

## Mini Review

# The Impact of Radiant Air-conditioning on Sleep Quality: A Mini-Review

Jihui Yuan\*

Department of Living Environment Design, Graduate School of Human Life and Ecology, Osaka Metropolitan University, Osaka, Japan

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\***Corresponding author:** Jihui Yuan, Department of Living Environment Design, Graduate School of Human Life and Ecology, Osaka Metropolitan University, Osaka, Japan,  
E-mail: [yuan@omu.ac.jp](mailto:yuan@omu.ac.jp) ; [yuanjihui@hotmail.co.jp](mailto:yuanjihui@hotmail.co.jp)

**ORCID:** <https://orcid.org/0000-0002-1608-9973>

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## Abstract

Sleep is a vital aspect of human health, influencing both physical and mental well-being.

Environmental factors, particularly indoor temperature, play a crucial role in determining sleep quality. Traditional cooling systems, while effective in temperature control, often create uneven cooling and noise, which can disrupt sleep. Radiant air-conditioning systems, which cool rooms through radiation without the use of fans, have emerged as a promising alternative for improving sleep quality. This mini-review discusses the effects of radiant air-conditioning on sleep quality, comparing it with traditional air-conditioning systems. The review highlights research findings that suggest radiant cooling promotes sleep by regulating body temperature, reducing stress, and minimizing noise disturbances. Studies indicate that individuals sleeping in rooms cooled by radiant systems experience better sleep quality, longer sleep duration, and fewer insomnia symptoms. The mechanisms underlying these benefits include the activation of the parasympathetic nervous system, improved thermoregulation, and a more stable thermal environment. Despite these advantages, most studies have been conducted in controlled environments, raising concerns about the applicability of these findings in real-world settings. Furthermore, research has largely focused on adults, leaving gaps in understanding how radiant air-conditioning affects other populations. Future studies should address these limitations by evaluating the performance of radiant cooling in various residential settings and across different age groups. Expanding research in this area could pave the way for more energy-efficient and sleep-promoting indoor climate solutions.

## Introduction

Sleep is a fundamental aspect of human life, essential for maintaining physical health, cognitive function, and overall well-being [1]. Quality sleep enhances mood, sharpens mental acuity, and supports bodily repair processes. However, many individuals face challenges in achieving good sleep due to environmental conditions, lifestyle habits, and physiological differences. Among these factors, the indoor environment, including temperature, noise, and air quality, plays a significant role in determining sleep quality [2]. In particular, temperature is crucial for sleep regulation, as it affects the body's thermoregulatory processes, which are vital for initiating and sustaining sleep.

Radiant air-conditioning has emerged as a promising solution for improving sleep by maintaining optimal indoor temperatures. Unlike traditional air-conditioning systems, radiant panels cool rooms by radiating heat directly to objects and people without relying on fans or blowers [3]. This approach offers efficient, quiet, and targeted cooling, making it particularly suitable for bedroom environments.

### Effect of radiant air-conditioning on sleep quality

Research has increasingly focused on the benefits of radiant air-conditioning in enhancing sleep quality. One key finding is that radiant panels can help mitigate discomfort in hot and humid environments, a common cause of sleep disturbances.



Cooling through radiant panels has been shown to lower core body temperature, which is essential for sleep onset and maintenance [4]. Du, et al. [5] conducted a study comparing sleep quality in rooms cooled by radiant panels versus traditional air conditioners. Participants in the radiant-cooled room reported better sleep and fewer insomnia symptoms, highlighting the technology's potential.

The sleep-enhancing effects of radiant air-conditioning may stem from its ability to create a thermally comfortable environment that promotes relaxation and reduces stress [6]. As stress and discomfort are major contributors to poor sleep, minimizing these factors can result in deeper and more restful sleep. Moreover, studies suggest that radiant air-conditioning can be particularly beneficial for individuals suffering from insomnia, as it reduces symptoms associated with the disorder [7].

### Comparison with traditional cooling systems

When comparing radiant air-conditioning with traditional cooling systems, the former demonstrates superior effectiveness in promoting sleep. Traditional systems, which rely on forced air, can create uneven temperature distributions and generate noise, both of which can interfere with sleep [8]. In contrast, radiant systems operate silently and provide uniform cooling, which contributes to a more stable and conducive sleep environment. The study by Kondo and Asawa [9] further supports these findings, showing that participants in a radiant-cooled room reported better sleep and fewer disturbances than those using conventional air-conditioning. These results underscore the advantages of radiant systems, particularly in challenging climates where humidity and heat exacerbate sleep problems.

