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SLEEP DISTURBANCES AND OPTIMIZATION IN NIGHT-SHIFT WORKERS - A LITERATURE REVIEW

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ABSTRACT

Sleep is a fundamental biological process essential for physical recovery, cognitive performance, metabolic regulation, hormonal balance, and mental health. Night and rotating shift workers constitute a high-risk population for sleep disturbances due to chronic circadian misalignment, irregular sleep-wake schedules, and elevated occupational stress. This narrative review synthesizes current evidence on sleep physiology, specific sleep disorders, and the acute and chronic health consequences of shift work, integrating insights from occupational health and sports recovery research. Shift work is consistently associated with altered sleep architecture, reduced slow-wave and REM sleep, and conditions such as Shift Work Sleep Disorder and social jet lag, leading to impaired vigilance, increased error risk, and mood dysregulation. Long-term exposure to night work is linked to adverse cardiometabolic outcomes, including hypertension, obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease, as well as disrupted eating behaviors and unfavorable meal timing. Emerging evidence also indicates neurological consequences such as accelerated brain aging, cognitive decline, and increased vulnerability to neurodegenerative and seizure disorders. Additionally, hormonal dysregulation involving melatonin, cortisol, sex hormones, and circadian clock gene expression may contribute to reproductive disturbances, immune dysfunction, and increased cancer risk. The review further discusses organizational- and individual-level interventions, including optimized shift scheduling, strategic light exposure, napping, sleep hygiene, meal timing, physical activity, and cognitive-behavioral strategies, highlighting practical approaches to mitigate sleep disturbances and improve health and performance among night-shift workers.

KEYWORDS

Shift Work, Circadian Misalignment, Sleep Disturbances, Night Shift Workers, Cardiometabolic Health, Sleep Optimization

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1. Introduction

Sleep is an important biological process that supports both physical and cognitive health. Adequate sleep plays a critical role in muscle repair, immune function, metabolic regulation, memory consolidation, attention, emotional regulation, and decision-making. There is a growing movement to view sleep not simply as passive rest, but as a dynamic, regenerative process essential for proper functioning [1] [2, 3]. The discussion about sleep has shifted from focusing solely on quantity to emphasising the importance of sleep quality. Researchers and clinicians increasingly stress that a certain number of hours of sleep does not necessarily guarantee restful or optimal recovery [4, 5, 6]. Sleep quality refers to several factors that collectively determine how restorative and beneficial a night's sleep is for the body and mind. These factors include environmental conditions such as the type of mattress, bedroom temperature, humidity, and noise levels, as well as pre-bedtime habits that affect how easily one falls asleep and the depth of sleep (caffeine intake, exercise, meals, etc.). An important component of sleep quality is progression through the different sleep phases, both REM (Rapid Eye Movement) and non-REM, which play distinct and significant roles in neuronal and physical recovery. Despite its crucial role in health and performance, repeatedly demonstrated in studies, sleep is often undervalued in modern society. This is due to the growing culture of constant grind and an accelerated pace of life. Work, training, commuting, screens, social commitments, lifestyle pressures, and a life of constant rush and stress often lead to reduced sleep duration and quality [7,8]. Insufficient sleep impairs neuromuscular coordination, reduces aerobic endurance, speed, muscle strength, and skill control, and increases the perception of effort during exercise, resulting in decreased overall athletic performance [9]. Furthermore, sleep deprivation impairs cognitive functions such as attention, working memory, and decision-making, which are critical for complex motor skills and strategic tasks in sport [10]. Beyond performance degradation, chronic sleep deprivation increases the risk of injury, delays recovery processes, and contributes to mood disorders such as anxiety and depression [1]. Two high-risk groups are particularly vulnerable to sleep deprivation. The first group comprises recreational and professional athletes whose bodies are exposed to repeated metabolic, mechanical, and neuromuscular stress, increasing their recovery needs [11]. The second group consists of night shift workers, such as healthcare professionals, who face chronic circadian disruption, irregular and often insufficient sleep, and increased exposure to physical and mental stressors [12]. Reviews often focus on a single population (e.g. athletic performance) or one setting (sleep health in the workplace), with less attention given to the fact that these groups sometimes overlap, as people who work shifts may also be active, run marathons, or participate in Ironman and other sports. The aim of this review is to bridge the literature on athletes and shift workers by identifying determinants of good sleep, summarising reliable biomarkers of recovery, and outlining interventions that can be used in both sport and occupational settings.

2. Methods

This literature review was based on the results of PubMed, Google Scholar and Web of Science. We included studies conducted between January 2020 and June 2025. The search terms combined sleep-related keywords with athletes and night shift workers specific terms. We used meta-analysis, observational cohorts, randomised controlled trials, clinical guidelines, expert consensus statements and case reports. We excluded non-human and in vitro models studies and articles that were not published in English.

