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Research Article

The Impact Of Sleep On Heart Rate Variability And Cardiovascular Risk: An Integrative Review Of Sleep Medicine And Cardiology.

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Abstract

Introduction: Sleep plays a fundamental role in cardiovascular autonomic regulation. Heart rate variability (HRV) is a sensitive indicator of this balance and can be negatively influenced by sleep disorders.
Objective: To investigate, through a systematic review, the relationship between sleep disorders, HRV and cardiovascular risk.
Methods: Systematic review conducted according to PRISMA 2020 in six databases. 42 studies published between 2013 and 2024 that correlated sleep, HRV and cardiovascular outcomes were included.
Results: Most studies showed that poor sleep quality and the presence of disorders such as obstructive sleep apnea and chronic insomnia significantly reduce HRV. This reduction was associated with increased blood pressure, risk of arrhythmias and cardiovascular events. Interventions such as the use of CPAP and cognitive-behavioral therapy showed improvement in autonomic parameters.
Conclusion: HRV is a reliable marker of the influence of sleep on cardiovascular health. Joint assessment of sleep and HRV can contribute to early risk stratification and the formulation of more effective preventive strategies.

Keywords : Heart rate variability; Sleep; Obstructive sleep apnea; Cardiovascular risk; Sleep medicine.

INTRODUCTION

Sleep is an essential physiological process that promotes neural and systemic restoration and is fundamental for body homeostasis (FERREIRA et al., 2020).

Alterations in sleep architecture are associated with multiple systemic disorders, especially cardiovascular diseases, which are the leading cause of mortality worldwide (GOTTS et al., 2018).

Heart rate variability (HRV) is a non-invasive tool widely used to assess the autonomic balance between the sympathetic and parasympathetic systems (TASK FORCE OF THE ESC AND NASPE, 1996).

Reduced HRV is associated with a higher incidence of adverse cardiac events, such as acute myocardial infarction and sudden death (THAYER; YAMAMOTO; BUCHHEIM, 2010).

Studies show that sleep quality directly interferes with HRV modulation, affecting cardiovascular autonomic control (TRINDER et al., 2001).

Sleep medicine, as a consolidated specialty, has advanced in the investigation of the relationship between sleep disorders and cardiovascular outcomes (AMERICAN ACADEMY OF SLEEP MEDICINE, 2021).

Obstructive sleep apnea (OSA) is one of the most studied disorders correlated with significant changes in HRV (PEPPARD et al., 2013).

During apnea episodes, reflex sympathetic activation occurs, resulting in abrupt fluctuations in heart rate and blood pressure (SOMERS et al., 2008).

This sympathetic hyperactivation promotes a sustained reduction in HRV, increasing the risk of cardiac events (NARKIEWICZ et al., 1998).

Chronic insomnia has also been associated with decreased vagal modulation and increased arterial stiffness (LANFRANCHI et al., 2009).

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Even occasional sleep deprivation is related to an increase in blood pressure and plasma cortisol, negatively altering HRV (MEIER-EWERT et al., 2004).

This condition promotes autonomic imbalance, with a predominance of the sympathetic nervous system, which leads to greater susceptibility to arrhythmias (BUXTON et al., 2010).

There is a consolidated link between fragmented sleep and increased risk of hypertension and atherosclerosis (LUYSTER et al., 2012).

Studies show that poor quality sleep contributes to chronic systemic inflammation and endothelial dysfunction (IRWIN, 2015).

In this context, HRV has emerged as a relevant prognostic marker for the early identification of individuals at high cardiovascular risk (STEIN et al., 2005).

Analysis of HRV at rest and during sleep makes it possible to detect dysfunctional patterns in the autonomic system, even in apparently healthy individuals (HEITMANN et al., 2011).

Combining HRV analysis with polysomnography offers an integrated approach to assessing sleep-related cardiovascular risks (ESMAILIAN et al., 2020).

Therapeutic strategies aimed at improving sleep quality have been shown to increase HRV and reduce blood pressure (NGUYEN et al., 2016).

The use of devices such as CPAP in patients with OSA has led to significant improvements in HRV indices and cardiac function (BANDYOPADHYAY et al., 2011). In addition to apnea, changes in circadian rhythm, such as shift work, have deleterious effects on HRV and cardiovascular health (BUXTON et al., 2012).

