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REVIEW ARTICLE

Emotional Dysregulation in Shift Workers

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Shift work continues to increase in frequency in industrial society and accounts for more than 20% of workers in modern society. Previous studies have reported that shift work is a representative environmental factor that disrupts circadian rhythm and is associated with various physical and mental problems, including sleep problems. In particular, problems with circadian rhythm are closely related to difficulties in emotional regulation that cause mood disorders. In this review, we reviewed previous studies on emotion dysregulation in shift workers and examined past studies on the neuroscience basis for these problems. If neurobiological research yields results on shift workers' vulnerability to emotional and sleep problems, it would be possible to suggest ways to prevent the adverse mental effects of shift work.

Keywords: Shift work; Circadian rhythm; Emotion; Mood; Sleep

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SHIFT WORK AND CIRCADIAN RHYTHM DISRUPTION

In today's society, more than 20% of workers engage in shift work. Shift work is defined by non-standard working hours (e.g., any time other than from 7:00 AM to 6:00 PM) that are often misaligned with natural circadian rhythms [1]. Shift work is necessary for various sectors, including 24-hour healthcare, transportation, and protective services [2]. Due to the heightened demands of modern society, shift work has become more prevalent [3,4]; this prevalence may increase the risks of mental and physical health problems among workers. Indeed, there is evidence that circadian rhythm disruption is associated with various mental and physical diseases, including sleep disorders, gastrointestinal disorders, metabolic disorders, neoplasms, immune diseases, and mood disorders such as depression [5]. In addition to emotional disturbances such as anxiety/depression, shift work-induced circadian rhythm disruption can lead to cognitive abnormalities such as poor concentration/memory [5].

Other adverse effects of shift work include daytime sleepiness, fatigue, decreased work efficiency, and accidents; approximately 25% of shift workers meet the diagnostic criteria for a circadian rhythm disorder [6].

SHIFT WORK AND SLEEP

As previously noted, shift work is a risk factor for various health problems, such as sleep–wake disorders and mood problems (e.g., depressed mood and anxiety) [1]. Shift workers often experience sleep disturbance and circadian disruption [7,8]. Shift work can result in desynchronization between homeostatic sleep pressure and circadian rhythmicity, leading to an increased risk of sleep disturbance [9]. Previous studies have shown that the uncoupling of homeostatic pressure and circadian alert signals increases vulnerability to sleep disturbance among shift workers [10].

Sleep disturbance after a circadian challenge increases the risk of "sleep work disorder" (SWD) and depressive mood in shift workers [11]. Additionally, major depressive disorders are more prevalent among shift workers [12]. Previous studies have revealed that 8.1%–43.0% of shift workers meet the criteria for SWD, which is defined as difficulty sleeping when sleep is appropriate and/or excessive sleepiness during the waking period [6,13]. It has been suggested that sleep disorders among shift workers occur only when shift work affects specific brain regions [11]. However, the mechanisms through which shift work-induced circadian rhythm disruption leads to cognitive and emotional abnormalities via changes in brain activity remain unclear.

CIRCADIAN RHYTHM DISRUPTION AND MOOD DISORDERS

The relationship between sleep disorders and bipolar disorder is well-known, and the risk of bipolar disorder increases with the degree of circadian rhythm fluctuation and sleep deprivation [14]. In addition, a recent meta-analysis showed that shift workers have a 1.33-fold higher risk of depression compared with daytime workers [1].

Circadian rhythm disorders and sleep disorders are associated with depression; chronotherapy, which corrects circadian rhythms through light therapy, sleep deprivation, and adjustment of social rhythms, serves as a major supplemental treatment for depression [15]. The genetic and molecular mechanisms through which circadian rhythm disruptions cause brain dysfunction, including cognitive decline and emotional disorders, have not been fully determined.

EFFECTS OF CIRCADIAN DISRUPTION AND SLEEP DISTURBANCES ON EMOTIONAL DYSREGULATION IN SHIFT WORKERS

Emotional dysregulation, which is associated with sleep disturbance and circadian disruption, constitutes a common feature of mood disorders [16,17]. Healthy volunteers and patients who experience disrupted sleep and circadian rhythms often report emotional dysregulation, including heightened emotional reactivity to negative events and difficulty regulating negative emotions [10,18,19].

Considering that shift workers report sleep disturbance and circadian disruption [7,8], along with vulnerability to mood problems [7,20,21], shift work may be a risk factor for emotional dysregulation. Additionally, the disruption of sleep–wake cycles is associated with negative emotions and delayed recovery from negative events [18,22]. Therefore, the ability to regulate emotions may be undermined by shift work.

