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Sleep Deprivation and Stress: Exploring the Genomic Consequences

Yuliana
Anatomy Department, Faculty of Medicine, Universitas Udayana
Jl. PB Sudirman Denpasar 80232, Indonesia. Tel. +62-361-222510, Fax. +62-361-246656.

Corresponding author
yuliana@unud.ac.id

Abstract: Sleep deprivation and stress are pervasive issues in modern society, with far-reaching consequences for physical and mental health. Recent studies have elucidated the complex interplay between sleep, stress, and genomic regulation, revealing novel insights into the molecular mechanisms underlying these relationships. This review highlights the genomic consequences of sleep deprivation and stress, with a focus on the impact on gene expression, epigenetic regulation, and genomic stability. This is a narrative literature review. Articles were selected from PubMed, Science Direct, and Google Scholar. Sleep deprivation has been shown to alter the expression of genes involved in critical cellular processes, including metabolism, immune function, and neuronal signaling. Furthermore, chronic stress can lead to epigenetic changes, such as DNA methylation and histone modification, which can influence gene expression and contribute to disease susceptibility. The genomic consequences of sleep deprivation and stress have significant implications for human health, including increased risk of metabolic disorders, cardiovascular disease, and mood disorders. Understanding the molecular mechanisms underlying these relationships can inform the development of novel therapeutic strategies to mitigate the adverse effects of sleep loss and stress. In conclusion, sleep deprivation and stress may have genomic consequences, such as changes in DNA methylation and gene expression, which contribute to disease susceptibility.

Keywords: epigenetics, genomics, gene expression, sleep deprivation, stress.

Introduction

Sleep deprivation and stress are pervasive issues in modern society, with far-reaching consequences for physical and mental health. Recent studies have elucidated the complex interplay between sleep, stress, and genomic regulation, revealing novel insights into the molecular mechanisms underlying these relationships. Sleep deprivation can have serious physiological consequences, including increased activity of the hypothalamic-pituitary-adrenal (HPA) axis, leading to elevated stress hormones like cortisol. This can disrupt sleep regulation and have negative effects on health (Nollet et al., 2020).

There is a high prevalence of sleep deprivation, i.e., 85.9% in the Middle East and 66% in the USA. Sleep deprivation has highest impact on medical officers such as from anaesthesia and paediatrics departments. Some occupational burdens are workload and staff shortage (Daher et al., 2024).

Sleep plays a crucial role in regulating various biological processes, including hormone secretion, cardiovascular function, and immune response. During sleep, the body experiences a decrease in heart rate, blood pressure, and body temperature. Sleep deprivation, on the other hand, can have negative effects on the body, including impaired cognitive function (affects attention, memory, and decision-making), increased risk of cardiovascular disease (raises blood pressure, heart rate, and cardiovascular disease risk), and a weakened immune system (makes the body more susceptible to infections). It can also lead to metabolic disorders (can lead to changes in appetite, glucose regulation, and weight management), and disrupt the release of neurotransmitters, affecting cognitive function,

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emotional regulation, and memory consolidation (Bendet et al., 2025).

This review highlights the genomic consequences of sleep deprivation and stress, with a focus on the impact on gene expression, epigenetic regulation, and genomic stability.

Materials and Methods

This is a narrative literature review. Articles were selected from PubMed, Science Direct, and Google Scholar.

Results and Discussion

Sleep deprivation has been shown to alter the expression of genes involved in critical cellular processes, including metabolism, immune function, and neuronal signaling. Furthermore, chronic stress can lead to epigenetic changes, such as DNA methylation and histone modification, which can influence gene expression and contribute to disease susceptibility. The genomic consequences of sleep deprivation and stress have significant implications for human health, including increased risk of metabolic disorders, cardiovascular disease, and mood disorders. Understanding the molecular mechanisms underlying these relationships can inform the development of novel therapeutic strategies to mitigate the adverse effects of sleep loss and stress. In conclusion, sleep deprivation and stress may have genomic consequences such as changes in DNA methylation and gene expression, which contribute to disease susceptibility as shown in Figure 1 (Gaine et al., 2018; Tsapanou et al., 2024).