In addition to traditional radiant cooling systems, newer approaches such as radiant cooling-assisted natural ventilation have gained attention. This hybrid method integrates natural ventilation with radiant cooling panels, allowing for the enhancement of thermal comfort and indoor air quality, particularly in mild climates. By leveraging natural airflow, energy consumption can be reduced further, while maintaining a consistent indoor temperature conducive to sleep. Studies highlight the potential of this approach to create a more energy-efficient system, improving comfort and reducing the reliance on mechanical ventilation [10].

While radiant cooling systems offer superior comfort, they come with higher initial investment costs. Installation of radiant panels, especially in existing buildings, can involve significant expenses related to materials, labor, and design modifications. However, the long-term energy savings from reduced mechanical cooling and improved efficiency may offset the upfront costs, making these systems economically viable in the long run. This is particularly true in regions with high cooling demand, where energy savings can lead to reduced operational costs.

### Mechanisms underlying the effect of radiant air-conditioning on sleep

The mechanisms through which radiant air-conditioning improves sleep are multifaceted and involve both physiological

and environmental factors. The primary mechanism is related to the body's thermoregulatory processes, which are critical for sleep. A slight drop in core body temperature signals the onset of sleep, and maintaining this cooler state is crucial for sleep continuity [11]. Radiant cooling effectively facilitates this process by directly influencing the skin and core body temperature, thus enhancing sleep initiation and stability.

Moreover, radiant air conditioning may stimulate the parasympathetic nervous system, which is responsible for promoting relaxation and reducing stress levels [6]. This activation supports a restful state conducive to sleep. Another advantage of radiant systems is their quiet operation. Traditional air-conditioning units, with their fans and compressors, can produce noise levels that disrupt sleep stages. The absence of such noise in radiant systems reduces this risk and contributes to a tranquil sleep environment.

### Limitations and future directions

Despite the encouraging evidence, several limitations exist in the current body of research. The majority of studies have been conducted in controlled laboratory settings, which raises questions about the generalizability of the findings to real-world environments. The performance of radiant air-conditioning systems in diverse home settings, where factors such as insulation, room layout, and external weather conditions come into play, remains underexplored. Additionally, the current research predominantly focuses on healthy adult participants, leaving a gap in understanding how radiant air-conditioning affects other demographic groups, such as children, adolescents, and the elderly, whose thermal comfort requirements may differ significantly.

Future research should aim to bridge these gaps by conducting field studies in real-world environments, with a broader demographic scope that includes more vulnerable populations. It is also essential to investigate the interactions between radiant cooling systems and other environmental variables such as humidity, air circulation, and air quality, as these factors can significantly influence thermal comfort and sleep quality. Furthermore, the long-term effects of radiant cooling, including its energy efficiency, user satisfaction, and overall system sustainability, should be explored to ensure its viability as a practical solution for improving sleep quality.

### Challenges and recommendations

While radiant air-conditioning systems offer many benefits, they are accompanied by certain challenges. One of the primary drawbacks is the high installation cost, which is driven by the need to lay pipes in floors, walls, or ceilings—a labor-intensive and costly process. Additionally, potential issues such as fluid leakages within the system can result in expensive repairs and maintenance. These challenges may deter widespread adoption, particularly in retrofit projects where installation complexity and costs are higher.

To overcome these obstacles, future developments should focus on creating modular, easier-to-install systems that require minimal invasive construction. Improved leak detection



technologies, coupled with better system designs that enhance durability and minimize the risk of malfunctions, are essential to enhancing the reliability of radiant cooling systems. Moreover, streamlining integration during the construction phase of buildings could significantly reduce installation costs. Addressing these technical challenges will not only improve the economic feasibility of radiant air-conditioning but also boost its long-term sustainability and user acceptance.

## Conclusion

In conclusion, radiant air-conditioning shows significant promise in improving sleep quality by providing a comfortable and quiet indoor environment. The technology's ability to regulate body temperature, reduce stress, and create a tranquil sleep setting positions it as a superior alternative to traditional cooling methods, especially in hot and humid climates. However, further research is needed to fully elucidate the underlying mechanisms and to assess the effectiveness of radiant systems in diverse real-world scenarios. Addressing these challenges will be key to advancing the development and practical implementation of radiant air-conditioning solutions that support better sleep and overall well-being.

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