

Original Article

# The Impact of Sleep Quality on Cognitive Function in Patients with Chronic Subjective Tinnitus

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**BACKGROUND:** The aim of this study was to explore the impact of sleep quality on cognitive function in patients with chronic subjective tinnitus.

**METHODS:** The Pittsburgh Sleep Quality Index (PSQI) and the Montreal Cognitive Assessment Scale (MoCA) were used to assess sleep quality and cognitive function in patients with chronic subjective tinnitus, sleep disorder patients (SD), and normal controls (NC). The tinnitus evaluation questionnaire (TEQ) and tinnitus loudness were used to assess the severity in patients with chronic subjective tinnitus. Tinnitus patients were divided into two groups based on PSQI results: "tinnitus with sleep disorder (TwSD)" and "tinnitus without sleep disorder (TnSD)." The MoCA scores in TwSD and TnSD groups were compared with those in SD and NC groups, and the correlation between PSQI, TEQ, tinnitus loudness, and MoCA scores in subjective tinnitus patients were analyzed.

**RESULTS:** Whether TwSD group or TnSD group, the MoCA score was significantly lower than those in the NC group and SD group. Meanwhile, there was no significant difference between TwSD and TnSD groups in MoCA score, and PSQI, TEQ, and tinnitus loudness were not significantly correlated with MoCA.

**CONCLUSION:** Subjective tinnitus may be an independent risk factor for cognitive impairment. The underlying neural mechanisms between subjective tinnitus, sleep disorders, and cognitive impairment need to be further explored and clarified.

**KEYWORDS:** Chronic subjective tinnitus, sleep quality, cognitive function

## INTRODUCTION

The cognitive impairment is an important component of tinnitus research because it contributes to a deeper understanding of subjective tinnitus' causes and effects, as well as its potential effects on a person's daily life, and beneficial to investigate subjective tinnitus evaluation and treatment options. Research support for tinnitus patients' cognitive impairment has grown in recent years,<sup>1</sup> but the exact cause of this impairment is still unknown.

Tinnitus and sleep disorders frequently coexist and are causally related to one another.<sup>2</sup> Sleep disorders were a significant risk factor for personal cognitive impairment, according to recent research.<sup>3</sup> Compared to well-rested people, for instance, sleep-deprived people were more likely to incorporate misleading post-event information into their responses during memory retrieval.<sup>4</sup> The imaging study also discovered that, in comparison to the control group, sleep-deprived patients displayed sporadic changes in the thalamus, secondary sensory processing area, and frontal parietal lobe control area, suggesting changes in cognitive function.<sup>5</sup> Cognitive function, operation, working memory, complex attention, alertness, situational memory, and problem-solving are among the cognitive impairments that are closely related to sleep disorders,<sup>6</sup> and are also common in tinnitus patients.<sup>7</sup> Therefore, it is critical to determine whether the cognitive impairment of tinnitus sufferers is caused by the competition for cognitive resources brought on by tinnitus signals, or the self-functional decline brought on by sleep disorders, or whether the two factors are jointly responsible.

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Based on this, the Pittsburgh Sleep Quality Index (PSQI) and the Montreal Cognitive Assessment (MoCA) were used in this study to preliminary investigate the effects of sleep quality on cognitive function in patients with chronic subjective tinnitus. This study's findings will serve as a reference for future studies on cognitive impairment in tinnitus patients.

MATERIAL AND METHODS

This study was approved by the Medical Ethics Committee of the Third Affiliated Hospital of Sun Yat-sen University ([2019]02- 229-01). All the participants were notified about the study and provided informed consent.

Subjects

Tinnitus Subjects

Tinnitus subjects were recruited from among patients who first reported tinnitus in the Department of Otolaryngology, Head and Neck Surgery.

Criteria for inclusion: (1) persistent high-frequency tinnitus and the tinnitus frequency matching hearing loss frequency; (2) the course of tinnitus exceeds 6 months; (3) age range from 20 to 50 years old; (4) the average thresholds of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz for pure-tone audiometry (PTA) are not higher than 25 dB HL; (5) high school or above education level; (6) volunteer participation.

Exclusion criteria: (1) tinnitus caused by organic lesions such as tumors or traumatic brain injury; (2) with external or/and middle ear diseases; (3) severe systemic diseases such as liver, kidney, and heart; (4) having severe dizziness symptoms; (5) severe mental illness; (6) unable to cooperate in completing all investigations.