3. Sleep physiology and adequate sleep need

Sleep is a fundamental component of human homeostasis, organised into cycles of non-rapid eye movement (NREM) and rapid eye movement (REM) that repeat every 90–110 minutes. NREM sleep is divided into three stages. Stage N1 is the initial, very light sleep stage, during which muscle tone decreases, eye movements slow, and brief awakenings are common. Stage N2 represents a more stable form of sleep, characterised by sleep spindles and K-complexes, which help maintain sleep continuity and are involved in memory processing; this stage accounts for the largest proportion of total sleep time. Stage N3, also called slow-wave sleep (SWS), is the deepest stage, marked by high-amplitude delta waves in the EEG and closely associated with physical restoration and endocrine regulation. REM sleep, by contrast, is defined by desynchronised EEG, muscle atonia, rapid eye movements, and vivid dreaming, and becomes longer as the night progresses [13].

SWS is a crucial sleep phase for physical recovery and endocrine balance. An experiment conducted by Van Cauter and colleagues showed that pharmacologically enhancing SWS with gamma-hydroxybutyrate doubled nocturnal growth hormone (GH) secretion in healthy men [14]. More recent evidence has confirmed that boosting SWS strengthens testosterone and GH release and shifts autonomic nervous system (ANS) balance towards recovery, eliminating sympathetic dominance [15]. SWS also supports the brain's cleaning system, the glymphatic system, which clears waste products and helps protect against neurodegeneration [16]. In addition, experiments in which SWS was reduced showed impaired glucose metabolism and lower insulin sensitivity, emphasising its importance not only for hormones but also for metabolic health [17].

REM sleep supports neural plasticity, memory, and emotion. A human imaging study shows that an uninterrupted REM phase calms the amygdala's response to earlier negative events, supporting emotional recovery [18]. Conversely, fragmented or interrupted REM disrupts this regulation [19]. When memories are reactivated during REM sleep, they are consolidated more strongly, resulting in better performance after waking [20]. REM is also linked to creativity: people awakened from REM generate more original ideas than from NREM or wake states [21]. Long-term studies further show that reduced REM sleep is associated with a higher risk of depression, highlighting its importance for mental health [22]. The circadian rhythm is organised through the suprachiasmatic nucleus (SCN), the brain's clock that regulates daily rhythms with light–dark cycles [23]. At night, the SCN signals the pineal gland to release melatonin, which strengthens and maintains the body's day–night cycle [24]. Daily gene cycles in organs, called peripheral clocks, regulate metabolism and repair. They depend on signals from the SCN but are also regulated by feeding and hormones, and can be disrupted by circadian rhythm dysregulation [25]. These findings highlight that uninterrupted deep sleep and a stable circadian rhythm are important for tissue repair, metabolism, and GH/testosterone regulation. This is particularly important for athletes and night-shift workers, whose overall regeneration demands are high.

Physical exertion strongly interacts with sleep homeostasis and circadian rhythm, increasing sleep pressure and sleep needs. After intense training or prolonged activity, the amount of slow-wave activity (SWA) in the subsequent sleep period usually increases. SWA refers to the high-amplitude, low-frequency brain waves observed on EEG during the deep N3 sleep period, and its increase indicates a greater need for recovery [26].

Studies on skeletal muscle and circadian biology show that exercise can influence sleep regulation. It not only promotes deeper sleep but also affects the body's timing signals – daily regulators such as hormone release and body temperature that help set sleep-wake rhythms [27]. However, the effect is modulated by exercise parameters: timing, intensity, duration, and individual fitness level [28]. For example, physically demanding, intensive workouts in the evening can make it harder to fall asleep or reduce the amount or quality of REM sleep, while moderate exercise during the day is more likely to improve sleep quality.

In high-demand populations such as athletes or healthcare workers, cumulative physical and mental load may increase baseline sleep need. The "extra sleep debt" that accumulates from heavy training or night-shift duties must be compensated by deeper or longer sleep to allow full recovery. If the available sleep window is too short, this mismatch can cause chronic under-recovery, fatigue, and reduced performance [29,30].

In general, the amount of sleep recommended for adults by consensus guidelines is approximately 7–9 hours per night to maintain health and lower the risk of chronic disease [31]. In athletes, however, this amount often appears insufficient. Reviews and expert consensus emphasise that extended sleep, closer to 9–10 hours, is associated with faster reaction times, improved accuracy, and reduced injury risk [32]. A systematic review also confirms that performance outcomes, especially in sports requiring speed, skill, and tactical precision, are highly sensitive to sleep duration, with long-term sleep extension showing the greatest benefits [33]. Furthermore, Nédélec and colleagues pointed out that elite athletes, particularly soccer players in that study, often require more sleep than the general guideline, and that individual strategies such as scheduled naps or earlier bedtimes may be necessary to meet their recovery needs [34].

