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The Impact of Sleep Disorders on Cardiovascular Risk - A Review

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1. ABSTRACT

Introduction: Sleep disorders are a variety of conditions that disturb the normal sleep-wake cycle. These conditions negatively affect the quality of sleep and the individual's overall health. These disorders are also associated with high levels of metabolic, neurocognitive, and cardiovascular complications. Given the global prevalence of sleep disorders and cardiovascular disease, understanding their relationship is extremely important given that sleep disorders are increasingly recognized as modifiable risk factors for cardiovascular disease.

Purpose of the study: This review examines the relationship between sleep disorders and cardiovascular risk, particularly emphasizing Mechanisms, Outcomes, and Prevention Strategies.

Materials and methods: A comprehensive literature review was conducted, analyzing 86 studies from the PubMed database (English-language, up to March 2025) that assess the association between sleep disorders and the risk of cardiovascular disease.

Conclusions: Sleep disorders, particularly insomnia and obstructive sleep apnea (OSA), have well-documented associations with increased cardiovascular risk. Evidence supports their role as independent and modifiable contributors to cardiovascular pathophysiology. The mechanisms responsible for their action include autonomic dysregulation, metabolic impairment, endothelial dysfunction, and systemic inflammation. Combining sleep assessment with cardiovascular care, including implementing proven interventions such as cognitive behavioral therapies for insomnia and CPAP therapy for OSA, may be beneficial in reducing morbidity. In addition, addressing determinants of sleep disorders, such as shift work, also seems important. Further research is needed to understand better the association of sleep disorders with cardiovascular risk, to assess long-term treatment effects, and to guide evidence-based integration of sleep medicine with strategies for the prevention and treatment of cardiovascular disease.

Keywords: Sleep disorders, cardiovascular risk, insomnia, obstructive sleep apnea, OSA

2. INTRODUCTION

- **Define sleep disorders and their prevalence.**

Sleep disorders comprise a variety of conditions that disrupt the normal sleep-wake cycle of the body, affecting the quality of sleep as well as the overall health of the individual negatively. General sleep disorders include chronic insomnia, obstructive sleep apnea (OSA), restless legs syndrome (RLS), and circadian rhythm disorders. In addition to causing irregularities in restorative healthy sleep, these disorders have also been associated with a high level of metabolic, neurocognitive, and cardiovascular complications.

Several epidemiological studies have provided estimates of the prevalence of these disorders in the general population. For instance, chronic insomnia persistent difficulty with

falling or staying asleep occurs in approximately 10–15% of adults, with severe cases occurring in approximately 6–10% in the long term [1]. Obstructive sleep apnea, a condition of repeated partial or complete upper airway obstruction during sleep, occurs in about 10–17% of middle-aged men and 3–9% of women and is characterized by large gender differences in prevalence [2].

Restless legs syndrome, a common movement disorder related to sleep, occurs in about 5–10% of the general population [3]. In addition, circadian rhythm disturbances, that are prevalent among shift workers or secondary to jet lag, are now a well-established large clinical problem. Also, evidence from the Pittsburgh Sleep Quality Index (PSQI) pool suggests sleep disorders in 45% of the population (95% CI: 40–50%). Together, sleep disorders may influence nearly half of all individuals, with prevalence substantially higher among the elderly [4].

By characterizing these disorders and measuring their prevalence, it is evident that sleep disturbances are not only prevalent but also a significant clinical and public health problem, particularly considering their increasing association with cardiovascular risk.

- **Overview of Cardiovascular Diseases (CVDs) and Their Burden**

Cardiovascular diseases (CVDs) are a collection of various cardiovascular and heart diseases such as coronary artery disease, heart failure, arrhythmias, and stroke. All of these conditions contribute to the total global cardiovascular health disease burden.

Several reversible risk factors, such as high blood pressure, obesity, diabetes, smoking, and unhealthy diet, are major contributors to the onset and progression of these diseases. Early identification and treatment of these risk factors are major determinants in the prevention of further disease development and catastrophic cardiovascular events [5].

According to the World Heart Federation, cardiovascular diseases remain the largest killer in the world, accounting for approximately 18 million deaths every year. The burden is disproportionately higher in low- and middle-income countries, where there are limited healthcare resources and lifestyle transitions are happening very rapidly [6].