According to the PSQI classification, patients with tinnitus were divided into 2 groups: tinnitus without sleep disorders (TnSD, level I sleep quality (PSQI ≤ 5), n=30; and tinnitus with sleep disorders (TwSD, level II, III, and IV sleep quality (PSQI > 5), n=41.

Subjects with Sleep Disorders

Subjects with sleep disorder (SD) were recruited among those undergoing sleep monitoring in the Department of Otolaryngology, Head and Neck Surgery, n=30.

Criteria for inclusion: (1) no previous history of tinnitus or hearing loss; (2) sleep disorders, PSQI > 5 points; (3) age range from 20 to 50

years old; (4) the average thresholds of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz for pure tone audiometry (PTA) are not higher than 25 dB HL; (5) high school or above education level; (6) volunteer participation.

Exclusion criteria: (1) unable to cooperate in completing all scale evaluations; (2) with external or/and middle ear diseases.

Normal controls

Normal controls (NC) were recruited through WeChat or posters, n=23.

Criteria for inclusion: (1) no previous history of tinnitus or hearing loss; (2) no previous history of sleep disorders, PSQI ≤ 5 points; (3) age range from 20 to 50 years old; (4) the average thresholds of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz for pure tone audiometry (PTA) are not higher than 25 dB HL; (5) high school or above education level; (6) volunteer participation.

Exclusion criteria: (1) unable to cooperate in completing all scale evaluations; (2) with external or/and middle ear diseases.

Evaluation scale

Tinnitus Evaluation Questionnaire

Tinnitus evaluation questionnaire (TEQ) is a tinnitus assessment scale developed by Chinese scholars, has similar validity and reliability to the tinnitus handicap inventory (THI) in the Chinese population, and is more operational with less time required.<sup>8-10</sup> The TEQ consists of 6 questions with a total score of 21; the higher the score, the higher the severity of tinnitus. The first 5 TEQ questions evaluated the loudness and duration of tinnitus, as well as the impact of tinnitus on sleep, attention, and mood, with 3 points for each question, totaling 15 points. The last question is the overall evaluation of the severity of tinnitus, with a total of 6 points.

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) is a tool to assess each person's sleep quality over the previous month. It consists of 5 additional evaluation questions in addition to 19 self-evaluation questions, of which 19th self-evaluation question and 5 other evaluation questions are not included in the score. With a total score of 21 points, the higher the score, the worse the sleep quality. The classification of sleep quality based on the PSQI score is as follows: Level I: 0-5, representing excellent sleep quality; Level II: 6-10, representing fair sleep quality; Level III: 11-15, representing average sleep quality; and Level IV: 16-21, representing subpar sleep quality. The subjects have sleep disorders if their sleep quality is level II or higher. The reliability and validity of PSQI scale have been evaluated by domestic scholars, which indicates that the scale has good reliability and validity. The scale can comprehensively assess the sleep quality of insomnia patients and is simple and easy to use, making it suitable for domestic patients.<sup>11,12</sup>

Montreal Cognitive Assessment Scale

The Montreal Cognitive Assessment Scale (MoCA) is a scale that can quickly detect cognitive dysfunction. The scale has 11 questions with a total of 30 points, and 26 or above are regarded as normal. According to research,<sup>13</sup> the MoCA scale (Chinese version) has good validity, reliability, and sensitivity and can be used for the initial

MAIN POINTS

- The Montreal Cognitive Assessment Scale (MoCA) scores in tinnitus without sleep disorder (TnSD) and tinnitus with sleep disorder (TwSD) groups were not only significantly lower than those in the normal control (NC) group but also significantly lower than those in the sleep disorder (SD) group.
- There was no significant difference in MoCA scores between TnSD and TwSD groups.
- Pittsburgh Sleep Quality Index (SQI), tinnitus evaluation questionnaire (TEQ), and tinnitus loudness were not significantly correlated with MoCA scores.

screening and evaluation of patients in China who have moderate-to-severe cognitive impairment. It is suitable for the evaluation and study of cognitive impairment in hospitals of various levels and can be operated with only a little training.

### Scale Evaluation Process

After informed consent, tinnitus subjects underwent TEQ, PSQI, and MoCA; subjects with sleep disorders and normal controls underwent PSQI and MoCA. Both subjects completed the scale assessment under the guidance of the same technician.