In contrast, healthcare workers, particularly those on rotating night shifts, often fail to achieve even the lower limit of 7 hours due to schedule demands and circadian disruption. In 2019, Ganesan and colleagues showed that chronic sleep restriction in this population increases fatigue, impairs alertness, and raises the risk of medical errors, with long-term consequences for both worker health and patient safety [35]. These findings illustrate that while 7–9 hours may suffice for the general population, athletes typically need more sleep to optimise recovery, and shift workers frequently obtain less than required, highlighting the need for individual interventions across different groups.

There is a growing body of observational and interventional evidence linking sleep duration, sleep timing, quality, and performance outcomes. In athletes, the Cunha et al. article reviews intervention studies in which extending nighttime sleep or strategic napping led to improvements in physical and cognitive metrics such as sprint time and reaction speed [36]. Gwyther and colleagues reviewed many studies and found that better sleep habits, supportive strategies, and longer sleep can significantly improve performance, mood, and cognition in different groups, including athletes, students, and clinical populations [37]. In summary, the optimal amount and quality of sleep are not the same for everyone. People with higher demands, such as athletes or shift workers, usually require more sleep than the general population to remain healthy and perform well.

4. Specific Sleep Disturbances in shift workers

Shift work, defined as employment outside conventional daytime hours, has become an integral yet physiologically costly component of modern economies. Epidemiological data estimate that over 20% of workers in developed countries are employed in shift work environments, primarily in healthcare, emergency response, manufacturing, transport, and security sectors [38]. These workers constitute a distinct risk group for sleep disturbances that extend beyond reduced duration. Their sleep architecture, timing, and quality are persistently compromised by circadian misalignment, irregular schedules, and high occupational demands. Repeated exposure to irregular or nocturnal schedules results in chronic circadian misalignment, a persistent desynchronisation between the body's internal clock and the external environment. This misalignment disrupts not only sleep timing and continuity but also the underlying architecture and restorative quality of sleep.

The most specific condition associated with shift work is Shift Work Sleep Disorder (SWSD), defined by chronic insomnia or excessive sleepiness directly linked to recurrent work schedules that overlap with usual sleep times. Epidemiological data indicate that up to 30% of night or rotating shift workers meet diagnostic criteria for SWSD, with higher prevalence among healthcare, industrial, and transportation employees [39]. Typical symptoms include difficulty initiating sleep, frequent awakenings, early morning terminal insomnia, non-restorative daytime rest, and overwhelming fatigue or microsleeps during work, particularly near the circadian nadir. Cognitive performance deteriorates in domains such as reaction time, vigilance, and decision-making, and is associated with fatigue-related occupational accidents. Increasing evidence suggests that long-term circadian misalignment also leads to depressive-like behaviours, dysregulation of melatonin and cortisol secretion, autonomic imbalance, and increased oxidative and inflammatory activity [40].

Beyond SWSD, many shift workers develop secondary insomnia: persistent difficulty sleeping that is not solely due to circadian misalignment but is compounded by behavioural and psychophysiological factors. This insomnia persists even during rest days and is not fully explained by work schedules alone. Studies report that insomnia symptoms affect 30% to 45% of rotating shift workers, often coexisting with mood disturbances and maladaptive coping strategies such as alcohol use or dependence on sedatives [39].

Another disorder observed in shift workers is social jet lag, a misalignment between one's internal clock and externally imposed obligations such as work hours or social engagements. In night or rotating shift workers, this misalignment often exceeds four hours and persists chronically, resembling a state of continuous jet lag. Social jet lag predicts shorter sleep duration, reduced subjective sleep quality, increased daytime fatigue, and greater metabolic instability [39, 41]. In a large field study of refinery employees working 12-hour rotating shifts, poor sleep quality was found to be strongly correlated with anxiety, depression, gastrointestinal symptoms, and a higher risk of fatigue-related workplace incidents. The most pronounced deficits have been documented during shift transitions, when sleep duration often falls below five hours, and under night-shift schedules that generate nearly seven hours of social jet lag [42]. Evidence from occupational studies highlights that not only the number of night shifts but also the type of rotation scheme plays a critical role in sleep health. A cross-sectional comparison between workers on regular forward-rotating schedules and those on irregular on-call shifts showed that unpredictable schedules were associated with markedly higher odds (13–27 times higher) of excessive daytime sleepiness, despite similar rates of poor sleep quality across groups [43].