The findings in previous studies suggest that emotional regulation can modulate the effects of emotional stress on sleep. When sleep disturbance and impaired emotional regulation coexist, emotional arousal tends to be greater and sleep difficulties are more likely, contributing to the development of depression [23]. Moreover, in combination with sleep disturbance, enhanced sensitivity and reactivity to sleep-related stimuli can exacerbate depressive symptoms [24]. However, few studies have examined emotional dysregulation in shift workers.

Emotional regulation has been correlated with neural activity in subcortical limbic (e.g., amygdala and insula) and prefrontal (e.g., lateral prefrontal cortex [PFC] and medial PFC) regions [25-27]. Shift workers may show neural alterations in regions implicated in emotional reactivity and regulation. Disrupted sleep and circadian rhythms, which are problematic for shift workers, have been associated with neural alterations in such regions [16,17]. For example, sleep disturbance increases neural activation in response to negative stimuli in the amygdala [28], but it is associated with reduced activity in the dorsomedial PFC and dorsal anterior cingulate cortex (ACC) during emotional regulation [29,30]. Additionally, mood problems, regarded as adverse consequences of shift work, appear to involve changes in brain regions implicated in emotional dysregulation [31-33].

At the molecular level, McClung [34] proposed that the relationship between disrupted circadian rhythms and emotional dysregulation was mediated by the effects of the molecular clock on major neurotransmitters implicated in mood regulation, such as serotonin, norepinephrine, and dopamine. The underlying mechanism remains unclear, although projections from the suprachiasmatic nucleus (SCN) to other brain regions implicated in the regulation of monoaminergic neuronal activity, such as the locus coeruleus, may play a role [34,35]. Additionally, the expression of circadian genes outside of the SCN (e.g., in the PFC) may contribute to emotional regulation through the rhythmic activity of monoamine neurotransmitters. Otsuka et al. [36] reported that circadian misalignment disrupted the expression patterns of clock and immediate early genes in the PFC, resulting in depression-like behaviors in rats. Considering that clock genes control the dopaminergic system and that PFC activity is associated with mood regulation, the PFC may mediate the relationship between clock function and mood regulation.

On the basis of the above studies, it is important to identify risk factors for circadian misalignment among shift workers, as well as risk factors for progression from sleep disturbance to depression.

NEURAL CORRELATES OF EMOTIONAL DYSREGULATION AMONG SHIFT WORKERS

Few brain imaging studies of shift workers have been conducted, partially because of the difficulties imposed by the heterogeneity and relatively small size of the study population. Nevertheless, a functional magnetic resonance imaging (fMRI) study revealed greater neural activity in the left dorsolateral PFC among rotating shift workers compared with controls during an emotional Stroop task that involved negative emotional words [37]. In that study, sleep disturbance was more strongly associated with depressive symptoms when left dorsolateral PFC activity was high. The left dorsolateral PFC may also play an important role in sensitivity to emotional information.

Cerebral perfusion was reportedly reduced in the cuneus, fusiform/parahippocampal gyri, and cerebellum of the right hemisphere in shift workers, whereas it was increased in the inferior occipital gyrus of the left hemisphere. Moreover, changes in perfusion were associated with depression and insomnia [38].

Regarding white matter integrity, shift workers exhibited higher fractional anisotropy (FA) values in the bilateral anterior cingulum compared with non-shift workers; increased FA in the right anterior cingulum was correlated with poor sleep quality [39]. A

resting-state fMRI study showed that shift workers exhibited altered functional connectivity in the salience network. In particular, they displayed reduced resting-state functional connectivity (rsFC) between the ACC and right insula, as well as increased rsFC of the ACC with the left occipital lobe and right superior frontal gyrus extending to the supplementary motor area [40].

FUTURE RESEARCH CONCERNING EMOTIONAL DYSREGULATION AMONG SHIFT WORKERS

Shift work, which is common in industrial societies, has been associated with various sleep and psychiatric disorders. However, few studies have explored the biological mechanisms underlying circadian misalignment among shift workers. The adverse effects of shift work are diverse and extensive. Historically, shift work research has focused on the direct consequences of circadian misalignment for sleep and sleepiness, but emerging research is highlighting the potential for emotional dysregulation. Future studies should explore the neurobiological basis of interindividual differences in the effects of shift work, as well as methods to promote resilience to its adverse psychological and biological consequences.

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Conflicts of Interest

Yu Jin Lee, a contributing editor of *Chronobiology in Medicine*, was not involved in the editorial evaluation or decision to publish this article.

Availability of Data and Material

Data sharing not applicable to this article as no datasets were generated or analyzed during the study.

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