### Evaluation of the Loudness of Tinnitus

The loudness of tinnitus was evaluated by the psychoacoustic method, which was performed using the Tinnologic audiological diagnostic and management system (BetterLife Medical, China) in a soundproof chamber as per the national standards. The matching frequency and loudness of tinnitus were obtained, and the hearing threshold of this frequency was measured (dB HL). The difference between them is the loudness of tinnitus, which is represented by dB SL.

### Statistical Analysis

The data were organized and analyzed using Statistical Package for the Social Sciences Statistics software, version 24.0 (IBM SPSS Corp.; Armonk, NY, USA). Independent sample *t*-test was used for intergroup comparison of continuous variables. The intergroup comparison of name variables and rank variables was conducted using the  $\chi^2$  test. The significant difference was  $P < .05$ .

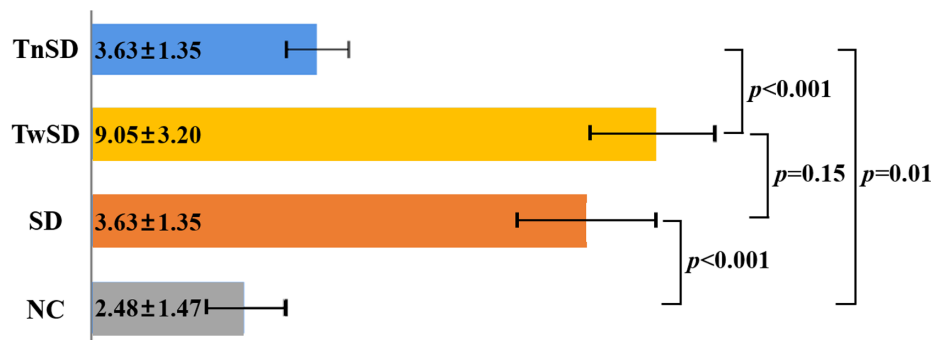
## RESULTS

### Basic Information

71 tinnitus subjects, 30 subjects with sleep disorders, and 23 normal controls were ultimately included in this project. The basic information is shown in Table 1.

### Comparison of Pittsburgh Sleep Quality Index Between Groups

The independent sample *t*-test showed that the PSQI scores in TwSD and SD groups were significantly higher than those in TnSD and NC groups ( $P < .001$ ), but there was no significant difference between TwSD and SD groups ( $P = .15$ ). In addition, although PSQI score did not indicate sleep disorders in the TnSD group, the TnSD group had a significantly higher score than the NC group ( $P = .01$ ) (Figure 1).



**Figure 1.** Comparison of Pittsburgh Sleep Quality Index scores between groups. The PSQI scores in TwSD and SD groups were significantly higher than those in TnSD and NC groups, and the TnSD group had significantly higher score than the NC group. NC, Normal healthy control; SD, sleep disorder patients without tinnitus; TnSD, tinnitus patients without sleep disorders; TwSD, tinnitus patients with sleep disorders.

**Table 1.** Basic Information of Enrolled Tinnitus Subjects/Normal Controls

Basic Information	TnSD	TwSD	SD	NC
Age <sup>a</sup>	35.67 ± 8.81	36.07 ± 8.10	36.53 ± 8.67	36.39 ± 9.58
Sex (M/F) <sup>b</sup>	20/10	24/17	17/13	14/9
Educational background <sup>c</sup>	9/18/3	10/25/6	8/17/5	4/16/3
·High school				
·University				
·Graduate student				

<sup>a</sup>Independent sample *t*-test was used to compare each 2 groups. The results showed that there was no significant difference in age between TnSD, TwSD, SD, and NC groups ( $P > .05$ ).

<sup>b</sup>Chi-square test was used to compare the sex composition ratio of the 4 groups. The result showed that there was no significant difference in the sex composition ratio between TnSD, TwSD, SD, and NC groups ( $\chi^2 = 0.73$ ,  $P = .87$ ).