5. Acute and chronic health consequences of shift work

5.1 Acute consequences

Among shift workers, acute and chronic consequences of this lifestyle can be distinguished. Sleep duration rarely exceeds 5–6 hours per 24-hour period, and its architecture is markedly altered, characterised by shortened slow-wave and rapid eye movement sleep, increased light sleep, and frequent awakenings. The consequences of this fragmented rest extend beyond transient tiredness, affecting psychomotor function, vigilance, emotional regulation, and ultimately workplace performance [44]. Sleep restriction and circadian misalignment impair cognitive domains crucial for safety-critical professions. In a multicentre US trial across paediatric intensive care units, researchers compared 24–28-hour traditional physician shifts with schedules capped at 16 hours. Residents working extended shifts exhibited significantly more attentional lapses, slower reaction times, and increased subjective sleepiness, with deficits accumulating over successive weeks. Shorter shifts reduced error risk by about 50% [45]. Similar results have been reported among medical interns and nurses. Massar et al. found that traditional 24-hour call systems produced greater sleep irregularity, impaired vigilance, and worse mood than a night-float model with 12-hour shifts [46]. Similarly, in a survey of U.S. hospital nurses, rotating shifts were perceived as more detrimental than fixed night shifts: most participants slept fewer than six hours per day, relied heavily on caffeine, and frequently experienced mood instability, family strain, and even fell asleep while driving home [47]. In another study, a single night shift raised 24-hour blood pressure, converted a healthy dipping pattern to nondipping, and flattened the morning surge – changes that tracked circadian phase more than minutes slept [48]. In a study of 352 firefighters, comparison before and after a night shift was followed by significant declines in composite, verbal and visual memory, complex attention, psychomotor and motor speed, and the neurocognitive index, with no improvement in any domain [49].

5.2 Cardiometabolic and eating behaviour consequences

Night and rotating shift work is increasingly recognised as a significant and dose-dependent risk factor for adverse cardiometabolic outcomes. A comprehensive review reported combined risks of metabolic syndrome, obesity, diabetes, hypertension, cardiovascular events, and cardiovascular mortality among night and rotating shift workers [50]. Other studies have reached similar conclusions, including an approximately 30% higher incidence of hypertension when night periods are included, and significant average systolic blood pressure elevations of 2–3 mmHg in permanent night workers [51].

Controlled protocols examining how shift work behaviours, such as wakefulness and eating during the biological night, affect health demonstrate that misalignment itself reduces insulin sensitivity, worsens postprandial glycaemia, elevates 24-hour blood pressure, and shifts autonomic balance towards sympathetic predominance. These effects are measurable even when sleep duration is held constant. Furthermore, circadian rhythm disruption and shift-related eating at inappropriate times particularly impair muscle glucose uptake and β-cell responsiveness [52; 53]. Another study shows that even short-term circadian misalignment and reduced sleep can impair glucose tolerance and raise daytime blood pressure, while reducing parasympathetic activity

– changes consistent with early signs of cardiometabolic risk. Over longer exposures, night and rotating schedules are linked with higher odds of obesity, metabolic syndrome, type 2 diabetes, hypertension, and ischaemic heart disease [54]. Vascular biology is also affected by night shifts. Under short-term misalignment, plasma protein analysis reveals an imbalance in coagulation and a shift towards hypercoagulability, marked by increased tissue factor activity and suppression of its inhibitor. These findings suggest a long-term cardiovascular risk through endothelial dysfunction and prothrombotic pathways [55].

Further evidence indicates that night shift work is associated with dyslipidaemia, characterised by reduced HDL-cholesterol. Notably, the study also reported prolonged QTc, a finding consistent with increased cardiac excitability and epidemiological links to atrial fibrillation among rotating and permanent night workers [56]. In one prospective UK study, night-shift exposure predicted new-onset atrial fibrillation and coronary heart disease, independent of genetic predisposition. The highest risk was observed among those with over 10 years of night work or those working an average of 3 to 8 night shifts per month [57]. Cohort studies among Scandinavian healthcare workers report graded increases in incidents of ischaemic heart disease with permanent night shifts and high annual night-shift counts, as well as higher incidences of diabetes in night workers [58; 59]. Consistent with these findings, a meta-analysis including only cohort studies found approximately a 30% higher incidence of type 2 diabetes among night workers, with greater risk observed in women, obese workers, and those with longer exposure to night shifts [60]. Beyond hypertension and diabetes, shift work was also associated with a higher risk of aortic aneurysm. An unhealthy lifestyle appeared to amplify this association, with smoking identified as a key contributor. However, overall lifestyle factors explained only a small portion, around 2% [61].

