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Literature Review on Sleep Disorder Research

Changcheng Yang[1, *]

[1]Hefei No.8 Senior High School, Hefei, China 230071
*Corresponding author: Xin520yi126@gmail.com

Abstract:

Sleep disorder has become a key global public health challenge, and its high prevalence rate (for example, among middle-aged and elderly people, insomnia is 17.3% and OSAHS is over 30%) seriously affects physical and mental health and leads to huge social and economic costs. This review focuses on the classification of sleep disorders (based on ICSD-3), physiological and psychological injury mechanisms, multi-level pathogenic factors (physiology, social environment and behavior) and comprehensive intervention strategies (precision medicine, cognitive behavioral therapy, environmental optimization and public policy). The key problems to be solved include the complex interaction between sleep disorders and chronic diseases, the vulnerability differences among different populations, and the effectiveness of interdisciplinary intervention. The conclusion of this review is that research on sleep disorders requires strengthened interdisciplinary collaboration, and future efforts need to solve the long-term cost-benefit gap between cross-cultural research and intervention measures in order to advance global sleep health governance.

Keywords: Sleep Disorders; ICSD-3 Classification; Pathogenic Mechanisms; Comprehensive Intervention; Public Health Governance

1. Introduction

Sleep is a crucial psychological function for maintaining human physical health [1]. Sleep disorders not only severely affect an individual's quality of life but are also closely associated with various chronic diseases, having become a major challenge in the global public health sector [2]. The International Classification of Sleep Disorders, 3rd Edition (ICSD-3), systematically categorizes sleep disorders into six major types, including insomnia disorder, sleep apnea, and circadian rhythm disorder, providing a unified standard for both academic research and clinical practice. Data from the World Health Organization in 2024 shows that the global prevalence of insomnia reaches 17.3%, while the prevalence of Obstructive Sleep Apnea Hypopnea Syndrome (OSAHS) among the middle-aged and elderly population exceeds 30%. These figures highlight the severity of the sleep disorder issue.

In terms of research paradigms, the academic community's understanding of sleep disorders has

evolved from mere descriptive accounts of events to in-depth studies on multi-system interaction mechanisms. The comorbidity between sleep disorders and cardiovascular events, metabolic syndrome, and neurodegenerative diseases has attracted increasing attention [3]. A cohort study published in *The Lancet* in 2023 confirmed this complex relationship. From a socioeconomic perspective, the American Academy of Sleep Medicine estimates that sleep disorders cause an annual productivity loss of up to $411 billion. This indicates that sleep disorders are not only a medical problem but also a significant socioeconomic one. Meanwhile, the intelligent evolution of polysomnography technology and the widespread application of wearable devices have brought new breakthroughs to the research and diagnosis of sleep disorders, driving the rapid development of this field. This paper analyzes the current research status of sleep disorders, summarizes their existing characteristics and pathogenic factors, and explores the construction of an intervention strategy system.

2. Concept Definition and Evolution of the Disease Spectrum

The ICSD-3 criteria for classifying sleep disorders are authoritative and scientific. They clearly define six major categories of sleep disorders, offering a clear framework for clinical diagnosis and academic research. Globally, the prevalence of sleep disorders is on the rise, a trend closely linked to modern lifestyle changes, population aging, and other factors. Taking chronic insomnia and OSAHS as examples, their high prevalence not only causes suffering to patients but also imposes enormous pressure on medical resources.

The paradigm shift in the understanding of diseases is reflected in the in-depth research on the pathogenesis of sleep disorders [4]. In the past, people mainly focused on the external manifestations of sleep disorders; nowadays, research has delved into the interactions among multiple systems such as the nervous, endocrine, and cardiovascular systems. This transformation is conducive to the development of more effective diagnostic and therapeutic methods and also lays the foundation for interdisciplinary research.

3. Health Status of Populations with Sleep Disorders

3.1 Physiological Damage Mechanisms

In the context of neuroendocrine function, numerous studies have demonstrated that sleep disorders can disrupt neuroendocrine balance [5]. A 2024 cortisol tracking experiment published in *Nature* revealed that patients with sleep disorders experience circadian rhythm disruption and overactivation of the hypothalamic-pituitary-adrenal (HPA) axis, which affects the body‘s stress response and metabolic regulation. At the same time, the secretion of growth hormone is inhibited, seriously impairing tissue repair and growth and development [6].