<sup>c</sup>Chi-square test was used to compare the educational background of the 4 groups. The result showed that there was no significant difference in the educational background between TnSD group, TwSD group, SD group, and NC group ( $\chi^2 = 1.77$ ,  $P = .94$ ). NC, Normal healthy control; SD, sleep disorder patients without tinnitus; TnSD, tinnitus patients without sleep disorders; TwSD, tinnitus patients with sleep disorders

### Comparison of Montreal Cognitive Assessment Between Groups

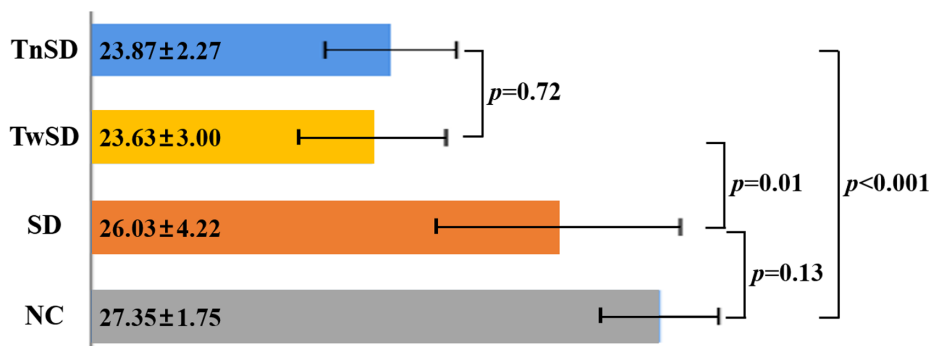
The independent sample *t*-test showed that the MoCA scores in the TnSD and TwSD groups were not only significantly lower than those in the NC group ( $P < .001$ ), but also significantly lower than those in the SD group ( $P = .02$ ,  $P = .01$ , respectively). Meanwhile, there was no significant difference in MoCA scores between the TnSD group and the TwSD group, and between the SD group and the NC group ( $P = .72$  and  $P = .13$ , respectively) (Figure 2).

### Related Factors of Montreal Cognitive Assessment in Tinnitus Subjects

The pair-to-pair correlation analysis of MoCA, PSQI, TEQ, and tinnitus loudness showed that PSQI was significantly correlated with TEQ ( $P = .016$ ), while PSQI, TEQ, and tinnitus loudness were not significantly correlated with MoCA ( $P = .693$ ,  $P = .803$ ,  $P = .690$ , respectively) (Figure 3).

## DISCUSSION

In recent years, more and more studies have shown that subjective tinnitus is a central nervous system symptom that involves global neural function remodeling,<sup>14,15</sup> and the impact of tinnitus on patient cognitive function has also received increasing attention from researchers.<sup>1</sup> However, as a common accompanying symptom of tinnitus, sleep disorders are also an important risk factor for individual cognitive impairment.<sup>6</sup> In order to better clarify the impact of

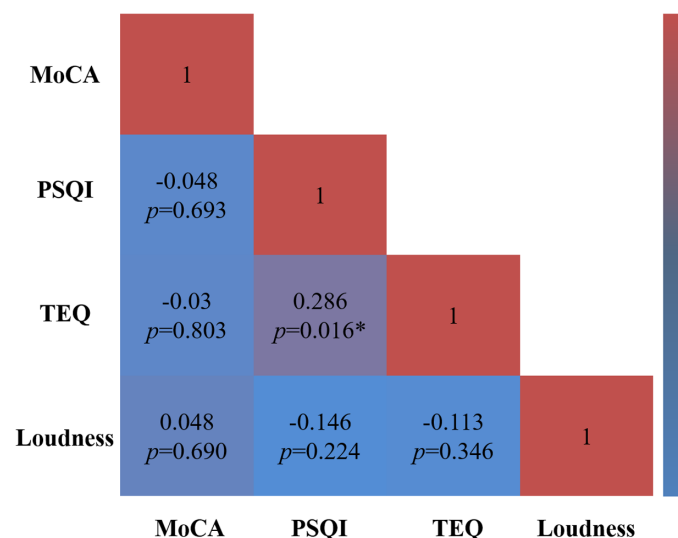


**Figure 2.** Comparison of MoCA scores between groups. The MoCA scores in TnSD and TwSD groups were significantly higher than those in NC and SD group, and there was no significant difference between TnSD and TwSD groups. MoCA, Montreal Cognitive Assessment; NC, Normal healthy control; SD, sleep disorder patients without tinnitus; TnSD, tinnitus patients without sleep disorders; TwSD, tinnitus patients with sleep disorders.

subjective tinnitus on the cognitive function of patients, this study divided the enrolled tinnitus patients into 2 groups through PSQI grading: the TwSD and TnSD groups. The MoCA was used to observe the differences in cognitive function between the TwSD, TnSD, SD, and NC groups. A preliminary exploration was conducted on the relationship between subjective tinnitus, sleep disorders, and cognitive impairment.

