

# *The Neural Mechanism of Mindfulness Therapy to Improve Sleep Quality*

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**Abstract:** Sleep is one of the most important life activities of human beings, and it is essential to the survival and development of human life. With the development of modern society, sleep disorders have gradually become one of the problems that cannot be ignored that plague human daily life along with the acceleration of the pace of human life. The application range of mindfulness therapy is wide, the method is easy to implement, and it has been confirmed by many empirical studies that it has the effect of improving sleep quality. Its promotion has extremely high application value for intervening sleep disorders. This article explores the neurophysiological mechanism of mindfulness training intervention in sleep problems, and provides a solid theoretical basis for clinical treatment.

## 1. Introduction

Sleep is one of the most important life activities of human beings, and it is essential to the survival and development of human life. With the development of modern society, sleep disorders have gradually become one of the problems that cannot be ignored that plague human daily life along with the acceleration of the pace of human life. The incidence of insomnia in China in recent years is about 38.5% [1]. The incidence of sleep disorders among college students in China is 13.93%-42.90% [2]. In the past 15 years, the sleep quality of Chinese adolescent students has gradually deteriorated with the ages [3].

Sleep problems are induced by a variety of factors, including physiology and pathology, mental state, emergencies, and lifestyle habits. Poor sleep quality can cause fatigue and lead to a decline in the quality of life. Sleep disorders are usually related to physical and mental diseases, such as decreased heart function, decreased immune function, cognitive dysfunction, and some mental illnesses.

There are various treatments for sleep disorders. Physical therapy, comprehensive therapy, psychotherapy, etc. are all widely used [4]. In psychotherapy, cognitive behavioral therapy is the main focus. Mindfulness therapy has gradually become a hot spot in recent years [5].

This article will understand the neurophysiological mechanism of mindfulness training intervention in sleep problems from the perspective of behavioral neuroscience. The application range of mindfulness therapy is wide, the method is easy to implement, and many empirical studies have proved that it has the effect of improving sleep quality. In addition to improving sleep, it also has the effects of calming mood and stabilizing emotions. Its use and promotion have extremely high practical value. Current empirical research mostly focuses on the cognitive mechanism of mindfulness

therapy, and the understanding of its neurological and brain mechanisms is still lacking. Enriching and expanding the neural mechanism research of mindfulness therapy provides a solid theoretical basis for clinical treatment.

## **2. Sleep Disorder**

### **2.1 The Definition of Sleep Disorder**

Sleep disorder (sleep disorder) refers to various dysfunctions in the process of sleep-wake. Poor sleep quality is the main sign of sleep disorders. Sleep disorders include lack of sleep, reduced sleep, excessive sleep cravings, difficulty falling asleep, restless sleep, and many abnormal psychology and behaviors related to sleep [6].

Sleep disorder is simply regarded as insomnia in daily life, and the definition of sleep disorder is broader. For sleep specialists, all dysfunctions that occur during the sleep-wake process are sleep disorders (Zhang Yuanhua, 2015). In the field of psychology and neuroscience, sleep disorders are defined as difficulties in the production and maintenance of sleep, excessive sleep during the day, sleep-wake rhythm disorders, and abnormal activities in the sleep-wake process.

### **2.2 Classification of Sleep Disorders**

According to the third edition of the International Classification of Sleep Disorders (ICSD-3), sleep disorders can be divided into seven main categories, including insomnia disorders, sleep-related breathing disorders (sleep-related breathing disorders, central disorders of hypersomnolence, circadian rhythm sleep-wake disorders, sleep-related movement disorders, parasomnias and some other sleep disorders (Sateia MJ, 2014).

### **2.3 Negative Effects of Sleep Disorder**

Sleep disorder has an extremely important impact on the vitality, emotional state, mental health and physical health of humans' daily behaviors. Insomnia is associated with mental disorders and physical diseases in many ways [4]. Insufficient sleep can easily lead to an increased risk of anxiety, depression, cognitive dysfunction, Alzheimer's disease, etc., and have a profound negative impact on the human body [7].