In a study of over 100,000 workers, shift schedules were linked to an approximately one-third higher risk of metabolic syndrome compared to day workers, with stronger associations observed in rotating systems and among women [62]. Similarly, other researchers reported that healthcare shift workers had more than double the odds of developing metabolic syndrome compared to day workers [63; 53]. Cheng et al. further demonstrated that night shift workers were associated not only with new onset of metabolic syndrome but also with central obesity, and a higher annual number of night shifts predicted new-onset hypertension [64]. Evidence from industrial populations mirrored these results: long-term night workers had higher blood pressure, triglycerides, waist circumference, and BMI. The association between shift work and metabolic syndrome remained significant after adjustment [65]. Additional evidence comes from a large study of Dutch nurses, emphasising the predisposition to obesity in postmenopausal women. Women working four or more nights per month, or four or more consecutive nights, were more prone to weight gain, and this effect was more significant among those with normal weight at baseline [66].

Eating behaviour in shift workers is not necessarily characterised by higher caloric intake, but rather by disruption of meal timing and portion sizes. Typical patterns include prolonged eating windows, shorter fasting periods, irregular meal timing, and greater reliance on high-fat, refined-carbohydrate snacks with fewer fruits and vegetables [50]. Interestingly, controlled trials have shown that identical meals consumed at night trigger higher glucose and insulin responses compared with identical daytime intake [67]. Extending this evidence, researchers have proposed a definition of circadian syndrome, requiring at least four of seven components: central obesity (waist ≥88 cm in women or ≥102 cm in men), elevated fasting glucose (≥100 mg/dL or medication), high triglycerides (≥150 mg/dL or medication), low HDL-C (<40 mg/dL in men or <50 mg/dL in women or medication), elevated blood pressure (≥130/85 mmHg or antihypertensive therapy), short sleep (<6 h/day), and depressive symptoms. In a group of 10,486 adults, 41.3% met the criteria for circadian syndrome. An unfavourable mid-eating time, defined as a later midpoint between breakfast and dinner, as well as meal skipping and shift work, were associated with a higher probability of circadian syndrome. Notably, meal skipping showed the strongest associations with central obesity, elevated glucose, low HDL-C, depressive symptoms, and short sleep [68]. Supporting these findings, another study indicates that shift-work-like lighting and nocturnal intake precipitate weight gain and metabolic dysfunction even in the absence of excess caloric intake, likely due to impaired lipid metabolism and disruption of thermogenic rhythms [69].

5.3 Neurological consequences

Emerging evidence shows that chronic exposure to night and rotating shift schedules causes measurable and cumulative effects on brain function, structure, and neurodegenerative risk. These changes go far beyond temporary fatigue or lapses in focus, resulting in real, lasting effects on brain function and even the ageing process. They include cognitive decline, accelerated brain ageing observed in electrical activity, and a higher risk of neurological diseases.

In one of the first EEG-based studies to assess how shift work affects brain ageing, researchers compared 45 female nurses working rotating day–night schedules (two days, then two nights) with 44 nurses working only daytime shifts, using polysomnography and machine-learning–derived Brain Age Index (BAI) scores. Night-shift nurses had significantly older brain age, approximately two years older. They also slept less overall (about 300 minutes versus 374 minutes). Quantitative EEG showed reduced slow wave (delta and theta) activity and lower sigma power, along with weaker deep sleep (N3) activity. This pattern suggests their brains were less synchronised and not receiving the same restorative benefits as normal sleep. Among shift workers, more frequent awakenings, more time spent in light sleep (N1), and longer shift-work duration independently predicted accelerated Brain Age Index (BAI) in EEG. In contrast, more deep sleep (N3) was protective and showed a dose- and age-dependent neurological burden of chronic night work [70].

Neuroimaging studies provide further evidence consistent with these physiological changes. Female nurses working shifts not only struggled more with sleep disturbances and depressive symptoms, but also showed reduced gray matter volumes in the postcentral gyri, paracentral lobule and left superior temporal gyrus. Importantly, gray matter loss in these regions appeared to form the missing link between poor sleep and mood disturbances, implying that chronic circadian disruption might literally reshape the brain in ways that make emotional regulation more difficult [71].

In one study of middle-aged miners in China, those working night shifts had poorer sleep quality, shorter sleep duration and significantly worse performance on tests of verbal and visuospatial learning (HVLT-R, BVMT-R) than day workers. Interestingly, these effects appeared mainly in miners with lower education levels, suggesting that cognitive reserve, the brain's built-in resilience from lifelong learning and mental activity, might buffer some of the damage [72].

On a broader scale, long-term disruption of the body's circadian rhythm may make the brain more vulnerable to neurological diseases. In a large UK study tracking participants for about 13 years, Dong et al. observed that usual or permanent night-shift work predicted a 29% higher risk of developing epilepsy, independent of chronotype, snoring or other sleep habits. Similarly, poor sleep quality, including daytime sleepiness, insomnia and extremely short or long sleep, showed a graded association with epilepsy risk [73].

