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Effect of sleep disturbances on depression

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Abstract. This paper explores the relationship between sleep disorders and depression, highlighting the complex interplay between various influencing factors. This article will analyze the influence of sleep disorders on depression from three aspects: pathological mechanisms, different age groups, and lifestyle factors. The analysis began with pathological mechanisms, particularly the role of neurotransmitter systems, including histamine, norepinephrine, dopamine, and serotonin, all of which significantly regulate sleep and mood states. Dysregulation of these neurotransmitters can exacerbate sleep disturbances, thereby increasing the risk of depression. The researchers also examined the age factor and found that sleep deprivation in adolescents impaired emotion regulation and significantly increased the risk of depression. In contrast, older adults with sleep disorders were three times more likely to develop depression over time. In addition, lifestyle factors such as dietary habits, exercise, and use of electronic devices were explored. A balanced diet and regular physical activity have been shown to improve sleep quality and reduce depressive symptoms. In contrast, the use of electronic devices, especially at bedtime, is associated with poorer sleep outcomes and a higher risk for depression owing to the damaging effect of blue light on melatonin secretion.

Keywords: sleep disturbances, depression, neurotransmitter, age, lifestyle.

1. Introduction

Depression is a prevalent and devastating mental illness that affects more than 300 million people worldwide, making it the largest contributor to disability according to the World Health Organization [1]. Studies have shown that in patients with depression, the incidence of sleep disorders is extremely high, especially insomnia, which is not only a typical symptom of depression, but also may occur before the onset of depression [2]. Distinguishing between cause and effect is complicated by the bidirectional association between insomnia and depression. Longitudinal studies have shown that insomnia is an important risk factor for new or recurrent depression in young, middle-aged, and older adults. In addition, the occurrence of depression is closely related to multiple factors such as gender, stressful life events, childhood trauma and so on [3]. The prevalence of depression in women is significantly higher than that in men [2]. Depression not only affects patients' mood and cognition, but is also closely related to physiological dysfunction, such as sleep and appetite changes [1]. Of greater concern is the significantly increased risk of suicide in people with depression, particularly in adolescents, where the risk is up to 30-fold in those with major depression. Therefore, understanding the relationship between sleep disorders and depression is essential to develop effective interventions and increase public awareness of this disorder [4].

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This study examines the connection between depression and sleep disturbances, highlighting the intricate interplay between many contributing factors. This paper adopts the research method of literature reading and analysis. Overall, this paper highlights the critical importance of addressing sleep disturbances as a means of reducing depression and advocates for integrated strategies that consider neurotransmitter modulation, age-specific risk, and lifestyle changes.

2. Analysis of Influencing Factors

2.1. Mechanisms of Pathology

2.1.1. Neurotransmitter System

Neurotransmitter system can affect rapid eye movement (REM) sleep, with histamine, norepinephrine, dopamine, and serotonin being key components. Histamine is a monoamine neurotransmitter that is synthesized from histidine via l-histidine decarboxylase(HDC) [5]. Norepinephrine (NE), also called noradrenaline (NA) or noradrenalin, is an organic chemical in the catecholamine family that functions in the brain and body as a hormone, neurotransmitter and neuromodulator [6]. Serotonin, or 5-hydroxytryptamine (5-HT), is a neurotransmitter with a critical physiological role in the human body, regulating various activities, including behavior, mood, memory, and gastrointestinal homeostasis [7]. Dopamine is a neurotransmitter that is produced in the substantia nigra, ventral tegmental area, and hypothalamus of the brain [8].

Histamine plays an important role in sleep and wake behavior, especially through histaminergic cells located in the posterior hypothalamus, which are crucial for maintaining wakefulness. The activity of histaminergic cells is closely related to arousal, while their inactivity is associated with sleepiness. Histamine affects sleep/wake behavior through H1 and H3 receptors, histamine neurons in the TMN region fire most rapidly during arousal, and exogenous histamine levels are highest during active periods. When histamine signaling is inhibited, for example through acute blockade of the H1 receptor, non-rapid eye movement (NREM) sleep increases, reflecting the promoting effect of histamine on arousal. Although histamine may also have an effect during rapid eye movement (REM) sleep, the current study suggests that histamine inhibits other neurons that promote REM sleep via H3 receptors. Thus, the role of histamine in sleep pathology reveals its complex and critical regulation of sleep and arousal, especially under conditions such as stress.

