International Journal of Clinical and Experimental Medicine Research, 2024, 8(4), 582-586
https: //www.hillpublisher.com/journals/ijcemr/
ISSN Online: 2575-7970
ISSN Print: 2575-7989

Exercise, Sleep Disturbances, and Related Dementia Diseases

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How to cite this paper: Yuyang Hu. (2024) Exercise, Sleep Disturbances, and Related Dementia Diseases. *International Journal of Clinical and Experimental Medicine Research*, 8(4), 582-586.
DOI: 10.26855/ijcemr.2024.10.008

Received: September 30, 2024
Accepted: October 28, 2024
Published: November 27, 2024

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Abstract

Many papers discuss the effects of exercise on sleep and vice versa, but few synthesize this research. This review aims to aggregate findings and clarify their interactions. Exercise can significantly improve sleep quality by reducing sleep latency, minimizing wakefulness after sleep onset, and increasing sleep efficiency. Furthermore, exercise may also decrease the duration of REM sleep while extending slow-wave sleep. On the other hand, these effects may change depending on the timing of exercise before bedtime. Sleep, particularly slow-wave sleep, is crucial for brain health and it is linked to dementia, which is largely due to its role in brain cleaning processes. Exercise also alleviates sleep disorders such as insomnia and sleep apnea, and it can aid individuals with Parkinson's disease by boosting their dopamine levels. Despite these benefits, the precise effects of exercise on sleep homeostasis and the mechanisms linking sleep to dementia remain areas that require further investigation.

Keywords

Exercise; Sleep disturbances; Dementia diseases

1. Introduction

REM sleep, characterized by rapid, irregular eye movements and vivid dreaming, is termed paradoxical sleep (PS) due to its wake-like physiological state, including rapid, low-voltage desynchronized brain waves. During REM, the brain produces acetylcholine, accelerating brainwave activity, yet physical movements are generally slower than when awake, and bodily functions remain unstable. Heart rate, cardiac pressure, cardiac output, arterial pressure, and breathing rate became irregular [1]. NREM sleep, also known as slow-wave sleep (SWS), encompasses the sleep periods outside of REM and is divided into three stages, each with distinct brainwave patterns. Different from REM, the eye will not move during NREM, and muscles will not be paralyzed during this sleep stage [2]. Sleep spindles are the unique characteristic of NREM, but their function and meaning it is still not clear [3].

Many factors contribute to an individual's perception of sleep quality, primarily including Sleep Latency (how long it takes you to fall asleep) [4]; Wake After Sleep Onset (WASO) [5]: the amount of time you are awake after first falling asleep; Sleep Efficiency (the ratio of time asleep to time lying in bed) [6]. Sleep quality can be measured by people themselves using the form of the Pittsburgh Sleep Quality Index (PSQI) [7]. Sleep stages are typically divided into four parts, with stages 1 and 4 being REM sleep, and stages 2 and 3 being NREM (slow-wave sleep). Stage 2 and 3 have distinct characteristics, with stage 3 being the deepest sleep, associated with the lowest blood pressure and heart rate. Sleep onset latency (SOL) refers to the time it takes to transition from wakefulness to sleep, typically starting with the shallowest stage of NREM, not REM.

Sleep disorders pose significant challenges for some individuals, severely impacting their physiological, psychological, and social-emotional functioning. These disorders can be categorized into various types,

including dyssomnias [8], parasomnias [9], and circadian rhythm sleep disorders. The most common types of sleep disorders are insomnia and sleep apnea. There are different diseases that may trigger [10], such as psychological stress, chronic pain, and heart failure. Sleep apnea is commonly caused by the obstruction of the upper airway or by the brainstem's failure to properly regulate breathing, leading to repeated interruptions in breathing during sleep. Patients may also feel sleepy and tired [11].

Dementia is a syndrome of lots of different kinds of neurodegenerative diseases [12]. Patients with dementia typically experience a decline in cognitive function, including a loss of executive abilities. This affects memory, behavior, thought processes, and the control of voluntary movements. The most famous dementia are Alzheimer's dementia [13] (AD) and Parkinson's disease dementia (PDD) [14]. Typical symptoms of Alzheimer's dementia include difficulties with language, disorientation (often leading to getting lost), mood swings, a loss of motivation, self-neglect, and behavioral problems.