- **Importance of studying the connection between sleep disorders and cardiovascular risk**

With the global prevalence of both sleep disorders and cardiovascular diseases, it is essential to understand their association to promote public health. Sleep disturbances have increasingly been recognized as modifiable risk factors for cardiovascular conditions. Understanding the association is vital to developing successful preventive and therapeutic interventions that are aimed at decreasing cardiovascular risk and improving overall global health outcomes.

3. STATE OF KNOWLEDGE

Inadequate or fragmented sleep enables normal activity during the day, affecting quality of life. Nevertheless, sleep disorders are predominant problems in both adults and children. Sleep-disordered breathing is a heterogeneous group, consisting of obstructive sleep apnea, central sleep apnea, upper airway resistance syndrome, sleep-related hypoventilation syndrome, and obesity hypoventilation [1,7]. OSA is defined as repetitive complete or partial airway obstructive episodes, leading to intermittent hypoxia, hypercapnia, arousals, and sleep fragmentation. The complex pathophysiology of OSA and its impact on the cardiovascular system remains incomplete. Research revealed that metabolic dysregulation, sympathetic excitation, endothelial dysfunction as well as oxidative stress are suggested to have a key role in triggering and escalating cardiovascular dysfunction in OSA-affected patients [8].

Evidence suggests that hypoxia during the OSA episode, so-called intermittent hypoxia (IH), lowers insulin-induced phosphorylation of the phosphatidylinositol 3-kinase/protein kinase B (PKB) and other targets in all main metabolic tissues, inducing increased fasting insulin levels. Chronic IH increases hypoxia-induced factor-1a (HIF-1a) expression and inhibits insulin signaling and insulin-stimulated glucose uptake [9, 10]. As a result, OSA leads to high glucose levels and a further risk of diabetes mellitus type 2, which initiates damage of arteries and atherosclerotic plaque formation [11,12]. Another study focused on rapid eye movement (REM) - predominant OSA suggested an association between OSA patient's decreased plasma levels of proteins Sirt2, LAP-TGF-B1, and Axin1 involved in glucose metabolism, with insulin sensitivity. An increase in levels of Sirt2 - the NAD+ - dependent deacetylase, improves insulin sensitivity [13,14]. Alternatively, research indicates that using acoustic stimuli to suppress or fragment non-rapid eye movement slow-wave sleep reduces insulin sensitivity by 20 % to 25% [11]. Moreover, REM sleep is related to longer apnoeas and greater desaturation compared to non-REM sleep [15,16].

Excessive sympathetic nervous system activity found in patients with OSA is

responsible for increased serum levels of norepinephrine, affecting not only glucose tolerance but also blood pressure [13,17]. Research reveals that after 2 weeks of severe IH, sympathetic activation significantly intensified mainly by increased peripheral chemoreflex sensitivity and a decrease in arterial baroreflex control of sympathetic outflow [18]. People with OSA present noticeably elevated muscle sympathetic nerve activity (MSNA) during night and daytime in comparison with control subjects [19]. Deactivation of chemoreflex with hyperoxia decreases MSNA and blood pressure in OSA patients but not in normal obese subjects without sleep-related disordered breathing [20]. Persistent high BP is responsible for greater cardiac workload, and risk of myocardial injury and what is more, it is an essential modifiable risk factor for all-cause and CVD morbidity and mortality globally [21,22].

Airway obstructive episodes cause low oxygen levels and following reoxygenation. This cycle mimics ischemia-reperfusion injury and triggers reactive oxygen species (ROS) bursts. In mitochondria hypoxia/reoxygenation cycles impair electron transport, enhancing ROS production [23]. Oxidative stress reduces nitric oxide (NO) secretion, impairs NO-mediated vasodilation, and promotes vascular stiffness [24]. This pathomechanism underlies the development of hypertension and atherosclerosis. Moreover, ROS are responsible for the activation of inflammatory responses [25].

Another mechanism in which IH activates inflammation is by hypoxia-sensitive transcription factors: nuclear factor NF-κβ and HIF-1. NF-κβ is an important mediator of inflammation, responding to both endogenous and exogenous stimuli, such as IH, leading to an inflammatory cascade. Once, activated, NF-κβ translocates to the nucleus and upregulates transcription of pro-inflammatory genes encoding proinflammatory cytokines and surface adhesion molecules such as TNF-A, interleukin-6, Il-8, which contributes to vascular inflammation, endothelial dysfunction, and overall higher cardiovascular risk. Studies showed increased NF-κβ activity in monocytes and neutrophils in OSA patients [15,26,27]. Hypoxia-induced factor - 1 (HIF-1) is a transcription factor, crucial in mediating the adaptive and inflammatory response to oxygen deprivation. Studies revealed that OSA patients present increased HIF-1 activity, enhancing the survival of inflammatory cells such as neutrophils, macrophages, and monocytes. Interestingly NF-κβ enhances HIF-1 expression, while HIF-1 modulates NF-kB activity, sustaining a loop of inflammation [15].