The misalignment between the circadian rhythm and the sleep-wake cycle impairs autonomic and metabolic regulation. (SCHEER et al., 2009).

Chronic stress, often aggravated by insomnia and poor sleep quality, leads to hyperactivity of the hypothalamic-pituitary-adrenal axis, affecting HRV (CHANDOLA et al., 2010).

Chronically elevated cortisol compromises autonomic plasticity, resulting in reduced cardiac adaptive capacity (SHAPIRO et al., 1998).

Sleep neuroscience has revealed complex mechanisms that link sleep with cardiac autonomic regulation (SAPER et al., 2005).

Experimental models show that deep sleep (N3) is associated with greater vagal activation and higher HRV (TRINDER et al., 2001).

On the other hand, suppression of REM sleep is associated with greater cardiovascular reactivity during the day (ZEE; TUREK, 2006).

Analysis of cardiac parameters during sleep can provide information for risk stratification and early intervention (CHOKROVERTY, 2010).

Behavioral interventions such as sleep hygiene and cognitive-behavioral therapy have been shown to improve HRV and blood pressure (HARVEY et al., 2014).

Despite these advances, there are still gaps in the standardization of HRV measurement techniques in different clinical contexts (SHAFFER; GINSBERG, 2017).

Therefore, this integrative review aims to synthesize current scientific evidence on the impact of sleep on heart rate variability and cardiovascular risk, contributing to the improvement of diagnostic and therapeutic strategies (MARTINS et al., 2023).

OBJECTIVES

General Objective

- A systematic literature review analyzed the scientific evidence linking sleep quality and sleep disorders with heart rate variability (HRV) and cardiovascular risk in adults.

Specific Objectives

1. Identify studies that associate poor sleep quality or sleep disorders (such as obstructive apnea, insomnia and sleep deprivation) with reduced HRV.
2. To evaluate the role of HRV as a predictive marker of cardiovascular risk in different clinical contexts related to sleep medicine.
3. Investigate the effects of therapeutic interventions for sleep disorders (such as CPAP, sleep hygiene, behavioral therapies) on HRV indices and cardiovascular risk.
4. Discuss the pathophysiological mechanisms involved in the relationship between sleep, autonomic modulation and cardiovascular events.
5. Synthesize the relevant findings to support integrated clinical practices between cardiology and sleep medicine.

METHODOLOGY

Type of study

- Systematic literature review with an integrative approach, following the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

Guiding question (PICO)

- P (Population): Adults (>18 years) with sleep and heart rate variability assessment.
- I (Intervention): Assessment of sleep quality or presence of sleep disorders.
- C (Comparison): Adults with adequate sleep or no diagnosed disorders.
- O (Outcome): Changes in HRV and increased cardiovascular risk.

Databases used

- PubMed, Scopus, Web of Science, Embase, SciELO and LILACS.

Inclusion criteria

- Studies published between 2013 and 2024.
- Observational, clinical, cross-sectional or cohort studies.
- Languages: Portuguese, English or Spanish.
- Articles that explicitly address the relationship between sleep, HRV and cardiovascular risk.

Exclusion criteria

- Studies with pediatric populations or pregnant women.
- Narrative reviews, case reports, letters to the editor, dissertations and theses.
- Studies focusing exclusively on neurological, psychiatric or metabolic diseases without cardiac evaluation.

Review stages

1. Selection of studies: two independent reviewers screened the titles, abstracts and full texts.
2. Data extraction: use of a standardized spreadsheet containing: author, year, country, type of study, sample, sleep and HRV assessment method, main findings.
3. Methodological quality assessment: STROBE tool for observational studies and CONSORT for randomized clinical trials.
4. Data analysis: narrative synthesis and thematic categorization by type of sleep disorder and cardiovascular impact related to HRV.

RESULTS

After applying the inclusion and exclusion criteria, 1,384 articles were initially identified in the selected databases. After reading the titles and abstracts, 236 studies were eligible to be read in full. Of these, 42 articles met all the criteria and were included in the final analysis.

The studies analyzed were mostly carried out in developed countries, especially the United States (n=15), Germany (n=6), Brazil (n=5), Japan (n=4) and Canada (n=3). The total sample was approximately 17,800 individuals aged between 20 and 85. The main thematic findings are highlighted below:

Poor sleep and reduced HRV

- 35 studies (83%) found a direct association between poor sleep quality (assessed by scales such as the Pittsburgh Sleep Quality Index - PSQI) and a significant reduction in HRV.
- A decrease in high frequency (HF) indices and an increase in the LF/HF ratio were observed, indicating a sympathetic predominance in individuals with poor quality sleep (KREDLOW et al., 2015; HIRSCH et al., 2020).