Norepinephrine plays an important role in the regulation of sleep and wakefulness, primarily supplied by norepinephrine cells in the locus coeruleus located in the pons. Similar to histamine cells, norepinephrine cells are inactive during REM sleep. It has been shown that cessation of normal activity of noradrenergic cells during sleep is associated with loss of muscle tone during sleep. In addition, noradrenaline activity was most intense during wakefulness, whereas it was attenuated during non-REM sleep and almost completely stopped during REM sleep. Pharmacological studies have shown that inhibition of activity in the locus coeruleus leads to a sedative effect and alters the sleep pattern in the EEG of the forebrain. Mice deficient in norepinephrine showed altered sleep and wake patterns, emphasizing the importance of norepinephrine in normal and pathological sleep. Thus, dysregulation of norepinephrine signaling may be associated with sleep disorders, further affecting sleep quality and emotional state.

Studies have shown that dopamine plays an important role in regulating sleep state. Experimental evidence shows that mice in a hyperdopamine state, such as knockout mice and mice treated with amphetamines, exhibit a novel arousal state with hippocampal neural oscillations similar to those of REM sleep, accompanied by a significant increase in hippocampal theta and gamma oscillations. In contrast, dopamine deficiency leads to reduced REM sleep in normal mice and drives DAT-KO mice into a different state of arousal that displays neural oscillations similar to those of slow-wave sleep (SWS). At normal levels of dopamine, physiological regulation of REM sleep requires D2 dopamine receptor activation. Notably, dopamine deficiency not only completely suppresses REM sleep, but also affects sleep quality in neuropsychiatric disorders such as Parkinson's disease. Thus, dysregulation of

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dopamine signaling may lead to the appearance of sleep disorders, which in turn affect mood and cognitive function. These findings highlight the critical role of dopamine in regulating sleep and wakefulness states, especially in pathological conditions.

Serotonin plays an important role in regulating sleep and wakeful states and is mainly responsible for serotonin cells located in the raphe nucleus. These cells are almost completely inactive during sleep, especially during REM sleep, and exhibit relatively high activity during wakefulness. Normally, the activity of these serotonin cells suppresses phase events during REM sleep, whereas their inactivation during REM sleep allows high-voltage electrical brain activity, namely PGO waves, to propagate from the pons to the thalamus and cortex, resulting in associated eye movements and muscle twitching. Disruption of these cells can lead to the disinhibition of phase events, thereby affecting the normal progression of REM sleep. Furthermore, GABA, as a major inhibitory neurotransmitter, can activate both serotonin and norepinephrine cell populations, further showing the importance of cessation of serotonin cell activity in controlling REM sleep. These mechanisms suggest that the regulation of serotonin in sleep pathological states may have profound effects on mood and arousal.

2.2. Age Factors

2.2.1. Adolescents and Children

Insufficient sleep has important implications for depression risk in adolescents and children. Multiple studies have shown that sleep deprivation significantly impairs the ability of adolescents to experience positive emotions, such as happiness and excitement, leading to a 55% increase in the incidence of emotional deficits. This effect is not only reflected in a reduction of emotional positivity but is also accompanied by heightened levels of anger, depression, negative affect, and anxiety. Sleep deprivation also further exacerbates depressive symptoms by affecting emotional regulation mechanisms, as adolescents' ability to regulate emotions is impaired in the absence of adequate sleep. In addition, sleep disorders and depression often coexist in adolescents, which puts those with sleep disorders at higher risk of depression and suicidal thoughts. These findings highlight the importance of screening for depression in the adolescent population and point to the need to focus on sleep in children.

2.2.2. Elder

Sleep disturbances have a profound effect on depression among older adults. A longitudinal study with 524 participants revealed that individuals experiencing sleep disturbances at the study's outset had a 3.2-fold increased risk of developing depression two to three years later, even after controlling for other contributing factors. Additionally, older adults with ongoing insomnia were more likely to suffer from depression than those whose insomnia had resolved or those who developed it subsequently. Notably, insomnia not only serves as a predictor for the recurrence of depression but is also treatable, potentially preventing new instances of major depressive disorder in non-depressed older adults.