Insomnia is yet another sleeping disorder linked with cardiovascular dysfunction. Likewise, OSA and insomnia affect metabolism, the endocrine system, and the inflammation

cascade [28]. Moreover, chronic insomnia induces hyperactivity of the hypothalamic-pituitary-adrenal axis, leading to excessive cortisol release [29]. Cortisol as the primary glucocorticoid hormone, increases vasoconstriction, and sodium retention, and impairs NO-dependant vasodilation which results in the development of hypertension and arterial stiffness. What's more, cortisol opposes insulin action, elevating hepatic glucose production leading to hyperglycemia and type 2 diabetes [30].

In conclusion, the pathogenesis of sleep-disordered breathing is not yet fully understood, further studies must be performed to discover all the elements of this complex process. As far as we know the main cause of amplified CVD risk in OSA patients is metabolic dysregulation, sympathetic excitation, endothelial dysfunction as well as oxidative stress. Insomnia as the most common sleep disorder also contributes to CVD risk, by additionally affecting circadian rhyme.

4. RESULTS

Sleep disorders are a very common phenomenon. They affect a third of the general population and women are 1.5 times more likely to suffer than men. They involve problems with quality, timing, and amount of sleep. There are many different types of sleep-wake disorders, of which insomnia is the most common.

Symptoms of insomnia occur in about one-third of the adult population, but 4-22% have symptoms to meet the criteria for chronic insomnia disorder.

Chronic insomnia is defined by the International Classification of Sleep Disorders – Third Edition as a patient describing difficulty falling asleep, maintaining sleep, waking up earlier than desired, feeling sleep as insufficient and associated feelings of tiredness during the day, lack of energy, sleepiness during the day and difficulties in important areas of person’s daily functioning To fit the criteria there must be at least 1 symptom that is a consequence of insomnia that lasts for 3 months or more [31].

We know that sleep can affect the endocrine system and the nervous sympathetic system, sleep loss can lead to dysfunction of these systems reflecting in metabolic abnormalities [32] increased cortisol [33] and catecholamine levels [34] endothelial dysfunction [35], and pro-inflammatory states [36]. These observed metabolic changes may be a fundamental mechanism for increased cardiovascular risk factors and disease.

Several observational studies and meta-analyses have shown an association between insomnia and cardiovascular disease (CVD) morbidity and mortality, including hypertension, coronary heart disease, and heart failure. These reports relate to dysregulation of the hypothalamic-hypothalamus axis, increased inflammation, and increased activity of the sympathetic nervous system [37, 38, 39].

About 45% of patients with coronary artery disease suffer from insomnia. Psychological factors, mainly anxiety, lifestyle, and subclinical inflammation, are strongly associated with sleep loss [40]. Depending on the symptoms of insomnia, the risk of an acute heart attack ranges between 27% and 45% after accounting for confounding factors such as BMI, cholesterol, blood pressure, and smoking. The highest risk of a heart attack was found among patients who had difficulties initiating sleep [41].

The incidence of insomnia in patients with heart failure ranges from 23% to 73%. There is more research indicating that insomnia is a result rather than a cause of heart failure. This is mainly due to anxiety and depression, medication, and breathing problems. However, there are reports where insomnia has been shown to precede HF occurrence. Again, difficulty getting to sleep was most strongly associated with HF occurrence [42].

Many sleep disorders are significantly associated with an increased risk of hypertension [43]. The results of a meta-analysis of prospective cohort studies showed that insomnia is associated with an increased risk of hypertension and could increase the risk by up to 21%. An increased risk of hypertension was observed in participants with difficulty maintaining sleep and early morning awakening, but about other cardiovascular diseases, it was not statistically significant in participants with difficulty falling asleep. In addition, the results were statistically significant in the European and Australian populations, but insignificant in the Asian and American populations. These findings may have important implications for the prevention of hypertension in patients with symptoms of insomnia [44].