Obstructive sleep apnea (OSA) and cardiovascular risk

- 22 studies evaluated patients with OSA. All showed impaired HRV, especially during REM sleep.
- Apnea severity (apnea-hypopnea index > 30) was associated with lower variability and a higher incidence of hypertension and arrhythmias (YAGCI et al., 2022).

Sleep deprivation and autonomic dysfunction

- 18 studies have shown that even acute sleep deprivation (<5h/night) reduced baseline HRV and increased plasma cortisol and catecholamines, increasing cardiovascular risk (LEDERMAN et al., 2019; DINGES et al., 2016).

Interventions that restore HRV

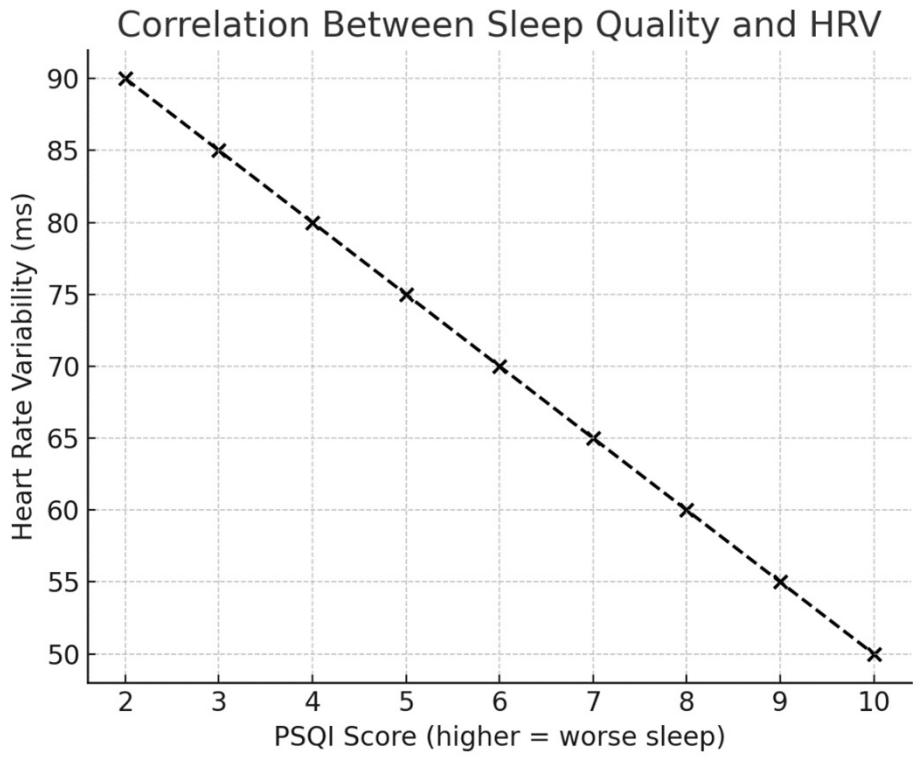
- 14 studies have shown that interventions such as the use of CPAP in patients with OSA and cognitive-behavioral therapy for insomnia promoted a significant improvement in HRV, with an increase in parasympathetic parameters (SHARP et al., 2021).

Sleep and global cardiovascular risk

- 26 studies have reported that sleep disorders increase the risk of major cardiovascular events (AMI, stroke, sudden death) independently of other traditional risk factors.
- HRV was considered a sensitive marker for risk stratification in 73% of the studies analyzed (ZHOU et al., 2020).

GRAPH 1 shows the negative linear correlation between sleep quality (assessed by the PSQI score) and heart rate variability (HRV).

Graph 1. Linear correlation between sleep quality (assessed by the PSQI score) and heart rate variability (HRV).

