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Epidemiological Evidence Public Health of Shift Work Circadian Disorders on Population Health

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Abstract. Shift work and night-shift schedules disrupt circadian rhythms, causing chronic misalignment between internal clocks and environmental cycles—an issue increasingly recognized as a key determinant of population health. This study synthesizes epidemiological studies and mechanistic evidence to explore circadian disruption's impact on population health and corresponding public health responses. Epidemiological studies consistently correlate shift work with heightened cardiovascular disease, metabolic disorder, malignancy, and mental disorder risk; mechanistic evidence supports correlations as circadian disruption alters endocrine regulation, suppresses glucose metabolism and reduces neurophysiologic clearance with sleep. Risks are concentrated disproportionately, with women, older adults, health care providers, and poor individuals carrying greater burdens as a result of biological and structural determinations. Current responses at the population health level are sparse and require personal (e.g., light exposure), organizational (e.g., schedule planning) and policy (e.g., protective regulation) intervention. Recognition of circadian disruption as an occupational hazard is fundamental for reduction of its global burden of illness and highlights extreme population health significance.

Keywords: Night-shift work, circadian disruption, epidemiology, metabolic disorders, public health interventions.

1. Introduction

Circadian rhythms regulate essential physiological processes such as sleep–wake cycles, metabolic control, and hormone secretion. These rhythms are coordinated by the suprachiasmatic nucleus in the hypothalamus and synchronized with peripheral clocks in organs throughout the body. When the internal timing system aligns with the external light–dark cycle, it maintains stability and efficiency across systems. Disturbance of this synchrony, however, leads to circadian misalignment, which is increasingly recognized as a factor that contributes to chronic disease rather than a source of short-term fatigue alone [1].

The growth of 24-hour economies has made this type of disruption widespread. Current estimates suggest that nearly one in five workers worldwide is exposed to night or rotating shifts, with particularly high prevalence in healthcare, manufacturing, and transport [2]. New forms of employment, including platform-based service work, have also extended irregular schedules to groups not traditionally involved in shift labor. In China, for instance, the expansion of the delivery

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and logistics industries has created large populations of workers facing chronic circadian strain. These changes mean that misalignment between internal clocks and environmental cycles is no longer a problem limited to specific sectors but has become a structural feature of modern labor markets.

Epidemiological evidence consistently illustrates that shift work increases risks across multiple areas. Large-scale cohort studies and meta-analyses show the fact that night-shift workers have higher incidence of cardiovascular disease, diabetes, obesity, and certain cancers among than day workers [3]. Importantly, these risks remain even after considering lifestyle factors such as smoking, diet, and exercise, which indicates that circadian disruption itself is an independent predictor of disease. Controlled laboratory experiments support this conclusion. With just a few days, inversions of the sleep-wake cycle have been demonstrated to impair glucose tolerance and decrease insulin sensitivity [1]. Neuroscience research further suggests that disrupted sleep impairs the brain's glymphatic system, reducing clearance of toxic metabolites and providing a plausible link to neurodegeneration [4].

Recognition of the seriousness of these risks has extended to policy frameworks. In 2019, the International Agency for Research on Cancer classified night-shift work involving circadian disruption as a probable human carcinogen [5]. This designation reflects not only epidemiological associations with breast and prostate cancer but also mechanistic plausibility involving melatonin suppression, immune disturbance, and impaired DNA repair. At the same time, regulatory and organizational responses remain uneven. Some high-income countries have introduced limits on hours or mandated rest periods, but enforcement varies widely. In many low- and middle-income countries, protections are minimal or absent. Organizational interventions—such as forward-rotating schedules, exposure to bright light at planned times, and workplace wellness programs—have shown promise but are inconsistently adopted [6].

These gaps point to the urgency of a comprehensive review. This paper has three objectives. The first is to synthesize epidemiological evidence linking shift work with health outcomes across cardiovascular, metabolic, oncologic, and psychological domains. The second is to outline biological mechanisms that provide plausibility for these associations, drawing attention to circadian misalignment as a unifying pathway. The third is to examine subgroup variation and evaluate current interventions, emphasizing the need for strategies that recognize differences in vulnerability across populations. Only by integrating evidence from these perspectives can circadian disruption be understood as a public health problem that demands a coordinated response.

2. Epidemiological evidence public health of shift work circadian disorders on population health

2.1. Epidemiological evidence

A growing body of epidemiological research has established that night-shift and rotating-shift schedules are associated with diverse long-term health risks. Large cohort investigations and quantitative syntheses consistently show that the consequences of circadian disruption extend well beyond transient fatigue, positioning shift work as an important determinant of population health. Research on cardiovascular outcomes is particularly extensive. Evidence from a meta-analysis of over two million participants shows that shift workers face a 17% elevated risk of cardiovascular events compared with those on standard daytime schedules. Within this category, coronary heart disease presented a significant risk increase, with a relative risk of 1.26 (95% CI 1.10–1.43) [7]. Further systematic syntheses reinforce this link, identifying biological pathways through which

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circadian disruption elevates blood pressure, alters lipid regulation, and triggers systemic inflammation [3]. These converging data suggest that long-term exposure to irregular schedules gradually erodes cardiovascular resilience, thereby compounding the disease burden at the level of entire populations.

Metabolic disorders show a similarly consistent pattern. A meta-analysis reported that shift work markedly increases the prevalence of metabolic syndrome, with stronger effects among women and employees on rotating schedules [8]. Prospective data from the Nurses' Health Studies demonstrated that night-shift workers had about a 30% higher risk of type 2 diabetes, independent of diet and physical activity [9]. Controlled laboratory protocols simulating circadian misalignment provide mechanistic confirmation: within less than a week of enforced schedule inversion, healthy participants exhibited impaired glucose tolerance and reduced insulin sensitivity [1]. These findings suggest that irregular meal timing, nocturnal caloric intake, and altered endocrine regulation jointly contribute to the excess prevalence of obesity and diabetes in shift-work populations.

Carcinogenic risk has generated ongoing debate, but converging evidence supports biological plausibility. In 2019, the International Agency for Research on Cancer classified night-shift work involving circadian disruption as a "probable carcinogen" (Group 2A) [5]. Evidence on breast cancer risk has been inconsistent across observational studies of night-shift work. Earlier reports suggested a modest elevation in risk with long-term exposure, but more recent high-quality prospective studies do not support this association. In a large pooled analysis of three UK cohorts, Travis et al. reported no significant link between shift work and breast cancer incidence. Relative risks for women who had ever worked night shifts compared with never-shift workers were close to unity across cohorts, with an overall estimate of 0.99. Even for prolonged exposure, such as ≥20 years or ≥30 years of night-shift work, relative risks remained essentially null [10]. These results indicate that, contrary to earlier concerns, long-term night-shift work may not be associated with increased breast cancer risk. Although associations with prostate and colorectal cancers remain less consistent, longitudinal studies indicate modestly elevated risks, consistent with hypotheses involving melatonin suppression, endocrine disturbance, and impaired immune surveillance.

Mental health consequences represent another important dimension. Cross-sectional and cohort studies in Europe and North America have consistently shown that night-shift workers experience higher rates of depression, anxiety, and burnout than day workers. A meta-analysis of 11 observational studies found that night-shift work was associated with a 43% higher risk of depressive symptoms [11]. Healthcare professionals are particularly affected, with prevalence estimates of depressive symptoms frequently exceeding 30%, far above population averages. Mechanisms proposed include chronic sleep restriction, dysregulated neurotransmitter signaling, social isolation, and persistent work–family conflict.

In summary, epidemiological evidence consistently demonstrates that shift work is linked to heightened risks across cardiovascular, metabolic, oncologic and psychological domains. The strength, breadth, and reproducibility of these associations provide a robust foundation for mechanistic research and underscore the urgency of targeted public health interventions. These cross-domain consistent associations not only confirm the intensity of the link between shift work and chronic diseases but also urgently require an exploration of the underlying driving mechanisms from a biological perspective to clarify the core question of "why shift work induces health risks."

2.2. Biological mechanisms

The health risks associated with shift work are biologically plausible through several interconnected mechanisms. Circadian misalignment is a central factor: exposure to light at night disrupts the

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suprachiasmatic nucleus, the master circadian pacemaker, and disturbs the synchronization of peripheral clocks in organs such as the liver, pancreas, and heart. This internal desynchrony produces widespread alterations in endocrine regulation, metabolic control, and immune activity [6].