The pathomechanism underlying the link between insomnia and hypertension risk remains unclear. Research suggests that short sleep duration may increase average 24-hour blood pressure and heart rate, increase sympathetic nervous system activity, and stimulate physical and psychosocial stressors, all of which may lead to hypertension [45].

The literature undeniably points to the impact of sleep on our health, and its lack has a negative impact on our quality of life, cognitive function, affective disorders, and even life span [46].

Excessive napping during the day also known as hypersomnia is defined as a state of excessive daytime sleepiness and sleep attacks that are not due to sleep deprivation or a prolonged transition from sleep to full wakefulness after waking up.

Extreme sleepiness occurs at least three times per week, for at least three months. Individuals with this disorder may have difficulty waking up in the morning, sometimes appearing dazed, confused, or even aggressive. Sleepiness causes significant distress and can lead to problems with functioning, such as issues with concentration and memory [31].

Several observational studies show a link of daytime naps with increased cardiovascular risk. Multiple studies show the effect of different sleep patterns and nap durations The greatest risk of cardiovascular events has been shown to be people who take naps lasting more than 60 minutes [47, 48, 49, 50].

Naps during the day can negatively affect the sleep cycle. During a disturbed sleep-wake cycle there is the unbalanced secretion of hormones, neurophysiological changes, and a decrease in insulin sensitivity and glucose homeostasis, all of which can act as pro-inflammatory and subsequently increase the risk of CVD [51]. Evidence indicates that longer naps may also cause abnormal secretion of hormones such as cortisol and melatonin, leading to impaired glycolipid metabolism that underlies the pathomechanism of CVD [52,53].

The meta-analysis of napping and the risk of CVD shows no significant association between napping and the risk of CVD and CVD mortality versus non-napping in the global analysis [54]. Repeated naps during the day are causally associated with an increased risk of CVD, mainly due to the development of coronary atherosclerosis [55]. A nap that lasts more than 60 minutes is associated with the greatest risk. There are several mechanisms responsible for the association between CVD and naps. Levels of inflammatory markers such as CRP and interleukin-17 were reported to increase in subjects who took long naps [56]. Unlike longer naps, short naps may be beneficial for reducing CVD risk and preventing memory deterioration [57, 58] which may explain the positive association between short naps and lower CVD risk.

One of the most common sleep disorders that affect the population of adult people is obstructive sleep apnea (OSA). It is a disease involving periodic closing or narrowing of the upper respiratory tract during sleep, which leads to deterioration of blood oxygenation and awakening from sleep [59]. The benefit is treated as a reduction in breathing amplitude by at least 90% for a minimum of 10 seconds. However, the shallow breathing is defined as a

reduction in the amplitude of pressure changes in the nasal cavity by ≥30% by ≥10 s + a decrease in SpO_2 by 3% or (micro)awakening. The number of apnea and release of breathing falling per hour is referred to as the apnoea-hypopnoea index (AHI). Respirator effort-related arousal (RERA) is characterized by increasing respiratory effort and a partial reduction of airflow (which does not meet the criteria of apnea or shallow breathing) for at least 10 seconds that lead to awakening. The number of apnea, breathing sharing, and RERA episodes per hour of sleep is referred to as the RDI (respiratory disturbance index) indicator. [60]. OSA is a known risk factor for many cardiovascular diseases, such as hypertension, ischemic disease and myocardial infarction, heart and conduction arrhythmias, heart failure as well as diabetes or metabolic syndrome [61, 63, 63, 64, 65].

One of the leading causes of death among younger patients due to cardiovascular reasons is arrhythmias. One of the important factors that affect the development of these changes is the OSA [66]. As a possible mechanism, which leads to arrhythmias in the course of the OSA, endothelial damage and the advantage of sympathetic impulse [67]. This is the first to be caused by excessive production of reactive forms of oxygen, while the activation of the sympathetic system results from overlapping hypoxemia and hypercapnia [68]. These two aspects lead to an increase in oxygen's heart rate over time, which reduces the time of repolarization and enables the potential initiation of various arrhythmias [69]. The most important aberrations of the heart rhythm caused by the OSA, which can significantly lead to life-threatening are ventricular fibrillation and Torsades de Pointes in the course of extending the QT interval [70, 71]. As a less frequently described, sinus bradycardia or atrioventricular blocks (AVB) of various types are exchanged [72, 73]. Moreover, the above changes may also lead to myocardial ischemia in connection with the disproportion between the demand and oxygen supply for myocardial cells [60].