This study found that MoCA scores in both the TwSD and TnSD groups were significantly lower than those in the NC group, suggesting that cognitive impairment was indeed present in subjective tinnitus patients. Although previous studies have shown that sleep plays an important role in maintaining normal cognitive function,<sup>4,6</sup> the data from this study have not been able to reveal the relationship between sleep disorders and cognitive impairment in subjective tinnitus patients because MoCA scores were also significantly lower in the TwSD and TnSD groups than in the SD group, and there was no significant difference between the TwSD and TnSD groups. Therefore, subjective tinnitus may be a risk factor for cognitive impairment independent of sleep disorders.

Meanwhile, it has been widely believed that although the incidence of tinnitus is relatively high, most of them are unbothersome tinnitus patients who do not require clinical intervention, and their lives are not affected by tinnitus. Therefore, current research mainly focuses on bothersome tinnitus patients who require clinical intervention. However, this study found that MoCA score was not significantly correlated not only with PSQI score but also with TEQ and tinnitus loudness. In addition, previous studies have also shown that even unbothersome tinnitus patients have experienced a decline in their cognitive function.<sup>17</sup> These results suggest that cognitive impairment may be a common phenomenon in subjective tinnitus patients. Every activity in our life, such as learning, reading, driving, etc., is the result of a series of cognitive processes in the brain. Therefore, whether the decline in cognitive function will also affect the normal life and work of unbothersome tinnitus patients was poorly understood at the present stage. With the increasing demand of people for quality of life, the cognitive impairment of unbothersome tinnitus patients, and its potential impact on daily life, and relevant intervention strategies should also gradually receive attention.



**Figure 3.** The correlation analysis of MoCA, PSQI, TEQ, and tinnitus loudness. There was no significant correlation between MoCA, PSQI, TEQ, and tinnitus loudness except PSQI and TEQ. MoCA, Montreal Cognitive Assessment; PSQI, Pittsburgh Sleep Quality Index; TEQ, Tinnitus evaluation questionnaire.

Li and his collaborators explored the mechanism of cognitive impairment in subjective tinnitus patients through a series of studies. Through auditory mismatch negative (MMN), they found that compared to the frequency difference between biased and standard stimuli, the frequency difference between biased and tinnitus induced a more significant MMN, suggesting that the intrinsic tinnitus signal may have replaced the standard stimulus in the test, the cognitive resources of tinnitus patients are difficult to detach from tinnitus signals.<sup>16</sup> Through the signal recognition paradigm, they found that the visual processing speed of subjective tinnitus patients was slower than that of normal controls, whether it was neutral stimulus or emotional stimulus, and this difference was mainly due to the decline in the speed of detection of the signals in the early stage of cognitive processing.<sup>17,18</sup> Further, they found a loss in vision dominance in subjective tinnitus patients in the early stage of cognitive processing.<sup>19</sup> Meanwhile, resting-state functional magnetic resonance imaging (rs-fMRI) found that the functional connections of visual- and auditory-related brain regions in subjective tinnitus patients were enhanced.<sup>20</sup> Therefore, it is speculated that the cognitive impairment in subjective tinnitus patients may be due to the difficulty in separating cognitive resources from tinnitus signals, resulting in a decrease in available cognitive resources and intensified competition



for cognitive resources between different sensory channels, thereby affecting cognitive processing.

This study explored the relationship between subjective tinnitus, sleep disorders, and cognitive impairment. The preliminary results showed that subjective tinnitus maybe an independent risk factor for cognitive impairment, but the relationship between sleep disorders and cognitive impairment in subject tinnitus patients is not clear. Further experimental data are required. First, this study just collected subjective data through scales, and the results would inevitably be interfered by the subjects' willingness and experience. Therefore, more objective sleep evaluation, such as polysomnography, and more specific cognitive tasks are needed to explore the sleep disorders and cognitive impairment in tinnitus patients. Second, the experiment was designed to match hearing levels, but it was limited to the average level of 4 frequencies: 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz, so the impact of hearing loss on cognitive function has not yet been ruled out. Third, the underlying neural mechanisms between subjective tinnitus, sleep disorders, and cognitive impairment are still unclear and may be influenced by factors such as age and nutrition, so further investigation and clarification are needed. Finally, the sample size of this study is relatively limited, and subsequent studies will expand the sample size to verify and clarify the results of this study.

**Ethics Committee Approval:** This study was approved by Medical Ethics Committee of the Third Affiliated Hospital of Sun Yat-sen University (Approval No: [2019]02-229-01, