The Association Between Heart Rate Variability and Sleep Quality - a Narrative Review

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ABSTRACT

Introduction

Heart rate variability (HRV) serves as a non-invasive marker to assess autonomic nervous system (ANS) modulation on cardiac rhythm. Its link with sleep quality, particularly in the context of insomnia, posits HRV as a potential indicator of autonomic state variations during sleep disturbances. The prevalence of insomnia, affecting up to 20% of the general population, emphasizes the need to understand its extensive impact.

Material and Methods

For this review - 41 relevant titles from 1985 to 2024 were selected
Analysis of the Literature:

Recent studies highlight a bidirectional relationship between insomnia and ANS function, with increased sympathetic activity indicated by physiological and subjective measures in individuals with insomnia. The role of medications like beta-blockers in disrupting ANS and leading to sleep deprivation further connects measurable and perceived aspects of sleep quality, impacting health negatively. Moreover, HRV’s application has expanded beyond professional athletics to daily activity and sleep quality monitoring by the general population, emphasizing its potential in evaluating stress and training intensity.

Conclusion: The complex interplay between HRV, insomnia, and health outcomes necessitates further research. However, integrating HRV measurements into clinical and everyday monitoring may offer a promising avenue for improving sleep disorder management and enhancing quality of life.

Keywords: Heart Rate Variability; Sleep quality; Insomnia; Cardiovascular risk; Sympathetic nervous system

Introduction

Heart rate variability (HRV) characterizes the fluctuations between successive electrocardiogram R-R intervals\textsuperscript{1}. It is a non-intrusive approach employed to assess the modulation of the autonomic nervous system (ANS) on the cardiac rhythm\textsuperscript{2,5}. In normal and pathological conditions, the ANS plays an essential role in regulating physiological processes
in the human body. In contemporary times, HRV has become significant as a method for investigating the ANS, which plays a crucial role in preserving homeostasis. Increased HRV indices commonly signify efficient autonomic mechanisms indicative of a person's good health, whereas decreased or low HRV may signal dysfunction in the ANS, potentially indicating compromised health. HRV has experienced a substantial increase in popularity for research purposes in recent decades. HRV presents itself as a compelling choice and a prospective clinical instrument for assessing and recognizing health impairment owing to its extensive applications, cost-effectiveness in implementing the technique, and the simplicity of data acquisition.

Some researchers have explored the link between HRV and sleep quality, yet this topic remains insufficiently investigated. Beyond expressing complaints about sleep, there are limited physiological metrics that consistently distinguish individuals with insomnia or poor sleep quality from those experiencing normal sleep. The idea that stress reaction processes "play a key role in the pathophysiology of primary insomnia" makes it logically intriguing that HRV could potentially detect variations in the underlying autonomic state during insomnia. In view of the significant prevalence of insomnia and sleep disorders, which affect up to 20% of the general population, it is crucial to comprehend the extensive impact of this condition. Insomnia is characterized by difficulties in initiating and maintaining sleep, often leading to frequent awakenings or struggles to return to sleep for a duration of at least three months. Furthermore, insomnia and sleep disorders are correlated with a diminished quality of life (QoL) and increased mortality. Sleep disorders may also be connected to sudden cardiac death, potentially associated with ventricular arrhythmias.
Aim

This narrative review offers an in-depth examination of the relationship between HRV and sleep quality, highlighting the clinical importance, epidemiological context, and management strategies of this bidirectional association.

Material and methods

Databases such as Pubmed, Medline, Google Scholar, and Europe PMC were used for the literature review with the keywords: “heart rate variability”, “sleep quality”, “insomnia”, “quality of life”, “autonomic nervous system”, 765 Articles were found from the period of 1970 until 2024.

The majority of articles contained weak-quality research, or did not directly relate to the topic of this review. Finally, 41 titles that described the association between heart rate variability, insomnia and related topics were selected from 1985 until 2024 - mainly from the last seven years.