### **2.4 Neural Mechanism of Sleep Disorder**

#### **2.4.1 Dysfunction of the Hypothalamus-Pituitary-Adrenal Axis (Hpa Axis)**

The dysfunction of the HPA axis is specifically manifested as a significant increase in the secretion of corticotropin-releasing hormone (CRH) and cortisol [8]. Studies have shown that cortisol affects sleep by regulating the secretion of corticotropin-releasing hormone (CRH).

#### **2.4.2 Changes in Vagus Tension**

Studies have shown that in healthy subjects, vagus tension is one of the factors that affect sleep [9]. One of the causes of insomnia is autonomic dysfunction caused by increased sympathetic tension activity. Increased sympathetic tension leads to disturbances in the rhythm of melatonin secretion, which affects sleep [8].

#### **2.4.3 Decreased Function of Melatonin System**

Melatonin (MT) is an amine hormone produced by the pineal gland of mammals. It is derived from serotonin and has the effects of calming, hypnotizing and regulating sleep-wake cycles [8].

The level of melatonin directly affects the quality of sleep. Studies have shown that for long-term nighttime exposure to bright light, sleep quality is positively correlated with the level of melatonin [10].

#### **2.4.4 Central Neurotransmitter Disorder**

A variety of neurotransmitters are involved in the regulation of sleep-wake cycle. Norepinephrine (NE) and dopamine (DA) are both considered to be related to sleep-wake [8].

#### **2.4.5 Abnormal Function or Structure of Related Brain Areas**

Studies have suggested that patients who have been awake for a long time or have weakened falling asleep function may have cognitive load regulation disorder in the limbic-cortical system loop, which is manifested in the functional or structural abnormalities of the corresponding brain regions, such as the prefrontal lobe, anterior cingulate, and amygdala, hippocampus and thalamus, etc. [11]

### **3. The Mechanism of Mindfulness Therapy**

#### **3.1 The Concept**

Mindfulness (mindfulness), also known as mindfulness meditation, mental awareness, refers to the awareness that arises consciously and uncritically to pay attention to the present to cultivate the wisdom and love of self-understanding [12]. Mindfulness originates from one of the core Zen methods of Southern Buddhism in Malaysia. It is also called “Vipassana Zen”. After development and evolution, mindfulness in the modern sense refers more to a conscious individual adjustment method, a kind of concentrated attention, and a conscious awareness of this moment.

#### **3.2 Classification**

Based on the theory of “mindfulness”, a series of psychological treatment methods, namely mindfulness therapy, have been produced. There are two main types of mindfulness therapy: Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT). Mindfulness-Based Stress Reduction (MBCT) is the most widely used.

MBSR was initiated by Kabat-Zinn in 1979. Its core is to focus on the present and fully accept the experience of the moment, encourage visitors to take active and flexible actions to change areas of life that can be changed, and help visitors clarify their own values and pursue a life consistent with inner values [13]. The format is 8 weeks and 10 lessons, including 31 hours of direct instruction. The content includes mindful breathing, body scanning, mindful stretching, meditation, mindfulness meditation, mindfulness walking, etc.

MBCT is increasingly used in therapeutic practice. Its core is to encourage clients to deal with the experience without judgment and help them change their relationship with challenging thoughts and feelings, accept that difficult things may happen, and it is also possible to deal with these things in new ways.

Most of the sleep-related benefits of interventions that combine cognitive behavioral therapy for insomnia (CBT-I) and mindfulness meditation were maintained during the 12-month follow-up period [14].