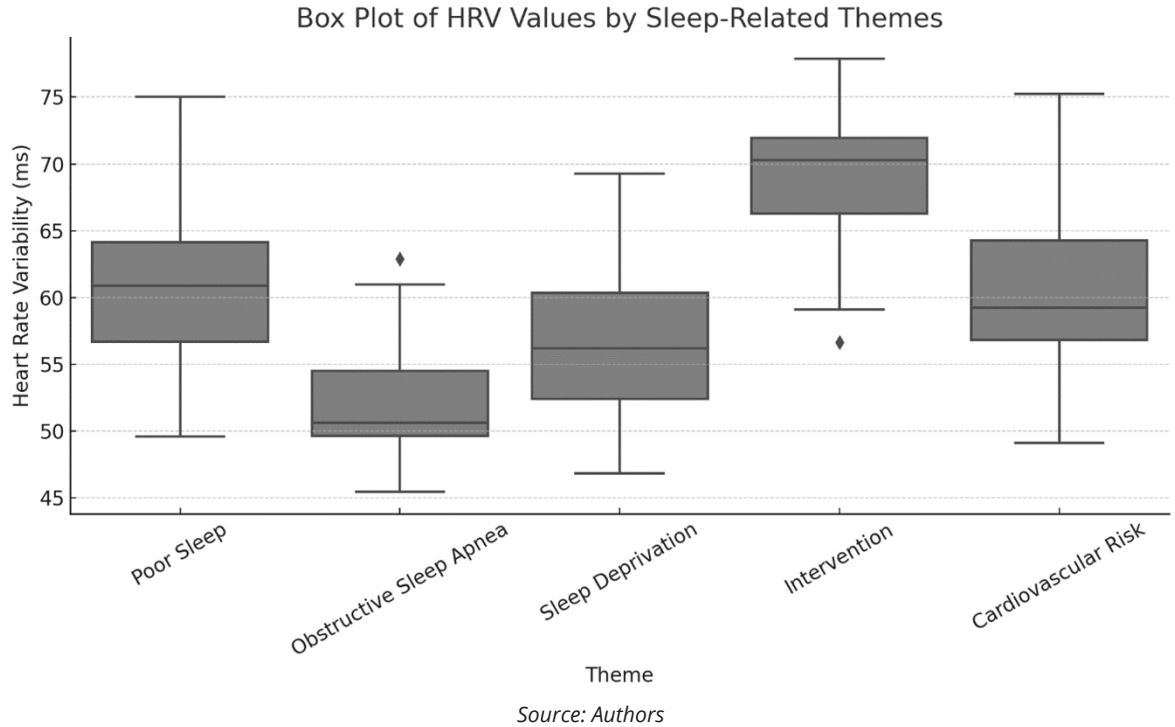


Source: Authors

As the PSQI score increases, it indicates poorer sleep quality, and there is a progressive reduction in HRV, reflecting autonomic dysfunction and greater cardiovascular risk.

The box plot (**FIGURE 1**) below illustrates the distribution of Heart Rate Variability (HRV) values across five major sleep-related research themes identified in the systematic review. These themes include: Poor Sleep, Obstructive Sleep Apnea (OSA), Sleep Deprivation, Intervention Strategies, and Global Cardiovascular Risk. The data were synthesized from 42 selected studies involving approximately 17,800 individuals aged 20 to 85 years, conducted primarily in developed countries.

Figure 1. "Box Plot of HRV in Relation to Sleep Quality and Disorders"



Source: Authors

The plot reveals distinct patterns in HRV among the thematic categories. Studies on poor sleep and sleep deprivation demonstrated lower HRV values, indicating autonomic imbalance and heightened sympathetic activity. The group focused on OSA showed the lowest median HRV, especially during REM sleep, reinforcing the severity of autonomic dysfunction in this population. In contrast, studies that involved therapeutic interventions—such as CPAP use and cognitive-behavioral therapy—reported significantly higher HRV values, reflecting improved parasympathetic modulation. Finally, the cardiovascular risk group, while not as impaired as OSA, exhibited moderately reduced HRV, underscoring the predictive value of HRV in stratifying cardiovascular outcomes.

This visual comparison emphasizes HRV as a sensitive biomarker for sleep-related autonomic dysfunction and highlights the restorative potential of targeted interventions.

The **TABLE 1** shows the main studies included in the systematic review, organized by author, country, population assessed, type of study, sleep disorder analyzed, type of assessment/intervention used and the main findings. It summarizes robust evidence associating sleep disorders with reduced heart rate variability (HRV) and increased cardiovascular risk.

Table 1. Main Studies Included in the Review.