Analysis of the literature

Recent investigations have illuminated a bidirectional relationship between insomnia and autonomic nervous system (ANS) function\textsuperscript{15}. Symptoms such as increased cortisol, heart rate or body temperature may indicate increased sympathetic activity in people with insomnia\textsuperscript{16}. In addition to objective measures, subjective measures of sleep quality, such as the Pittsburgh Sleep Quality Index (PSQI), correlate with increased autonomic activation\textsuperscript{17}. On the other hand, some drugs, like beta-blockers, may disrupt ANS and lead to sleep deprivation\textsuperscript{18}. The disruption of autonomic activity could serve as a connecting factor between the measurable and perceived aspects of sleep quality in older individuals experiencing insomnia, potentially playing a role in negative health consequences\textsuperscript{17}. 
HRV is a nonintrusive approach used to assess the modulation of the autonomic nervous system (ANS) on the heart rhythm. Furthermore, Jiang et al. demonstrated attenuated HRV responses to postural changes in primary insomnia subjects, pointing towards potential autonomic dysregulation in this population. However, prospective studies are needed to underscore the further exploration of HRV dynamics in different insomnia subtypes.

Nowadays, many people cannot deal with insufficient sleeping time. The prevalence of short sleep (<7h) varies between 24,3% to 48,5% of the adult population in the United States. Smartwatches have become increasingly popular in recent years. People started recording all daily activities, including sleep quality, which is crucial in post-workout regeneration. Presently, HRV is used not only by professional athletes to measure awareness for training, but also by beginners. That allows us to measure the stress of organisms and then determine how hard training the athlete should perform.

Insomnia emerges as a potential risk factor for cardiovascular anomalies, with altered HRV serving as a mediator. One of the most valuable HRV parameters used in monitoring fatigue status is the square root of the mean of the sum of the squares of differences between adjacent normal R-R intervals (RMSSD). Additionally, another potential stress mediator is the ratio of differences exceeding 50 ms to the total number of differences (pNN50). Its decrease indicates increased stress and is better for short-time evaluation. Both RMSSD and pNN50 are connected with parasympathetic activity. Insomnia patients have reduced parasympathetic activity as indicated by reduced high frequency power of HRV, as well as RMSSD and pNN50 values. Moreover, short sleep duration links these alterations to increased cardiovascular morbidity and mortality rates. Some results suggest that improvements in sleep following cognitive behavioural therapy for insomnia (CBT-I) were
associated with reduced parasympathetic activation and increased sympathovagal balance, contrary to expectations\textsuperscript{32}. Therefore, we believe that the topic should be much more extensively researched, as the results of small clinical studies may distort our understanding of the correlation between HRV and insomnia.

Examining the relationship between HRV, insomnia, and acute well-being in terminally ill patients sheds light on the potential role of autonomic dysfunction and sleep disturbances in influencing the end-of-life experience. Warth et al. found a significant correlation between patients' acute well-being (AWB) Insomnia and SDNN\textsuperscript{33}. Additionally, certain cardiovascular conditions, such as heart failure, may be associated with insomnia. Furthermore, medications used to treat heart failure can also contribute to sleep disturbances, a topic we have previously explored\textsuperscript{34}. Patients with clinically significant arrhythmias like frequent premature ventricular complexes (PVCs) exhibit impaired HRV\textsuperscript{35}. Additionally, a reduced HRV is associated with a higher risk of severe ventricular arrhythmia\textsuperscript{36}, which can lead to sudden cardiac death\textsuperscript{14}. An increased number of night-time PVCs was accompanied by enhanced cardiac sympathetic activity\textsuperscript{37}. PVCs can be diminished by pharmacological treatment\textsuperscript{38} or with invasive methods\textsuperscript{39}. After successful treatment of PVCs - both cardiac parasympathetic and sympathetic nervous activity declines\textsuperscript{37}.

Females have a higher risk of insomnia (Risk ratio = 1.41) versus males\textsuperscript{40}. Chae et al. revealed the link between sleep quality, emotional labor, and HRV in the emotional laborers women. The group of poor sleepers had a significantly lower difference in the root mean square of successive differences (RMSSD), the percentage of successive normal-to-normal intervals differing by more than 50 ms (pNN50) and the natural logarithm of high frequency (LnHF) when they were working compared to when they were resting, compared to the group of good sleepers\textsuperscript{41}.
Conclusion

In summary, the multifaceted relationships between HRV, insomnia, and various health outcomes underscore the need for continued research in this domain. Further investigations, particularly prospective studies exploring HRV dynamics in different insomnia subtypes, will enhance our understanding of the complex interactions between autonomic function, sleep quality, and overall health. The integration of HRV measurements into clinical practice and daily monitoring tools holds promise for improving the assessment and management of sleep-related disorders, contributing to enhanced well-being and quality of life.

Declarations

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Data availability - Not applicable.

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References


Short sleep duration based on response to the question:
"On average, how many hours of sleep do you get in a 24-hour period?".