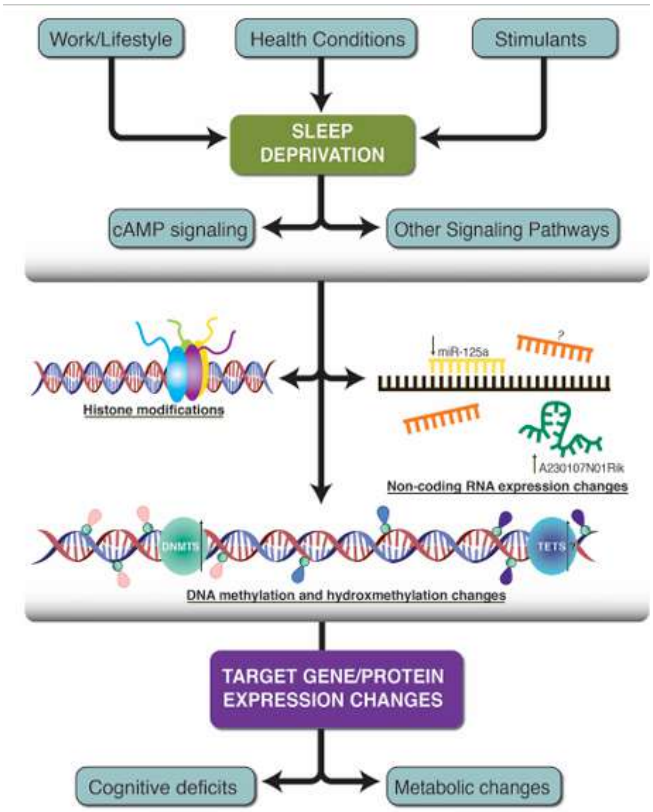

Figure 1. Mechanism of DNA methylation due to sleep deprivation (Gaine et al., 2018)

Sleep Deprivation occurs when someone doesn't get enough sleep or has poor sleep quality. It can be caused by various factors, such as lack of sleep time, sleep disruptions, stress, excessive physical activity, caffeine, or alcohol consumption. Symptoms are fatigue, difficulty concentrating, mood instability, and impaired cognitive performance. Insomnia is different from sleep deprivation. Insomnia is a sleep disorder characterized by difficulty falling asleep or staying asleep, despite having the opportunity to sleep. It can be caused by stress, anxiety, depression, other health conditions, or certain medication use. Symptoms are difficulty falling asleep, waking up in the middle of the night, and being unable to fall back asleep, non-restorative sleep. Sleep Deprivation is a broader condition that can be caused by various factors, while Insomnia is a specific sleep disorder that involves difficulty falling or staying asleep (Yu et al., 2025)

Researchers studied how sleep deprivation affects people's response to stress and mood. They found that people who didn't sleep reported feeling more stressed, anxious, and angry when faced with low-stress tasks, but when faced with high-stress tasks, both sleep-deprived and well-rested

individuals felt equally stressed and had negative moods. This suggests that sleep deprivation makes people more sensitive to stress, but doesn't necessarily make them more reactive to high-stress situations (Minkel et al., 2012).

A study of 231 medical officers in Malaysia found that sleep deprivation is a common problem that affects their performance. The study showed that sleep-deprived medical officers reported difficulties with communication, diagnosis, and taking longer to complete tasks. They also felt unsafe driving and were more prone to errors. The researchers concluded that sleep deprivation is a serious issue that puts patients and healthcare providers at risk, and that measures need to be taken to address this problem and ensure medical officers get enough sleep. Sleep deprivation is a widespread issue affecting people of all ages and professions, with serious consequences for physical, cognitive, and emotional health. Factors contributing to sleep deprivation include socio-demographic factors like age, gender, and marital status, as well as occupational factors like job designation, working hours, and shift work. Medical professionals, particularly medical officers, are at high risk of sleep deprivation due to long working hours, irregular shift timings, and high stress levels. This can lead to impaired cognitive function, reduced attention span, and increased risk of medical errors (Daher et al., 2024).

Sleep deprivation has also been linked to various health problems, including hypertension, diabetes, obesity, and cardiac issues. Furthermore, it can affect brain connectivity, leading to poor communication, impaired memory, and learning difficulties. The impact of sleep deprivation on medical professionals is significant and can compromise patient safety. Strategies to address sleep deprivation, such as promoting healthy sleep habits and providing support for medical professionals, are essential to ensure the well-being of healthcare workers and the quality of care they provide (Liew & Aung, 2021).

Sleep deprivation is a major concern for medical officers in Malaysia, impacting their performance, professionalism, and patient safety. The demanding nature of their job, combined with high patient volumes and staff shortages, contributes to burnout and sleep deprivation. In fact, a staggering 39.1% of medical officers in Malaysia reported burnout during the pandemic (Daher et al., 2024).

The effects of sleep deprivation are far-reaching, impairing attention, cognition, mood, and motor skills. This can lead to serious ethical issues, compromised patient safety, and decreased quality of care. The Malaysian healthcare system faces significant challenges, including a doctor-population ratio of 2:1000, highlighting the need for innovative solutions. Key impacts of sleep deprivation are impaired cognitive performance (decision-making), problem-solving, and communication skills. There are reduced reaction times and motor function, increased risk of medical errors and compromised care, and negative effects on overall well-being and burnout (Daher et al., 2024).