Defining exercise can be challenging due to its broad scope. Broadly, exercise can be categorized based on oxygen consumption, duration, and frequency. The most common types include anaerobic exercise, aerobic exercise, acute exercise, and regular exercise.

2. Exercise effects on sleep

The average data of five studies of the elderly showed the effect of aerobic exercise training effects on humans, to illustrate that exercise training could improve sleep quality with shortened sleep latency, while sleep duration, sleep efficiency, and sleep disturbance remained unchanged. Most importantly the training decreased the usage of medication for sleep assistance. However, Pei-Yu Yang, et al found that exercise would not alter sleep latency but sleep stage duration. They assessed the effect of exercise effect on humans to show that alteration of exercise time and levels affect sleep stages that exercise prolonged sleep stage 2 and shortened the duration of sleep stage 1, which might result from the time for exercise since the latency changes increased with at least 60min for once [15].

Exercise Taiichi which is a type of traditional Chinese mild sport to strengthen physics could improve the sleep quality of elderly people. In 2008, Michael R Irwin et al assessed the effect of 25-week Taiichi exercise on the sleep quality of 112 healthy people (59 years old to 86 years old), to show that regular Taiichi exercise did improve sleep parameters such as sleep duration and sleep disturbance [16]. Several data from surveys of the effects of exercise on people's sleep quality illustrate that both acute and regular exercise could improve people's sleep quality. It includes elongate time of SWS, REM, total sleep time (TST), and sleep latency. Evidence has shown that acute exercise may negatively affect the longitude of time of REM but increase the duration of SWS and shortened sleep latency. Moreover, it also increased the duration of total sleep time. Whereas, wake episodes after sleep onset remained unchanged, implying no sleep fragmentation [17].

In contrast, Shiro Oda et al. [18] found that acute exercise negatively affects REM and SWS. In the research,14 healthy men aged 25 were assessed sleep immediately after acute exercise, and sleep latency increased by 14 minutes, heart rate increased by 25.7 per minute and TST declined by 14.6 minutes [18].

The reason why the two research could have such a difference can be explained by sports timing, subjects in [18]'s investigation measured sleep right after acute exercise which has the opposite effect with day-time exercise, originating from the hyper-active neuronal activity eventually deteriorating sleep quality.

In addition, regular aerobic exercise could also reduce the duration of REM, and sleep latency and increase the duration of SWS and TST. From 12 surveys of chronic exercise, both SWS and TST have a positive effect index, especially an obvious prolonged SWS. As for REM, sleep latency, and wake episodes during sleep have a shorter time than before. Therefore, people with regular aerobic exercise could sleep faster, deeper, and longer.

3. Sleep disturbances and dementia diseases

The length of sleep duration is tightly related to dementia. According to the experiment of Séverine Sabia, short sleep time may be related to the occurrence of dementia. Between 1985 and 1988, they recruited 10,038 volunteers and recorded their whole sleep duration. After 24.6 years, 521 people got dementia. They concluded that between ages 50 to 70, subjects with TST≤6 hours are highly likely to get dementia, compared with people with 7 hours of TST, and the possibility of getting dementia of subjects with less sleep increased by 30% (HR = 1.30, 95% CI, 1.00-1.69) [19]. In addition, Kristine Yaffe et al. claimed that insomnia could lead to Hippocampal atrophy, Inflammation, and Neurotransmitter disruption, and cause the pathogenesis of dementia [20].

However, some research showed that stretched time of sleep may also signal a higher possibility of dementia. Andrew J. Westwood et al. conducted an experiment with 2,457 subjects in 10 years. They found 234 cases of

dementia in it. Andrew took sleep duration and education level into account. He then found that people with longer sleep than before and lower education levels may experience dementia. He also found that people with longer sleep time(>9h) have smaller Total Cerebral Brain Volume (TCBV) than people with shorter time for sleep(<6h) but with less understanding of the mechanism [21]. From the results of the research, maintaining sleep homeostasis and maintaining a certain sleep duration level is important for people to keep mental health by not sleeping too little or too much, which was proved by Greg J. Elder, who claimed that both long-term and short term sleep can play a role in the pathogenesis of LBD, a specific kind of dementia [22]. Also, another essay written by Michail Katsoulis et. al, proposed that the time of sleep is positively a process of the subject, which is not accurate [23].