In the context of the cardiovascular and cerebrovascular systems, a 2023 study on the mechanism of atherosclerosis published in the *New England Journal of Medicine* pointed out that intermittent hypoxia caused by obstructive sleep apnea leads to oxidative stress damage, increasing the risk of atherosclerosis. Additionally, patients with sleep disorders have reduced heart rate variability, and their risk of ventricular arrhythmia increases by 3.2 times, posing a serious threat to cardiovascular health.

In terms of immune metabolism, sleep fragmentation causes an increase in pro-inflammatory molecules such as IL-6 and TNF-α, disrupting the balance of the immune system. Meanwhile, the imbalance in the leptin/ghrelin ratio has a dose-response relationship with obesity, further exacerbating metabolic disorders.

3.2 Mental Health Crises

The comorbidity between sleep disorders and mood disorders is substantial. A 2024 meta-analysis published in JAMA Psychiatry showed that insomnia patients have a 4.8-fold higher relative risk of developing depression. Evidence from functional magnetic resonance imaging (fMRI) indicates that rapid eye movement (REM) sleep deprivation leads to hyperactivity of the limbic system, affecting emotional regulation.

Regarding cognitive function, a 2025 study on cerebrospinal fluid dynamics published in *Science* found that a reduction in slow-wave sleep decreases the clearance efficiency of beta-amyloid, increasing the risk of neurodegenerative diseases. At the same time, damage to the attention network leads to a 47% increase in work error rates, seriously affecting work and quality of life.

4. Multi-level Analysis of Pathogenic Factors

4.1 Physiological and Pathological Basis

Genetic susceptibility plays an important role in the development of sleep disorders. Genome-wide association studies have found that mutations in the DEC2 gene are associated with short sleep phenotypes [7]. Abnormalities

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in the function of the brainstem reticular formation, particularly abnormal activity of noradrenergic neurons in the locus coeruleus, are also closely related to the progression of sleep disorders.

4.2 Socio-environmental Drivers

Light pollution and artificial lighting exert adverse effects on sleep, exacerbating sleep disorders [8]. A 2024 global light survey published in *Proceedings of the National Academy of Sciences of the United States of America* (PNAS) showed that the peak secretion of melatonin in urban residents is delayed by 2.1 hours, disrupting normal circadian rhythms. Shift work has a significant impact on sleep disorders; the incidence of circadian rhythm disorders in shift workers such as medical staff is 3.7 times higher than that in the general population.

4.3 Behavioral Triggers

Dependence on electronic devices has become a major trigger for sleep disorders [9]. A follow-up study published in the Journal of Clinical Medicine showed that for each additional hour of mobile phone use, sleep latency increases by 22 minutes [10]. The cognitive arousal theory proposes that a vicious cycle forms between the sleep effort paradox and conditional anxiety, further exacerbating sleep disorders [11].

4.4 Vulnerability of Special Populations

Perimenopausal women are prone to sleep disorders due to fluctuations in estrogen levels, which disrupt the function of the thermoregulatory center. After the COVID-19 pandemic, studies have found that COVID-19 sequelae may cause sleep disorders through potential damage to the suprachiasmatic nucleus by the virus.

5. Construction of a Comprehensive Intervention Strategy System

5.1 Breakthroughs in Precision Medicine

In terms of pharmaceutical research, the efficacy of lemborexant, an orexin receptor antagonist, has been validated, providing a new option for the treatment of insomnia [12]. In the field of individualized respiratory support, the Auto-CPAP pressure titration algorithm has been optimized through machine learning, improving treatment efficacy and patient comfort.

5.2 Innovations in Cognitive Behavioral Therapy

Digital cognitive behavioral therapy (CBT) programs use virtual reality (VR) technology to simulate sleep restriction environments, enhancing treatment effectiveness [13]. Mindfulness-based stress reduction training, combined with real-time feedback from functional near-infrared spectroscopy, improves sleep quality by regulating the functional connectivity of the amygdala.

5.3 Improvements in Environmental Engineering

In the field of residential acoustic design, low-frequency noise, characterized by long wavelengths and strong penetrability, is difficult to be effectively blocked by conventional sound insulation materials, making it a key factor disrupting deep sleep. Recent studies have shown that the human ear is sensitive to low-frequency noise in the range of 20-200 Hz, which often resonates with the delta wave (0.5-4 Hz) and theta wave (4-8 Hz) bands in human brain waves, thereby disrupting the stability of deep sleep. Based on this, a new noise cancellation system adopts active noise control technology, generating anti-noise waves through the principle of sound wave interference to offset low-frequency noise in the environment. Relevant experimental data show that in residential environments equipped with this system, the proportion of deep sleep in subjects increased from 18.7% to 25.3%, markedly improving sleep outcomes. Additionally, the system‘s automatic adjustment function can optimize noise reduction parameters in real-time based on the ambient noise, further enhancing its adaptability to the sleep environment.