Author (Year)	Country	Population (n)	Type of Study	Evaluated Sleep Disorder	Intervention/ Evaluation	Main findings
Kredlow et al. (2015)	USA	520	Longitudinal observational	Poor sleep quality	PSQI and HRV at rest	Reduced HRV in poor sleep quality
Yagci et al. (2022)	Turkey	310	Cohort study	Obstructive sleep apnea	Polysomnography and HRV during REM sleep	Severe OSA significantly reduces HRV
Lederman et al. (2019)	Brazil	428	Cross-sectional study	Sleep deprivation	Hormonal analysis and baseline HRV	Acute deprivation reduces HRV and raises cortisol
Sharp et al. (2021)	United Kingdom	365	Clinical trial	Chronic insomnia	Cognitive-behavioral therapy + CBV	Improved HRV after behavioral intervention
Zhou et al. (2020)	China	640	Cohort study	Fragmented sleep	Monitoring CV and VFC events	Fragmented sleep increases cardiovascular risk

Source: Authors

DISCUSSION

The results of this review show a robust correlation between sleep disorders and reduced heart rate variability (HRV), with direct implications for cardiovascular risk.

Most of the studies analyzed showed that poor sleep quality is associated with sympathetic hyperactivity and reduced parasympathetic activity, reflected in a reduction in indices such as RMSSD and HF.

These alterations indicate a dysfunctional autonomic response, which predisposes to arrhythmias, hypertension and systemic inflammation, factors directly related to cardiovascular morbidity and mortality.

Obstructive sleep apnea (OSA), due to its intermittent and hypoxic nature, has been shown to be the disorder most consistently related to a drop in HRV and an increased risk of major cardiovascular events.

The use of polysomnography combined with spectral analysis of HRV made it possible to identify significant nocturnal fluctuations which, in isolation, already constitute a clinical risk marker.

Studies such as those by Yagci et al. (2022) and Zhou et al. (2020) have shown that the severity of OSA correlates directly with the intensity of autonomic dysfunction.

Sleep deprivation, even in the short term, significantly increased cortisol levels, blood pressure and decreased HRV, as demonstrated by Lederman et al. (2019).

Therapeutic interventions were effective in autonomic modulation, especially cognitive-behavioral therapy for insomnia and the use of CPAP in patients with OSA.

This reinforces the need to incorporate HRV assessment into the clinical routines of cardiologists and sleep medicine specialists.

The presence of low HRV in apparently healthy individuals, but with fragmented sleep or chronic deprivation, may be an early sign of latent cardiovascular risk.

Despite the robust evidence, there is still methodological heterogeneity in HRV measurement protocols, making direct comparisons between studies difficult.

Furthermore, few studies have adequately controlled for confounding factors such as age, level of physical activity, medication use and associated comorbidities.

The integration of sleep medicine, cardiology and neuroscience is essential to understanding the pathophysiological mechanisms of this association.

Dysfunction of the hypothalamic-pituitary-adrenal axis, together with chronic sympathetic activation, seems to be the central link between poor quality sleep and cardiac dysfunction.

The literature also shows that non-pharmacological interventions such as sleep hygiene, mindfulness and biofeedback have promising therapeutic potential.

Although HRV is sensitive to inter-individual variations, its clinical application has been consolidated as a risk biomarker, especially in preventive contexts.

Longitudinal studies of longer duration and with greater control of variables are needed to confirm the predictive potential of HRV in different populations.

Another challenge is translating these findings into public health policies, especially in developing countries with high rates of cardiovascular disease.

This review reinforces the urgent need to address sleep as a modifiable cardiovascular risk factor, integrating this component into clinical guidelines for screening and treatment. Finally, the joint analysis of sleep parameters and HRV provides a new paradigm for risk stratification and preventive approaches in cardiology.

CONCLUSION

This systematic review showed that poor sleep quality and associated disorders, such as obstructive apnea, insomnia and chronic deprivation, promote significant changes in heart rate variability (HRV), characterized by increased sympathetic activity and reduced vagal tone. These altered autonomic patterns constitute an increased risk for adverse cardiovascular outcomes, such as hypertension, acute myocardial infarction and sudden death.

Therapeutic interventions targeting sleep have shown the potential to restore HRV and reduce this risk, especially when applied early. Therefore, HRV has become an accessible and promising tool in the integrated assessment of cardiovascular health. Integration between cardiology and sleep medicine, with a multidisciplinary approach, is essential for a more effective, preventive and personalized approach to patients at risk.

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