In addition, the loss of SWS is also a signal of dementia and caducity. Jayandra J. Himali et. al established an experiment with 346 participants. They gave the participants twice Polysomnography between 1995 and 1998 and from 2001 to 2003. They concluded that for every loss of 1 % of SWS, the risk of dementia would increase by 27% [24].

According to Albert Henry [23] et al., the causal relation between the longitude of sleep time and level of cognition cannot be determined, but there is a certain relation between those factors. They did 2 experiments. In the first experiment, they recruited 197,902 samples and found that for every extra hour that people sleep during the night, their reaction time will increase by 1%, and also fault in vision memory increase by 3%. Moreover, during their Mendelian randomization study (MR), they found a nonlinear relation between vision memory and reaction rate. In the long-term observed group, the Local average causal effect (LASE) between the reaction time and TST has a higher absolute value. It might suggest a stronger relationship [23].

4. Exercise effects on diseases with sleep disorders

Exercise can also reduce the severity of sleep apnea. 43 senditary, obese adults were invited, and most of them were tested with the value of Apnea Hypopnea Index (API) equal to or even higher than 15. The researchers separated them into two groups, one was the control group, and people in the other group did low-intense stretching exercises. Then the researchers measured the effect of exercise on sleep apnea. The value of AHI decreases from 32.2±5.6 to 24.6±4.4, with the value of the control group increasing from 24.4±5.6 to 28.9±6.4. In addition, the oxygen desaturation index (ODI) and deep sleep stage also improve. The research also used the Pittsburgh Sleep Quality Index, Pulse Signal Generator (PSG), and 7 days of actigraphy to compare the sleep quality of the two groups. They found that the group that exercised had better sleep quality, while the control group did not change.

Exercise could also improve the sleep quality of old people who have insomnia problems. 60-70-year-old people with serious insomnia and low sleep quality. participated in the experiment held by Paula Moreno Reyes. He offered them exercises like Taichi, and Yuga, with a frequency of 3 per week and a duration of 60 minutes each time. After 3 weeks of the experiment, the rate of PSQI rate decreases significantly, from 8.5 (±2.1) to (±1.8), $p < 0.005$. In addition, symptoms of insomnia decrease as well [25]. In another study, conducted by Reid et al., they conducted an experiment on 23 sedentary old women with insomnia. The participator had 4 times of exercises each week, with 40 minutes each time. After 6 weeks, their PSQI value decrease significantly, from 1.90 ± 0.57 to 0.08 ± 0.63 [24].

Exercise could also improve and reduce the symptoms of Parkinson's disease, especially in the physical aspect [26]. According to Cynthia L. Comella, MD et al., doing physical exercise could overall alleviate the symptoms of PD. They evaluate the statistics of their experiment by the Unified Parkinson's Disease Rating Scale (UPDRS). They recruited 18 patients with an average age of 66 and a history of PD of 10 on average. After 2 periods of 4-week exercise training time with a 6-month interval between them. Researchers found that UPDRS Scores, ADL subitem, and sports subitem improved significantly, but the mental subitem did not significantly change. In another study by Schenkman M. et al., they tested the effect of exercise on the flexibility of the spine and body change. They recruited 51aged 55 to 84 PD patients, and separated them into 2 groups, with a control one and an experimental one. The experimental one had a 10-week personal exercise while the control group only maintained regular exercise. the result showed that the change value of Functional axial rotation (FAR) is 12 degrees, which is a significant difference from the control group. They also recorded the patient's response that they feel easy to stand and walk.

5. Discussion

Many essays investigate the distinct effects of exercise on sleep and vice versa, but a limited number synthesize these findings holistically. This review aims to aggregate the research and elucidate the intricate relationship between exercise and sleep.

