (SWS), improves NREM consolidation, and reduces REM sleep. The Hot Bath Effect[42] represents a fundamental connection between temperature and sleep, with heat exposure favoring vasodilation initially and subsequent body cooling with the onset of sleep occurring during the circadian temperature drop, and NREM being associated with additional reductions in central and brain temperature.[43]

Practical Recommendations

Athletes intending to participate in the 2024 Olympics or Paralympics cannot rely solely on chance. The Olympic and Paralympic teams should consider strategies to facilitate heat dissipation to mitigate potential deleterious effects on the quantity and quality of athletes' sleep resulting from an uncomfortable thermal environment in the sports villages.

To establish cooler temperatures before sleep time (not just during nighttime sleep, as athletes can nap or sleep during the day when buildings are often warmer) some strategies can be employed, such as cooling vests containing cooling elements or pockets for ice packs placed in strategic areas to enhance body cooling. Other specialized devices, such as gloves or boots designed to cool hands and feet, can also be used as a peripheral cooling strategy. Increasing air circulation (using fans) can be employed to promote heat loss through convection. Additionally, special attention should be paid to hydration.

Another possible strategy to improve sleep in a warm environment involves the use of a high-heat capacity mattress. This is a non-pharmacological approach to provide a thermal intervention on sleep.[28] Studies comparing a common low-heat capacity mattress with a high-heat capacity mattress showed that the latter has a larger decrease in core body temperature in sleep, which was mediated by increased heat conduction from the body core to the skin and subsequently to the mattress, associated with an increased amount of stage 3 sleep.[28,44] However, to our knowledge, this intervention has yet to be trialed with athletes or parathletes with thermoregulatory dysfunctions. Specific research in this area is required, as this approach has a strong plausible strategy rationale for enhancing the sleep of individuals in warm environments.

Therefore, it is recommended that Olympic and Paralympic teams act with special attention when devising strategies to reduce potential negative impacts on athletes' sleep resulting from an unfavorable thermal environment found in the rooms of Olympic and Paralympic villages. In a highly competitive sports environment, the incorporation of an expert in chronobiology, sleep, and sports performance in the technical framework of national Olympic and Paralympic committees demonstrates a commitment to the wellbeing and pursuit of athletic excellence, as many teams may overlook this crucial dimension of athletic preparation.

The implementation of personalized sleep routines and strategies to improve sleep quality would contribute to proper muscle recovery (minimizing the likelihood of musculoskeletal injuries) and optimized cognitive capacity (increased focus and concentration) as crucial aspects for the sporting success of teams during the Paris 2024 Olympic and Paralympic Games.

Author Contributions

J.P.P.R. conceived the study's idea. J.P.P.R. and C.A.B.L. wrote the manuscript in consultation with A.S. and M.T.M. A.S. and M.T.M. encouraged J.P.P.R. to investigate heat impact in Paralympic athletes' sleep and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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Conflict of Interests

The authors have no conflict of interests to declare.

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