Findings from controlled laboratory studies demonstrate the immediacy of these effects. When participants are subjected to schedule inversion for only a few days, they exhibit significant reductions in insulin sensitivity and impaired glucose tolerance, indicating a direct causal pathway from circadian disruption to metabolic dysfunction [1]. Animal models provide complementary mechanistic insight: Clock mutant mice develop hyperphagia, obesity, and metabolic syndrome–like traits, showing that disruption of core circadian genes alone is sufficient to induce systemic pathology [12].

Hormonal dysregulation further mediates the adverse effects of night-shift work. Experimental sleep restriction consistently reduces leptin and elevates ghrelin, shifting energy balance toward increased hunger and caloric intake [4]. Within occupational settings, these hormonal changes compound the consequences of irregular meal timing and nocturnal eating, thereby accelerating weight gain and insulin resistance.

A neurological pathway has also been proposed. The glymphatic system, which clears neurotoxic metabolites during deep sleep, functions less effectively when sleep is shortened or fragmented. In rodent models, sleep promotes the clearance of amyloid-β, whereas sleep deprivation accelerates its accumulation [13]. Although long-term human data remain limited, this mechanism provides a plausible link between chronic circadian disruption and elevated risk of neurodegenerative disease.

Collectively, these strands of evidence indicate that circadian disruption is not limited to generating fatigue but initiates system-wide alterations in metabolism, endocrine function, and neural maintenance. Taken together, mechanistic evidence supports the plausibility of the epidemiological findings, showing that circadian disruption can affect multiple physiological systems ranging from metabolism to neurocognition. After clarifying the biological pathways of shift work-related health risks, it is particularly critical to further analyze the risk heterogeneity among different populations—not all shift workers face the same health threats, as factors such as age, gender, and occupation significantly affect individuals' risk exposure and tolerance.

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2.4. Subgroup difference

The health consequences of shift work are not distributed evenly across populations. Demographic, occupational, and socioeconomic factors shape vulnerability, producing heterogeneous risk profiles that call for tailored interventions. Age is a critical determinant: younger workers may exhibit partial short-term adaptation to irregular schedules, but cumulative exposure over decades is associated with increased risks of hypertension, obesity, and diabetes. By contrast, older workers tend to manifest immediate strain, including heightened insomnia, reduced cardiovascular resilience, and impaired recovery capacity. Evidence from longitudinal cohorts suggests that cumulative exposure duration is a stronger predictor of adverse outcomes than the age at which shift work begins, underscoring the significance of lifetime biological load [9].

Gender differences are most clearly observed in oncological outcomes. A recent dose–response meta-analysis encompassing over 6.8 million person-years found that women with 30 years of night-shift work experienced a 13% higher risk of breast cancer, with a linear increase across exposure duration [14]. Male shift workers, in turn, display elevated risks of prostate cancer and metabolic syndrome. Beyond cancer, women also face higher rates of reproductive complications, including menstrual irregularities, reduced fertility, and adverse pregnancy outcomes, reinforcing the need for gender-specific occupational health strategies.

Occupational context further modifies susceptibility. Healthcare professionals—particularly nurses and physicians—are among the most extensively studied groups and consistently exhibit elevated prevalence of cardiovascular disease, metabolic syndrome, and depression [7]. These effects are compounded by high job strain and limited recovery opportunities. Industrial and transportation workers face increased accident rates due to circadian misalignment combined with sustained demands on vigilance and safety. More recently, workers in the gig economy, such as ride-share drivers and delivery couriers, have emerged as a growing group exposed to irregular hours but lacking sufficient labor protections, highlighting new domains of occupational health inequality.

Finally, socioeconomic status plays a decisive role. Lower-income workers are disproportionately concentrated in shift-dependent occupations yet often lack access to healthcare or preventive resources, amplifying the cumulative burden of circadian disruption. In many high-income countries, racial and ethnic minorities are overrepresented in sectors such as healthcare, service, and transportation, which further compounds preexisting health inequities. Thus, subgroup analyses confirm that risks are unevenly distributed across demographic and occupational lines, implying that universal interventions are unlikely to be effective. This significant subgroup risk difference

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indicates that a single "one-size-fits-all" intervention cannot effectively alleviate the health burden of shift work; instead, a hierarchical intervention framework needs to be constructed from the individual, organizational, and policy levels, combined with the characteristics of different populations.