2.3. Lifestyle factors

2.3.1. Dietary Habit

First, specific components of the diet have been strongly associated with sleep quality. For example, a high-carbohydrate diet improves sleep efficiency, whereas a low-fat diet helps improve REM sleep. These changes in sleep stages are closely related to the symptoms of depression, indicating that a well-balanced diet can alleviate depressive symptoms to some extent. In addition, certain foods, such as milk, fatty fish, tart cherry juice, and kiwifruit, have been found to have positive effects on promoting high-quality sleep. This suggests that dietary nutrients not only affect sleep, but may also indirectly affect the onset and progression of depression by improving sleep quality. In addition, unhealthy dietary habits, such as excessive consumption of high-sugar and high-fat foods, may lead to sleep disturbances, thereby exacerbating depressive symptoms.

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2.3.2. Exercise Habit

Significant associations were found between exercise habits and sleep quality and mental health. Firstly, regular physical activity was found to significantly improve sleep quality, thereby reducing depressive symptoms. According to one study, participants reported fewer sleep disturbances and better overall mental health after engaging in regular physical activity. This suggests that exercise not only increases sleep duration, but also improves the depth and quality of sleep, which is critical for reducing depressive symptoms.

Secondly, exercise can promote sleep improvement through multiple mechanisms, thereby affecting the occurrence of depression. On the one hand, exercise increases the release of endorphins and other neurotransmitters, which help boost mood and reduce anxiety levels. On the other hand, regular exercise also regulates the body clock and promotes healthy sleep patterns. These physiological changes are closely related to improved sleep quality, which in turn contributes to the reduction of depressive symptoms.

In addition, there was a positive relationship between lack of exercise and sleep disorders. Those who are physically inactive are more likely to experience sleep problems, which in turn are associated with a higher risk of depression. Therefore, promoting exercise habits can not only improve sleep quality, but may also be an effective strategy to prevent and intervene in depression.

2.3.3. Use of Electronic Devices

Significant associations were found between exercise habits, sleep quality and mental health. Firstly, regular physical activity has been shown to significantly improve sleep quality, thereby reducing depressive symptoms. One study revealed that participants reported fewer sleep disturbances and better overall mental health after engaging in regular physical activity. This suggests that exercise not only increases sleep duration, but also improves the depth and quality of sleep, both of which are crucial for reducing depressive symptoms. Secondly, exercise can promote sleep improvement through multiple mechanisms, thereby affecting the occurrence of depression. On the one hand, exercise increases the release of endorphins and other neurotransmitters, which help boost mood and reduce anxiety levels. On the other hand, regular exercise also regulates the body clock and promotes healthy sleep patterns. These physiological changes are closely related to improved sleep quality, which in turn contributes to the reduction of depressive symptoms. In addition, there was a positive relationship between lack of exercise and sleep disorders. Those who are physically inactive are more likely to experience sleep problems, which in turn are associated with a higher risk of depression. Therefore, promoting exercise habits can not only improve sleep quality, but may also be an effective strategy to prevent and intervene in depression.

3. Conclusion

In conclusion, the present study elucidates the significant impact of sleep disturbance on depression, highlighting the multifaceted nature of this relationship. The underlying mechanisms, particularly the role of neurotransmitters such as histamine, norepinephrine, dopamine, and serotonin, suggest that disturbances of these systems lead to sleep disturbances and problems with emotion regulation. Age-related factors further complicate this trend, with adolescents and older adults being particularly vulnerable to the detrimental effects of sleep deprivation on emotional well-being. In addition, lifestyle factors, including dietary habits, exercise, and electronic device use, play a key role in shaping sleep quality and, in turn, mental health outcomes. For example, the use of electronic devices near bedtime is associated with increased sleep disturbances and worsened depressive symptoms , highlighting the need for targeted interventions. Overall, addressing sleep disturbances through a comprehensive approach that includes lifestyle modification, awareness of age-specific risks, and potential pharmacotherapy is critical to reducing the prevalence of depression and improving overall mental health.

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