In terms of artificial circadian lighting, dynamic color temperature adjustment devices are designed to address the circadian rhythm disorders in patients with Alzheimer‘s disease. These devices simulate the variation patterns of natural light to create a lighting environment that better meets the physiological needs of patients. Patients with Alzheimer‘s disease have impaired suprachiasmatic nucleus function, resulting in reduced sensitivity to ambient light, abnormal melatonin secretion, and disrupted sleep-wake cycles. The dynamic color temperature adjustment devices provide high-color-temperature (5000-6500 K), high-illuminance (1000-2000 lux) light stimulation during the day to enhance patients‘ alertness and activity levels. At night, they switch to a warm light environment with low color temperature (2700-3000 K) and low illuminance (50-100 lux) to promote melatonin secretion and induce sleep. Clinical studies have shown that in nursing institutions using this device, the number of nighttime awakenings in patients with Alzheimer‘s disease decreased by 32%, sleep continuity was significantly improved, and their daytime cognitive function scores also increased.

5.4 Public Health Policies

The management of sleep disorders is evolving towards a multi-dimensional and systematic approach (as shown in Figure 1) . At the enterprise level, German companies have used sleep health interventions to reduce workplace accident rates and improve productivity [14]. At the community level, Australia‘s sleep disorder screening programs and China‘s smart sleep community pilots have achieved precise interventions through technological means. At the international organizational level, the World Health Organization (WHO) and the International Labour Organization (ILO) have jointly launched initiatives, and the World Bank has established a special fund to promote global sleep health governance. These policies work in synergy across different fields to jointly build a sleep health management system. The following table further presents typical public health policies in various countries and their effectiveness data.

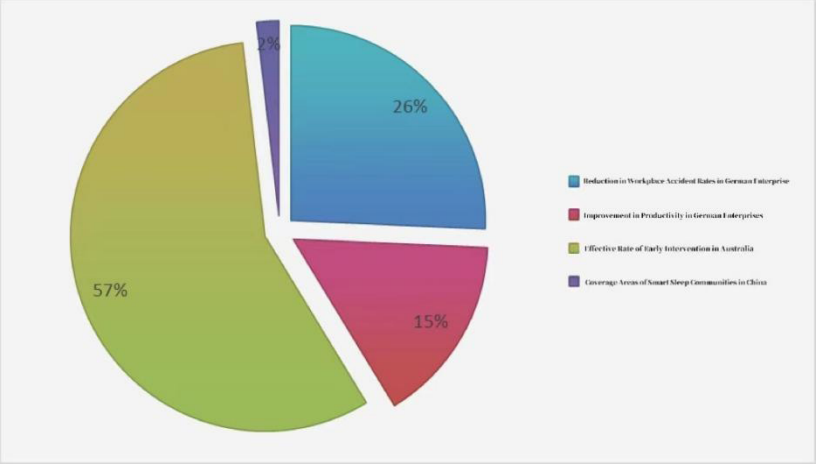

Fig. 1 Effectiveness of Typical Public Health Policies for Sleep Disorders

6. Conclusions

Research on sleep disorders involves multiple disciplines such as neurology, environmental engineering, and public health. Interdisciplinary collaboration is an inevitable trend in future research. Technological advancements, such as closed-loop brain stimulation systems, offer new possibilities for regulating the sleep-wake cycle. This review confirms that sleep disorders constitute a severe global public health and socioeconomic challenge (e.g., 17.3% global insomnia prevalence, $411 billion annual productivity loss). It analyzed their physiological/mental harms (HPA axis overactivation, 4.8-fold higher depression risk in insomniacs), multi-level causes (genetics, light pollution, device dependence, vulnerable groups like perimenopausal women), and discussed comprehensive interventions (precision medicine like lemborexant, VR-based CBT, noise control, public policies). Key conclusions: sleep disorders need cross-discipline synergy, while gaps like insufficient cross-cultural studies require future exploration. However, there are still gaps in the current research field, such as insufficient cross-cultural comparisons and the need to strengthen the assessment of the long-term cost-effectiveness of intervention measures. Future research should focus on addressing these gaps to provide more scientific and effective strategies for the global sleep health field.

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