2.5. Public health implications and interventions

The recognition of shift work as a determinant of chronic disease underscores the need for multi-level interventions. Because circadian disruption influences health at biological, behavioral, and social levels, strategies must be implemented across individual, organizational, and policy domains. At the individual level, evidence supports behavioral strategies such as education on sleep hygiene, scheduled exposure to bright light, and, in some cases, judicious melatonin supplementation. Controlled trials show that morning light therapy can advance circadian phase, whereas evening exposure can delay rhythms, improving adaptation to rotating schedules. Wearable technologies that monitor sleep and circadian markers provide opportunities for personalized feedback. Complementary lifestyle interventions, including physical activity and structured dietary timing, may buffer cardiometabolic risk [6].

At the organizational level, employers shape the structure of work schedules and thereby influence circadian strain. Forward-rotating schedules, restrictions on consecutive night shifts, and mandatory rest periods have been shown to reduce fatigue and enhance performance. In healthcare, where elevated baseline risks are well documented, workplace wellness initiatives—such as counseling, stress management, and structured programs to promote sleep quality—provide significant value [7]. Alongside these, occupational health surveillance that incorporates cardiovascular and metabolic screening allows employers to identify problems early and intervene before conditions progress, thereby positioning organizations as active stewards of worker health.

At the level of governance, shift work has increasingly been conceptualized as a formal occupational hazard. The International Agency for Research on Cancer has gone so far as to classify night-shift work that disrupts circadian rhythms as a “probable carcinogen,” thereby offering a strong scientific rationale for its recognition within occupational disease compensation frameworks [5]. National legislation aimed at reducing risk—through mandated rest intervals, maximum working-hour restrictions, and improved access to preventive care—forms the backbone of systemic protection. Public health campaigns, meanwhile, reinforce these efforts by disseminating knowledge about the long-term cardiovascular and metabolic consequences of circadian disruption.

Globally, the adoption of such measures is uneven. High-income countries increasingly integrate surveillance and wellness programs into workplace structures, while low- and middle-income nations often expand shift-based labor in the service sector without equivalent safeguards. This divergence underlines the need for international cooperation and standardized occupational guidelines that extend protection across diverse labor markets. Ultimately, reducing the systemic burden of shift work requires a multi-level strategy that integrates behavioral interventions, employer accountability, regulatory oversight, and global equity. Only through such coordinated measures can the long-term risks associated with circadian misalignment be effectively addressed.

3. Conclusion

The disruption of circadian rhythm caused by shift work is the main determinant of chronic diseases. Large-scale cohort studies and meta-analyses have shown that it significantly increases cardiovascular, metabolic, tumor, and psychological risks. Mechanism studies have confirmed the

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rationality of the above association. Nighttime light exposure disrupts the core rhythm regulation structure, leading to peripheral rhythm asynchrony and subsequently triggering hormonal, metabolic, and immune disorders. Laboratory experiments have shown that short-term rhythm disorders can reduce insulin sensitivity and alter glucose tolerance. Sleep restriction promotes weight gain by regulating relevant hormones, and animal models have also confirmed that abnormal rhythm genes can lead to obesity. Sleep interruption can also impair the clearance of neurotoxic substances in the brain, suggesting a possible pathway for neurodegeneration, indicating that the association between shift work and chronic diseases is rooted in underlying physiological mechanisms. It is worth noting that the risk distribution is uneven. Women who have been on night shift for a long time have a higher risk of breast cancer and reproductive complications. Older workers, with a diminished ability to re-synchronize biological rhythms, face greater risks of hypertension, obesity, and sleep-related disorders. In the healthcare sector, constant exposure to high occupational stress and inflexible shift patterns has led to a marked increase in both physical ailments and psychological strain among staff. Meanwhile, low-income employees, disproportionately concentrated in service, manufacturing, and gig industries, encounter structural disadvantages—such as limited job security, poor working conditions, and restricted access to healthcare—that compound their biological susceptibility. These differences underscore the necessity for interventions that are sensitive to population-specific needs rather than uniform solutions. For public health systems, the implication is clear: strategies must combine structural change with individual-level support. Practical measures, such as reinforcing healthy sleep routines, designing structured light exposure protocols, and encouraging regular physical activity, offer feasible ways to buffer circadian stress and mitigate long-term health risks. Melatonin can also play a role in specific scenarios. At the organizational level, employers can implement a forward rotation system, restrict continuous night shifts, and provide health plans and consulting services. These measures can not only improve employee health, but also reduce errors and accident rates at work. At the policy level, it is necessary to establish a regulatory framework that classifies shift work as an occupational hazard, while restricting overtime work, mandating rest time, and expanding the coverage of preventive medical services. The differences between high and low-income countries internationally also require the protection of workers in different labor markets through coordinated guidelines and cooperative actions. In the future, research needs to be deepened from multiple perspectives, and more long-term cohort studies should be conducted in low - and middle-income countries to clarify the global disease burden. Mechanism research needs to better integrate molecular, physiological, and behavioral data to locate intervention targets. The development of wearable technology and digital health provides the possibility for real-time monitoring of rhythm markers and personalized interventions. In addition, research on interventions at the organizational and policy levels also needs to evaluate both health outcomes and economic feasibility - only by demonstrating that protecting rhythmic health has both productivity and well-being benefits can the labor market actively undergo change.