Addressing sleep deprivation is crucial to ensuring the safety of patients and doctors. Stakeholders and health professionals must work together to formulate effective solutions, prioritizing the well-being of medical officers and the quality of care they provide. Sleep deprivation is a widespread issue affecting people of all ages and professions, with serious consequences for physical, cognitive, and emotional health. Factors contributing to sleep deprivation include socio-demographic factors like age, gender, and marital status, as well as occupational factors like job designation, working hours, and shift work (Daher et al., 2024).

Key factors contributing to sleep deprivation such as socio-demographic factors: Age, gender, marital status, children, caffeine consumption, smoking status, and alcohol consumption. Occupational factors: Job designation, working hours, shift work, and high stress levels. Medical professionals, particularly medical officers, are at high risk of sleep deprivation due to long working hours, irregular shift timings, and high stress levels. This can lead to impaired cognitive function, reduced attention span, and increased risk of medical errors.

Consequences of Sleep Deprivation are an increased risk of hypertension, diabetes, obesity, and cardiac problems. Impaired decision-making, problem-solving, and memory often occur.

Emotional Health*: Increased stress, anxiety, and burnout. Addressing sleep deprivation is crucial to promoting the well-being of healthcare workers and ensuring the quality of care they provide. National strategies and innovative solutions are needed to address this issue and mitigate its consequences (Daher et al., 2024).

Sleep deprivation is a major concern for medical officers, impacting their ability to deliver safe and quality care. Lack of sleep can impair brain connectivity, affecting communication, memory, and learning. High cortisol levels during stressful conditions can also impact the hippocampal memory processing center, further compromising doctors' abilities. The consequences are alarming: impaired attention, cognition, mood, and motor skills threaten patient safety and professionalism. In fact, sleep deprivation has been shown to affect surgeons' laparoscopic skills, highlighting the need for urgent action. Specific brain circuits, including the ventral tegmental area and lateral habenula, play a role in this stress-induced sleep (Daher et al., 2024).

The prevalence of sleep deprivation among medical officers is concerning, with a significant impact on their workload and patient care. The migration of doctors from public to private sectors and the complexity of cases managed at public tertiary centers contribute to this issue. The nature of work in anaesthesia and pediatrics involves high-stakes decision-making, long hours, and intense stress, making it challenging for medical officers to get adequate sleep. This highlights the need for targeted interventions to address sleep deprivation and support the well-being of medical officers (Daher et al., 2024).

Sleep quality and duration are crucial factors that impact medical officers' (MOs) functioning. Research shows that sleep deprivation-related fatigue contributes to errors among anaesthetists, highlighting the need to address this issue. The impact of sleep deprivation are circadian rhythm disruption because night shifts disrupt the natural sleep-wake cycle, leading to impaired cognitive function. The consequences are reduced attention, delayed response, and increased risk of accidents. Sleep deprivation affects personal life, leading to strained relationships and decreased quality of life (Bansal et al., 2025; Sun et al., 2023). Some strategies to mitigate sleep deprivation include short naps can help alleviate sleep deprivation. Sleep deprivation is seriously impacting medical officers' ability to formulate diagnoses and make sound clinical judgments. This is largely due to impaired cognitive function, which affects attention span, responsiveness, reaction times, memory, and decision-making. Impaired decision-making and problem-solving skills, difficulty formulating ideas and expressing them effectively. Motor Skills*: Reduced coordination and reaction times. These effects can lead to medical errors, compromising patient safety and professionalism. In fact, studies have shown that sleep-deprived medical officers are more likely to make mistakes, including errors in laparoscopic surgery. The consequences of sleep deprivation are increased risk of medical errors and adverse outcomes, compromised decision-making and communication skills, and inducing irritability, agitation, and mood disturbances. To address this issue, providing medical officers with better working arrangements, such as flexible scheduling and adequate rest periods, is crucial. This can help mitigate the effects of sleep deprivation and promote optimal healthcare delivery (Daher et al., 2024).

Sleep deprivation can lead to endothelial dysfunction, increasing markers of inflammation (IL-1 and IL-6). This is associated with a higher risk of cardiovascular disease (CVD). The Multi-Ethnic Study of Atherosclerosis found that sleep deprivation may increase CVD risk, making it a new risk factor. Lifestyle modifications (good sleep, healthy diet, physical activity) can help mitigate this risk. Sleep deprivation decreases NO production, impairing vasodilation. Impaired NO production leads to decreased vasodilation and increased CVD risk (Bendet et al., 2025).

Conclusions

In conclusion, sleep deprivation and stress may have genomic consequences such as changes DNA methylation and gene expression, which contribute to disease susceptibility. Sleep deprivation decreases NO production, impairing vasodilation. Impaired NO production leads to decreased vasodilation and increased CVD risk. Therefore, it is

essential to get enough sleep to maintain the homeostasis of the body system.

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