Hypertension is the most common disease occurring in the populations of developed countries [74]. Many studies have shown a connection between the development of hypertension and earlier occurrence of the OSA. Thanks to this, it has been shown that OSA as a sleep disorder is an important cardiovascular risk factor [75, 76, 77]. As a pathomechanism of increased blood pressure, a complex combination of several aspects is perceived, including the connection between endothelium and the sympathetic system described above [78]. Dysregulation in this matter is responsible for the increased activity of the Renina-Angiotesin II-Aldosterone system, which results in increased vascular resistance as well as excessive

retention of sodium in the body, which directly translates into increasing the value of blood pressure [79, 80]. In addition, one should not forget that the service should also be seen as an inflammatory disease [81]. Among the patients affected by this disease, increased levels of inflammatory markers (e.g. CRP or Interleukin-6) are observed in the blood, which promotes the development of hypertension and thus translates into a high cardiovascular risk [82, 83]. Moreover, the last research results indicate a significant correlation between the occurrence of OSA and obesity or metabolic syndrome, which directly affects the high cardiovascular risk among patients suffering from OSA [84].

5. DISCUSSION

The results of this research underline the high prevalence of sleep disorders in the general population revealing that chronic insomnia has a prevalence of 4-22% in adults and is linked to numerous cardiovascular risk factors. This is consistent with previously published studies that have established a complex interplay between sleep disorders, particularly insomnia and obstructive sleep apnea (OSA), and cardiovascular health [1, 85].

Our findings support the hypothesis that lack of adequate sleep and disruptions in the normal sleep cycle lead to the development of metabolic imbalances, activation of the sympathetic system, and inflammation which progressively increases the risks for cardiovascular disease as previously reported by other observational studies and meta-analyses.

For practical purposes, the detection and management of sleep disorders must be considered in patient management, especially those with underlying cardiovascular disease. Treatment of sleep disorders is a plausible strategy to prevent the development of hypertension, coronary artery disease, and heart failure [86].

These conclusions suggest a need to screen for insomnia in patients with cardiovascular risk factors due to the possibility of unsolved insomnia causing added harm and worsening health outcomes, and promoting education about sleep hygiene as part of patient care. Treating patients with cardiovascular diseases should also address the associated sleep disorders and the impact of the disease on the patient's sleep. Furthermore, policies encouraging work-life balance and facilitating reduced disruption to circadian rhythms in certain populations, namely shift workers, may help loosen the burden of sleep disorders.

Nonetheless, this study does have some limitations. There is still a need for further development of the models describing the exact pathomechanisms in which sleep disorders affect cardiovascular health, especially the role of inflammatory and metabolic processes. It would be useful to analyze the results of some particular treatments, such as cognitive behavioral therapy for insomnia or continuous positive airway pressure (CPAP) therapy for obstructive sleep apnea (OSA) patients, and their effects on cardiovascular risk management. Furthermore, analyzing the impact of specific public health policies designed to enhance the quality of sleep and studying their effects on the population-level burden of cardiovascular disease would be insightful.

The results of this research present the existing literature on the interrelation of sleep disorders with cardiovascular disease and its risk factors. There is enough evidence for sleep disorders to be considered a modifiable risk factor that, if properly addressed, can deliver significant clinical and public health benefits constituting a notable potential in terms of reducing morbidity and mortality from cardiovascular diseases.

6. CONCLUSION

Sleep disorders, notably insomnia and obstructive sleep apnea (OSA), are prevalent conditions with clearly documented associations with increased cardiovascular risk. Current evidence supports their role as independent and modifiable contributors to cardiovascular pathophysiology, acting through mechanisms such as autonomic dysregulation, metabolic impairment, endothelial dysfunction, and systemic inflammation.

Recognizing the bidirectional relationship between sleep disturbances and cardiovascular disease is essential for improving risk stratification and clinical outcomes. Sleep disorders not only co-occur with conditions such as hypertension, coronary artery disease, and heart failure but may also precede and contribute to their development and progression.

Integrating sleep assessment into routine cardiovascular care, along with the implementation of validated interventions—including cognitive behavioral therapy for

insomnia and CPAP therapy for OSA—may offer measurable benefits in reducing morbidity. Moreover, addressing population-level determinants of sleep disruption, such as shift work, should be considered within public health frameworks.

Further research is warranted to refine our understanding of causal pathways, assess the long-term effects of treatment, and guide evidence-based integration of sleep medicine into cardiovascular prevention and management strategies.

7. DISCLOSURE

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