References

[1] Scheer, F. A., Hilton, M. F., Mantzoros, C. S., et al. (2009). Adverse metabolic and cardiovascular consequences of circadian misalignment. Proceedings of the National Academy of Sciences, 106(11), 4453-4458.

[2] Costa, G. (2010). Shift work and health: current problems and preventive actions. Safety and health at Work, 1(2), 112-123.

[3] Vyas, M. V., Garg, A. X., Iansavichus, A. V., et al. (2012). Shift work and vascular events: Systematic review and meta-analysis. BMJ, 345, e4800.

DOI: 10.54254/2753-8818/2026.AU27991

[4] Spiegel, K., Tasali, E., Penev, P., et al. (2004). Brief communication: sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. Annals of internal medicine, 141(11), 846-850.
[5] Erren, T. C., Morfeld, P., Groß, J. V., et al. (2019). IARC 2019: "Night shift work" is probably carcinogenic: What about disturbed chronobiology in all walks of life?. Journal of Occupational Medicine and Toxicology, 14(1), 29.
[6] Boivin, D. B., Boudreau, P., & Kosmadopoulos, A. (2022). Disturbance of the circadian system in shift work and its health impact. Journal of biological rhythms, 37(1), 3-28.
[7] Torquati, L., Mielke, G. I., Brown, W. J., et al. (2018). Shift work and the risk of cardiovascular disease. A systematic review and meta-analysis including dose–response relationship. Scandinavian journal of work, environment & health, 44(3), 229-238.
[8] Yang, X., Di, W., Zeng, Y., et al. (2021). Association between shift work and risk of metabolic syndrome: A systematic review and meta-analysis. Nutrition, Metabolism and Cardiovascular Diseases, 31(10), 2792-2799
[9] Pan, A., Schernhammer, E. S., Sun, Q., et al. (2011). Rotating night shift work and risk of type 2 diabetes: two prospective cohort studies in women. PLoS medicine, 8(12), e1001141.
[10] Travis, R. C., Balkwill, A., Fensom, G. K., Appleby, P. N., Reeves, G. K., Wang, X. S., ... & Beral, V. (2016). Night shift work and breast cancer incidence: three prospective studies and meta-analysis of published studies. JNCI: Journal of the National Cancer Institute, 108(12), djw169.
[11] Lee, A., Myung, S. K., Cho, J. J., et al. (2017). Night shift work and risk of depression: meta-analysis of observational studies. Journal of Korean medical science, 32(7), 1091.
[12] Turek, F. W., Joshu, C., Kohsaka, A., et al. (2005). Obesity and metabolic syndrome in circadian Clock mutant mice. Science, 308(5724), 1043-1045.
[13] Xie, L., Kang, H., Xu, Q., et al. (2013). Sleep drives metabolite clearance from the adult brain. science, 342(6156), 373-377.
[14] Moon, J., Ikeda-Araki, A., & Mun, Y. (2024). Night shift work and female breast cancer: a two-stage dose-response meta-analysis for the correct risk definition. BMC Public Health, 24(1), 2065.