Exercise has the potential to enhance multiple facets of sleep quality, such as reducing sleep latency, minimizing wakefulness after sleep onset, and increasing sleep efficiency. It may also decrease the length of rapid eye movement (REM) sleep and extend the period of slow wave sleep (SWS). The debate over whether exercise positively or negatively influences sleep can often be attributed to the timing of physical activity relative to bedtime.

Sleep, particularly its quantity and quality, is linked to the pathogenesis of dementia. Insufficient sleep and a reduction in slow-wave sleep (SWS) may play a role in the onset of dementia, potentially because of inadequate time for cerebrospinal fluid to remove amyloid proteins from the brain—a process that is implicated in the development of Alzheimer's disease.

Exercise has the capacity to ameliorate symptoms associated with specific sleep disorders and neurological conditions. Consistent physical activity can relieve symptoms of insomnia and sleep apnea. Furthermore, exercise may aid Parkinson's patients in achieving greater stability while standing and walking, which could be a result of increased dopamine production in the nigrostriatal pathway during exercise, potentially offsetting the dopamine deficit that characterizes Parkinson's disease.

Further investigation is warranted in certain areas. Specifically, the impacts and underlying mechanisms of exercise on sleep homeostasis and its relationship with dementia must be rigorously examined and confirmed through research.

Exercise generally exerts a beneficial impact on both sleep duration and quality. Various types of exercise, including acute, aerobic, and pre-sleep exercise, may have distinct effects on sleep. Most forms of exercise tend to enhance sleep quality by extending the total sleep time (TST), slow-wave sleep (SWS), and stage 2 sleep, while decreasing rapid eye movement (REM) sleep, wake after sleep onset (WASO), and stage 1 sleep. The effects of acute exercise on sleep are a subject of debate. Some studies suggest that acute, intense exercise can improve sleep quality by reducing REM and WASO duration and increasing SWS and TST. Conversely, other findings challenge this, and the discrepancies may be attributed to the timing of exercise. The proximity of exercise to bedtime could be a significant factor affecting sleep quality; exercise too close to bedtime might lead to hyper-excitability of neuronal activity, resulting in longer sleep latency. In contrast, morning or midday exercise allows neuronal activity to subside, promoting physical rest and potentially improving sleep quality.

The duration of sleep, both at night and during the day, is associated with the risk of developing dementia. Studies suggest that a total sleep time (TST) of less than 6 hours at night may increase the likelihood of pathological changes leading to dementia. Conversely, excessively long sleep durations may also raise the risk of dementia. The loss of slow-wave sleep (SWS) is indicative of declining memory and cognitive function. The controversy surrounding these experimental results may stem from the role of cerebrospinal fluid (CSF) in clearing amyloid proteins, a key biological marker of Alzheimer's disease (AD), a specific type of dementia. Adequate sleep is necessary for CSF to effectively remove amyloid proteins from the brain. When sleep is too short or too long, CSF may not have sufficient time to clear all the amyloid proteins, potentially leading to their accumulation and the subsequent development of dementia. Moreover, during SWS, CSF activity intensifies, which is crucial for the removal of amyloid proteins. Therefore, a reduction in SWS, particularly in older adults, could limit the time available for CSF to fully clear amyloid proteins from the brain, potentially contributing to the development of AD.

Exercise can beneficially affect certain sleep disorders and diseases. Consistent aerobic exercise has been shown to decrease the Apnea-Hypopnea Index (AHI) and increase slow-wave sleep (SWS) duration. Activities such as Tai Chi and Yoga can also enhance sleep quality in the elderly and address insomnia issues. Studies have observed a significant reduction in the Pittsburgh Sleep Quality Index (PSQI) scores following regular physical activity. Furthermore, exercise can mitigate symptoms of Parkinson's disease (PD). After several weeks of exercise, patients often report a decrease in the bother caused by their condition. The alleviation of PD symptoms may be linked to the secretion of dopamine during exercise, which occurs via the Nigrostriatal Pathway. Since the primary issue in PD is the lack of dopamine in this pathway, the increased dopamine levels resulting from exercise can substantially relieve PD symptoms.

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