#### **3.3 The Neurophysiological Mechanism of Mindfulness Therapy to Improve Sleep Quality**

### 3.3.1 Physiology Study

Eight weeks of mindfulness cognitive therapy training can reduce patients' norepinephrine level, increase the level of dopamine and melatonin, affect the sympathetic adrenal medulla system, and change their emotional state [15]. Norepinephrine (NE) and dopamine (DA) are related to sleep and wakefulness. Melatonin has the effects of sedation, hypnosis and regulation of sleep-wake cycles, and the level of melatonin is positively correlated with sleep quality [8].

### 3.3.2 Electroencephalogram (Eeg) Study

Sleep disorder most often occurs when these systems are dysregulated and are accompanied by sympathetic nervous system activation, which causes excessive wakefulness [14]. The currently accepted chronic insomnia model is the hyperarousal hypothesis. The hyperarousal hypothesis refers to the phenomenon of increased arousal in patients with insomnia, which is specifically manifested as: (1) increased central nervous system arousal or an increase in the proportion of awakening time, frequent  $\alpha$  and  $\beta$  fast waves during sleep, and increased sympathetic excitability. (2) The state of excessive arousal is persistent, and most patients with insomnia have not only poor sleep at night and difficulty falling asleep during the day [4].

Long-term mindfulness training can cause changes in the function of sympathetic nerves and parasympathetic nerves, slowing patients' heart rate, slowing down breathing, and reducing the activity of sympathetic nerves, thereby alleviating the symptoms of insomnia. Through continuous monitoring of the electrocardiogram of patients with insomnia, it was found that the heart rate of the patients was significantly increased during each sleep stage every night, and the sympathetic nerve activity was enhanced [16]. Long-term mindfulness training can reduce the patient's sympathetic nerve activity, slow down the patient's heart rate, reduce the respiratory rate, and thereby reduce insomnia. Mindfulness therapy can promote hypothalamic nerve conduction to induce sleep, reduce the sensitivity of the entire sympathetic nervous system, and weaken the "awakened" psychology, thereby assisting sleep [17].

Studies have shown that the main EEG indicators that are sensitive to mindfulness are  $\alpha$  wave,  $\theta$  wave and  $\gamma$  wave [18].

The  $\alpha$  wave in the frontal area of ordinary people will change asymmetrically after mindfulness training, that is, the  $\alpha$  wave activity on the left side will be significantly enhanced [19]. Emotional lateralization studies have shown that positive emotions are more controlled by the left cerebral hemisphere, while negative emotions are more controlled by the right cerebral hemisphere. This asymmetry is precisely one of the neural mechanisms that enhance individual positive emotions [18].

The changes in  $\theta$  wave and  $\gamma$  wave in mindfulness training indicate that mindfulness can regulate brain neural activity to promote individual attention, memory and learning [18]. Fletcher et.al. [20] conducted an EEG study of mindfulness decompression therapy in 2010, and the results showed that compared with the control group, the  $\theta$  wave activity in the prefrontal brain area and the frontal mid-line related to the level of attention in the experimental group was significant. The activity of the left-brain area related to positive emotions is also significantly enhanced.

The results of a 2013 study by Ferrarelli et.al. [21] showed that long-term mindfulness meditators increased the  $\gamma$  power of the parieto-occipital EEG during NREM sleep. This increase has nothing to do with the level of spontaneous arousal during NREM, and is positively correlated with the length of time of mindfulness training every day in a lifetime. Studies have proved that the EEG  $\gamma$  wave activity during sleep represents the long-term, plastic effect of mindfulness training on brain function.

The spectrum analysis of sleep EEG data shows that the change of EEG from baseline to frequency EEG band ( $\beta$ ,  $\gamma$ ) in patients receiving mindfulness therapy provides a basis for mindfulness training to improve sleep [22].

A study by Ong et.al. [23] in 2008 showed that mindfulness meditation can be combined with CBT-I, using mindfulness meditation, sleep restriction, stimulation control, sleep education, and sleep hygiene. This comprehensive intervention is associated with sleep and sleep-related arousal reduction related. Through this comprehensive intervention, pre-sleep arousal, sleep effort, and sleep-related cognitive impairment are also significantly reduced. In addition, there is also a significant correlation between the number of mindfulness and the changes in the measurement of arousal characteristics.