A systematic review of seven human studies found inconsistent but suggestive evidence that working night shifts may increase dementia risk, with higher incidence in permanent night workers and with longer exposure durations. Importantly, carriers of the APOE ε4 gene variant with prolonged night-shift histories faced even greater vulnerability when they also had long histories of night-shift work. This suggests a potential gene-environment interaction, where disrupted circadian rhythms may accelerate neurodegenerative processes in those who are genetically predisposed [74].

5.4 Psychological and mental health consequences

Night and rotating shift work place a significant psychological burden on well-being, driven by chronic sleep deprivation, circadian misalignment, and high occupational stress. Multiple cohort and occupational studies consistently link shift work to increased rates of depression, anxiety, burnout, and psychological distress.

Large-scale studies confirm these patterns. In a UK cohort of over 247,000 adults followed for nearly 13 years, night-shift workers had significantly higher risks of developing depression, with risk increasing in line with night-shift frequency. Importantly, this risk was independent of genetic predisposition [75]. These findings are consistent with another UK cohort of over 175,000 adults followed for nine years, where night-shift workers had a higher risk of developing depression and anxiety. There was also a clear association showing that the incidence of depression increased proportionally with the frequency of night-shift exposure. Lifestyle factors such as poor sleep, higher body weight, smoking, and reduced activity accounted for only about one-third of the increase, leaving much of the burden directly attributable to the disruption of living out of sync with natural rhythms [76].

Supporting evidence shows that depressive symptoms are particularly elevated in women working night shifts, especially those under 60 and those who were highly committed to their jobs [77].

In a multicentre sample of 9,181 nurses, researchers found that shift work was most strongly related to both depression and anxiety, primarily through overtime, psychological stress associated with night duties and poor sleep quality before and after shifts. Once stress and fatigue were taken into account, the ability to recover and the overall workload appeared to play a greater role in mental health outcomes than the specific rotation pattern [78]. Similarly, a national Chinese survey of nurses showed that 58% met criteria for shift work disorder (SWD), 65% reported burnout and 58% screened positive for psychological distress. Burnout was the key link connecting shift work disorder to mental distress, emphasising that chronic stress and emotional fatigue are the main drivers of psychological decline among night workers [79]. Consistent results were reported by Booker et al., who observed that nurses at high risk of SWD scored significantly higher for depression and anxiety than their low-risk peers. SWD explained almost 20% of the variance in depression and half of the variance in anxiety, linking circadian disruption directly to mental health burden and work absenteeism [80].

Similar patterns appear well beyond nursing. Among psychiatric medical staff, they found that those working night shifts reported significantly worse physical and mental health than day staff, with burnout emerging as the single strongest predictor of diminished well-being [81]. Similarly, a study among Mexican surgeons found that burnout affected 40% of respondents and was most prevalent among those working night shifts, under 40 years old, or with less than 10 years of professional experience. This demonstrates that the youngest, probably most driven yet inexperienced clinicians exposed to frequent night duties are most vulnerable [82].

A national Korean survey of over 56,000 workers found that on-call and night-shift staff had markedly higher odds of insomnia, depression, and anxiety, especially when combined with workplace violence or work–life imbalance [83]. On a neurobiological level, disruption of circadian rhythms, whether from night work, artificial light exposure, or irregular sleep schedules, has been linked to nearly every major psychiatric disorder. Walker et al. reviewed converging evidence linking circadian misalignment to major depressive disorder, anxiety, bipolar disorder, and schizophrenia. Common mechanisms include altered melatonin and cortisol rhythms, disrupted clock gene expression (PER, CRY, CLOCK) and desynchronisation of sleep–wake cycles. In depression, night-shift workers show an approximately 40% higher risk, while in bipolar disorder, even small shifts in circadian phase can change mood polarity: advances push towards mania, delays towards depression. Schizophrenia also appears sensitive to circadian disruption. Irregular sleep and altered melatonin rhythms are linked to more severe symptoms and slower recovery [84].

5.5 Hormonal consequences

Night-shift work, associated with sleep and circadian disruption, may contribute to a disturbance of hormonal rhythms. Moreover, chronic sleep deprivation leads to increased stress in the body, which in turn results in a decreased immunity.

The authors of many cohort studies and studies on shift work have consistently linked shift work to hormonal dysregulation, such as sex hormone disruption (PCOS, menstrual dysregulation), thyroid axis dysregulation, and immune deficiency (which may consequently be associated with an increased risk of cancer).

Yu-Xuan Peng and Wen-Pei Chang conducted a study among 213 female rotating-shift nurses between the ages of 20 and 45 [85]. The aim of the study was to investigate factors influencing the sleep quality and connect them to menstrual regularity. The researchers found that female rotating-shift nurses who reported higher perceived stress or worked night shifts, had significantly higher odds of poor sleep quality and were more likely to have irregular menstrual cycles.

The authors of many other studies agreed that good sleep quality is vital to maintaining a regular menstrual cycle.

Kennedy et al. conducted a study among 579 women of reproductive age in which he observed the occurrence of factors that affect the regularity of periods and lead to heavier menstrual bleeding [86]. These factors included short sleep duration, poor sleep quality, and stress. Researchers Maher et al. agreed with this thesis, additionally finding poor sleep quality to be an independent predictor of late or missed periods [87]. Furthermore, Attia et al. have highlighted the fact that in the long term, irregular menstrual cycles can affect mental and reproductive health [88].

In another multicenter questionnaire-based survey, performed by Wang et al., authors examined whether disruption of circadian rhythms (for example due to night-shift work) can be associated with polycystic ovarian syndrome (PCOS) [89]. The study included a multicentre questionnaire of women (436 PCOS cases and 715 controls) to assess night-shift work exposure, and experimental in vivo (PCOS-model rats) and ex vivo (human ovarian GCs) investigations. Researchers have observed that night-shift work and exposure to UV light during the night hours affects the hypothalamic suprachiasmatic nucleus (SCN) causing hypothalamic–pituitary–

adrenal (HPA) axis disruption. The disturbance of this axis has known links to low-grade inflammation. The ongoing low-grade systemic inflammatory process induces changes in chromatin accessibility and, consequently, gene expression in ovarian granulosa cells (GC), including clock-gene networks and metabolic pathways, which can be associated with PCOS.

Working night shifts leads to circadian misalignment - due to night-time exposure to external light, the internal mechanism of the circadian rhythm is dysregulated. Joshi and Sundar in their narrative review observe the influence of this misalignment on transcription of genes involved in circadian rhythms, sleep

homeostasis, oxidative stress, and metabolism, with particular relevance for lung tissue [90]. The authors emphasize the correlation between sleep deprivation and upregulated transcription of genes involved in tumorigenesis, chronic inflammation, and cardiovascular disease, but downregulated transcription of genes involved in immune function. As a result, these mechanisms promote a pro-inflammatory state in the lungs and increase the risk or worsening of chronic lung disease.

As mentioned above, dysregulation of the circadian rhythm by shift work affects gene transcription. This applies primarily to the so-called circadian genes or clock genes, whose protein products are essential for the generation and reg-ulation of circadian rhythms. Ritonja et al. in their research associate night shift work with altered DNA methylation (epigenetic changes) in core circadian clock genes, specifically CSNK1E, NR1D1, and ARNTL [91]. These genes have known links to cancer biology. Because DNA methylation typically influences gene expression, these epigenetic modifications could disrupt normal circadian regulation, potentially contributing to oncogenic processes (e.g., by affecting proliferation, DNA repair, cell cycle regulation).

6. System- and Individual-Level Interventions

Night-shift work disrupts the natural circadian rhythm, which results in sleep disturbances, reduced alertness and increased susceptibility to both physical and mental health problems. Minimizing the above-mentioned health consequences requires a comprehensive approach at the organizational- (institutional scheduling strategies, workplace environment adjustments) and individual level (behavioral modifications, sleep hygiene practices, and targeted therapies). In this section we will focus on discussing interventions that should be undertaken to reduce the negative impact of shift work and highlight behaviors that can improve sleep quality, maintain circadian balance and promote overall well-being among night-shift workers.

At the organizational level, careful rota design is a key strategy. The authors agree that forward shift rotation (morning → afternoon → night) is more consistent with circadian trends than backward rotation, as it reduces sleep disruption and daytime sleepiness [46, 92]. Authors also emphasise the role of fixed night shifts. These are shifts, when an employee is assigned exclusively to night shifts for a specific period, rather than rotating between morning, afternoon, and night shifts. They allow shift workers to stabilize their sleep-wake cycles and achieve more consistent rest. To get more sleep during rest periods and experience less sleepiness during shifts, workers maximum shift length should be limited up to 16 hours per day. Shorter shift durations and avoidance of excessive consecutive night shifts are associated with improved alertness, fewer errors, and better overall well-being [45, 92]. Another important intervention is implementing protected nap periods and scheduled rest breaks, particularly in safety-sensitive industries such as healthcare and aviation. These breaks in the above-mentioned professions have shown measurable improvements in alertness and performance during night shifts [93].

Another critical organizational strategy is the implementation of fatigue risk monitoring and management systems. They benefit from integration with light-based interventions, such as strategically timed exposure to bright light during night shifts to promote alertness, and circadian reentrainment measures, including melatonin supplementation, which can help realign circadian rhythms and facilitate restorative sleep during off-hours. These tools should proactively identify fatigue-related risks, monitor workload, and ultimately reduce accidents and improve employee health [94].

At an individual level, employees themselves can implement appropriate behavioral strategies and coordinate their lifestyles to mitigate the negative impact of shift work to the extent possible. Regular physical activity and a balanced diet, with strategic meal timing, support circadian balance, reduce metabolic imbalances, and promote overall well-being [95]. Caffeine is a well-known psychostimulant reputed to alleviate the harmful effects of sleep deprivation. Its appropriate dosing is a documented tool for improving alertness during night shifts [96]. However, caffeine use requires precise timing and moderation - workers should stop caffeine intake at least 8–9 hours before intended sleep to limit impairment of sleep depth and duration. The authors suggest that restricting eating to a specific time window (time-restricted eating, TRE), synchronized with activity, can help restore the biological clock and reduce the risk of obesity. This involves avoiding snacking immediately before sleep or limiting caloric intake during biological night hours. It further mitigates metabolic and gastrointestinal stress [95]. To improve individual well-being and minimize the negative psychological effects of shift workers (i.e. depression, anxiety, and burnout), the authors recommend the use of cognitive-behavioral techniques or training programs in mental resilience and stress management [84].

7. Limitations

Several important limitations must be acknowledged in this literature review. The main limitation is considerable methodological heterogeneity in the underlying literature. "Shift work" is variably defined, exposure is measured with simplified metrics (ever vs never, years in shift work, nights per month) and sleep is often assessed with different questionnaires and cut-offs rather than standardised, objective measures. Sleep and health outcomes cover a wide spectrum, from subjective sleep complaints to cardiometabolic, neurological, and psychological endpoints (e.g. CVD, diabetes, dementia), assessed with diverse tools and follow-up durations. This heterogeneity complicates direct comparison between studies and precludes robust dose–response modelling. Much of the data come from cross-sectional or retrospective cohorts, restricting causal inference and making it difficult to disentangle the effects of circadian misalignment from co-occurring factors such as stress, physical workload and lifestyle. Secondly, there are relevant gaps and biases in the populations studied. Many cohorts are restricted to specific occupational groups (often nurses or industrial workers), with underrepresentation of men in some sectors and women in cardiometabolic and neurocognitive research. Most data are observational, truly interventional work is limited, typically short-term, underpowered and focused on single factors such as melatonin, light exposure or minor rota changes, rather than comprehensive approaches that reflect real-life complexity.

To address this gap, there is a clear need for well-designed prospective studies and randomised controlled trials based on harmonised definitions of shift schedules and core outcome sets spanning sleep, performance and health. Integrating wearable technologies, heart rate variability and circadian biomarkers into occupational protocols could enable early detection of chronic under-recovery and allow personalisation of countermeasures according to chronotype and vulnerability.

8. Conclusion

Shift work profoundly disrupts sleep architecture, circadian timing and recovery, with effects extending far beyond transient fatigue. Night and rotating schedules reduce total sleep, fragment slow-wave and REM sleep and cause chronic circadian misalignment, leading to a range of acute and chronic consequences: impaired vigilance and psychomotor performance, increased risk of errors and accidents, adverse cardiometabolic effects, neurocognitive changes, hormonal dysregulation and higher rates of mood and anxiety disorders. These risks are dose-dependent and accumulate over years of night-shift exposure.

The evidence reviewed here indicates that protecting sleep and circadian health in night-shift workers cannot rely on generic advice to "sleep more". Effective mitigation requires interventions explicitly grounded in chronobiology: forward-rotating or stabilised schedules, limits on shift length and consecutive nights, strategic bright-light exposure and protected darkness, carefully timed melatonin, protected naps and deliberate timing of exercise and food intake. Psychological tools, including cognitive-behavioural strategies for insomnia and structured stress-management or resilience programmes, are necessary complements to address the mental load accompanying chronic circadian disruption.

Ultimately, meaningful progress will depend on systems-level redesign rather than placing responsibility solely on individual workers. From a public health perspective, ignoring these issues effectively externalises the cost of 24/7 services onto workers' long-term health and safety. Organisations and regulators need to recognise sleep and circadian integrity as core occupational health assets and safety resources, on par with staffing levels or equipment. Implementing fatigue risk management systems, integrating wearable-based monitoring of sleep and recovery and tailoring schedules to chronotype where feasible are practical steps towards aligning work demands with human physiology. This approach has the potential not only to reduce morbidity and burnout among night-shift workers, but also to enhance performance and safety in sectors where errors can have critical consequences.

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