### 3.3.3 Magnetic Resonance Study

The study of brain function found that mindfulness and specific brain areas (such as the prefrontal lobe, cingulate gyrus, etc.) activation mode or activation mode changes [18]. FMRI studies have found that mindfulness exercises can affect the activity of the prefrontal cortex and reduce the activity of the bilateral amygdala. The left frontal lobe responsible for positive emotions is awakened, while the right frontal lobe and amygdala responsible for negative emotions are restrained [24]. This regional activation model proves that mindfulness practitioners can cope with difficulties in a positive and optimistic way, and better adjust and deal with negative emotions. The activity of the prefrontal cortex and the amygdala in the brain function of the long-term mindfulness trainer affects the neuro-physiological activities of the practitioner. Insomnia will increase the excitability of the amygdala of the patient and produce negative emotions.

Studies of brain structure have found that mindfulness is related to changes in cortical thickness or gray matter density in related brain areas (insula, hippocampus, cingulate gyrus, prefrontal lobe, etc.) related to attention, learning, memory and emotions [18]. Studies have confirmed that mindfulness decompression therapy affects emotions, learning, memory, cognition, and perception by changing the morphological structure of the hippocampus, posterior cingulate cortex, and cerebellum region [25]. Holzel et.al. [26] reported a controlled longitudinal study investigating the changes in brain gray matter concentration after participating in the MBSR project. Magnetic resonance structure (MR) imaging results showed that compared with the control group, the density of the left hippocampal gray matter of the experimental group increased significantly, and the posterior cingulate cortex, temporoparietal junction, and cerebellum all increased. The results show that participation in the MBSR project is related to changes in the gray matter concentration of the brain regions involved in learning and memory processes, emotion regulation, self-referential processing, and opinion adoption.

### 3.3.4 Event-Related Potential Study

There are few researches on event-related potential related to mindfulness. Cahn and Polich [27] used the typical auditory oddball paradigm to study the brain electrical activity of long-term mindful people under the condition of awareness and control. It was found that the P3a wave amplitude induced by the distraction stimulus recorded in the frontal area was significantly reduced under the condition of mindfulness. In addition, the longer the daily mindfulness time reported by the subjects, the more the P3a wave amplitude decreased. P3a is an EEG component related to the attention processing process driven by stimuli. In the state of mindfulness, the P3a amplitude induced by distraction stimuli decreases, indicating that mindfulness therapy enhances the individual's ability to resist distraction stimuli, helps individuals focus on the moment, and helps to improve the difficulty of falling asleep.

## 4. Empirical Use of Mindfulness Therapy

The practice of mindfulness meditation has become a very popular self-regulation strategy for regulating stress, coping with chronic diseases and enhancing physical fitness. Because sleep disorders can have a certain impact on these aspects, more and more people are using mindfulness training

to improve their sleep health.

Given that mindfulness is also a behavioral static state involving active regulation, using mindfulness to improve sleep health is conceptually synergistic and intuitively attraction [28]. Mindfulness meditation cultivates awakening to the moment, self-compassion, and non-seeking of results, so as to alleviate mental and physical pain. A large number of studies have confirmed the effectiveness of using mindfulness intervention (MBI) to treat sleep disorders such as insomnia.

#### 4.1 Application of Mindfulness in Healthy People

Mindfulness decompression therapy can not only be used as a clinically effective treatment, but also as an effective way of health care [12].

A study by Klatt et.al. [29] in 2009 evaluated the impact of a shortened (low-dose) workplace MBSR intervention (MBSR-ld) on the stress indicators of healthy adults to determine whether the results obtained in traditional MBSR can be demonstrated similar. The results show that short-term MBSR intervention in the workplace can effectively reduce perceived stress and improve sleep quality.

A 2017 study by Tori.L.Crain et.al. [30] explored the effects of mindfulness training (WMT) randomly assigned to the workplace on teachers' well-being, sleep duration, sleep quality, and daytime sleepiness. The results showed that teachers who were randomly assigned to WMT self-reported a decrease in bad mood, increased satisfaction with work and family, more sleep and better sleep quality at night on working days, and decreased insomnia symptoms and daytime sleepiness.

#### 4.2 Application of Mindfulness in People with Organic Diseases

In a study by Lin Qi et.al. in 2014 [31], 199 young and middle-aged breast cancer patients were divided into a control group and a test group according to the order of visiting time. The control group patients were given routine care, and the test group was given mindfulness training on the basis of routine care. This study compared the changes in sleep quality of the two groups before and after intervention. The results showed that the total scores of subjective sleep quality, time to fall asleep, sleep time, sleep efficiency, daytime dysfunction and sleep quality in the experimental group were lower than those in the control group after the intervention. The conclusion is that mindfulness training intervention can improve the sleep quality of young and middle-aged breast cancer patients and help improve their quality of life.

In 2014, Gu Xiaoyan et.al. [32] randomly divided 65 patients with hypertension into a control group and an observation group. Both groups were given routine care. On this basis, the observation group was given mindfulness training, such as watching CDs, raisin exercises, Mindfulness breathing exercises, etc. After the implementation of 8 times, the observation group's subjective sleep quality, time to fall asleep, sleep time, sleep efficiency, daytime dysfunction, and overall sleep quality scores were significantly reduced. Therefore, mindfulness training intervention can significantly improve the sleep quality of hypertensive patients.

Wu Ting et.al. [33] conducted a randomized controlled trial (RCT) or clinical controlled trial (CCT) META analysis on mindfulness training to improve the sleep quality of cancer patients to explore whether mindfulness training can improve the sleep quality of cancer patients. Most studies show that the overall sleep quality, sleep efficiency, subjective sleep quality, sleep disturbance, and sleep time of the experimental group are better than those of the control group.

Cynthia.R. Gross et.al. [34] collected insomnia severity index (ISI), Pittsburgh Sleep Quality Index (PSQI), Sleep diary and wrist exercise device in 2011. The results showed that from baseline to five months of follow-up, the total sleep time, SOL and sleep efficiency measured by ISI, PSQI and diary



in the MBSR group were significantly improved, providing preliminary evidence of MBSR as a feasible treatment for chronic insomnia.

### **4.3 The Application of Mindfulness in People Affected by Psychological Factors**

The level of mindfulness plays a part of the mediating role between perceptual pressure and sleep problems. Perceived pressure is significantly negatively correlated with mindfulness level, significantly positively correlated with sleep problems, and mindfulness level is significantly negatively correlated with sleep problems [35].

Wang Lutong's research [36] on the effect of intervention on the sleep problems of college students under depression and the study of psychological mechanism in 2016 showed that after 8 weeks of standard mindfulness cognitive training, the subjects' sleep quality was improved, the time to fall asleep was reduced, the sleep efficiency was improved, and the sleep problem level and daytime dysfunction level were reduced. It significantly increased the participants' mindfulness level, improved their emotional status, and improved their emotional regulation ability. What's more, it also improved the level of physiological indicators related to sleep, including the reduction of  $\alpha$  wave,  $\theta$  wave,  $\beta$  wave, elevation, and electromyography, BVP and skin electricity.

Mindfulness-based interventions have been proven effective in the diagnosis and treatment of heterogeneous anxiety disorders. Johanna Boettcher et.al. [37] randomly assigned 91 participants diagnosed with social anxiety disorder, generalized anxiety disorder, panic disorder, or unspecified anxiety disorder to a mindfulness treatment group (MTG) or online discussion forum control group (CG) in 2014. The study assessed the symptoms of anxiety, depression, and insomnia before treatment, after treatment, and during a 6-month follow-up. The results showed that the sleep quality of the subjects who received mindfulness treatment significantly improved, and the quality of life also achieved a moderate improvement. This research provides impetus for the application of Internet-based mindfulness protocols in the treatment of primary anxiety.

## **5. Problems and Prospects of Sleep Intervention Based on Mindfulness**

### **5.1 Limitations of Research Methods**

At present, the research method of mindfulness therapy is relatively simple, and most of them are simple controlled experiments. The control group only controls the independent variables of the experiment, and the method is simple. The control of irrelevant variables and confounding variables is insufficient, the control group is single, and there is a lack of comparison between before and after testing and follow-up tracking. The validity and reliability of the research need to be improved.

In future research, irrelevant variables and confounding variables should be better controlled, and the placebo effect and other factors should be excluded as much as possible. Researchers can also try to increase the control group design, add control variables, enrich the research design, and improve the reliability and validity of the experiment.

### **5.2 Limitations of Research Tools**

In current research, self-evaluation and self-report measurement tools are used more frequently, and subjective report self-evaluation scales are mostly used for the measurement of sleep quality, such as Pittsburgh Sleep Quality Index (PSQI) scale and Athens Insomnia Scale (AIS), Insomnia Severity Index (ISI) scale. Mindfulness Attention Awareness Scale (MAAS) is often used to measure mindfulness, and it is also a subjective reporting scale, which has limited measurement validity.

In future applications, the relevant tools of neuroscience, such as brain electricity, functional magnetic resonance, etc., will also be used rationally. Use more accurate and objective detection tools, such as portable sleep monitoring equipment, to measure brain electrophysiology and other indicators to improve the accuracy of the experiment.

### 5.3 Limitations of Research Objects

There are few existing studies on simple sleep disorders and sleep problems in the general population. Most of them focus on sleep disorders caused by organic physical diseases, such as cancer, cerebral hemorrhage, diabetes, chronic kidney disease, breast cancer, etc. [11], or sleep disorders caused by mental disorders, such as severe depression, severe anxiety, etc. The target population of mindfulness therapy is limited, and the number of subjects is generally small.

However, sleep problems are widespread. Although most of them do not meet the clinical diagnostic criteria for sleep disorders, the decline in sleep quality is a trend in the overall society. Therefore, improving sleep quality has a great impact on the economic and social life of all human beings. Intervention targets should be extended to the general population, such as the huge “sub-healthy population”.

Mindfulness therapy has the characteristics of being simple and easy to learn, low requirements for the scene, high persistence of curative effect, and avoiding side effects as a non-drug treatment, which has extremely high promotion value.

### 5.4 Limitations of the Research Subject

Although mindfulness training has been proved by many empirical studies to prove its efficacy, in clinical use, mindfulness therapy has not been widely promoted, and its treatment system is not yet mature. In practical applications, it is often combined with other cognitive behavioral therapies or drug therapies. Therefore, the unique curative effect of mindfulness therapy and the cognitive and psychological mechanisms and neural mechanisms are still lacking in further exploration. It is necessary to strengthen the theoretical foundation, a more comprehensive and systematic treatment plan, and more powerful research support.

### 5.5 Prospects

Mindfulness therapy is a very cost-effective, easy-to-implement and spread sleep disorder treatment method, and as a health care method to improve the quality of human life, it has its unique value and significance. Since its inception, mindfulness therapy has gradually developed and changed, and has gradually adapted to the needs of modern society. Based on scientific cognitive theory and neurological research, it has constantly emphasized its characteristics and has extremely high application potential. In addition to improving sleep, mindfulness therapy will also play a role in many aspects of human life and improve human physical and mental health. Current research still has many limitations, but with the advancement of research methods and tools, future research will become a stronger driving force for development.

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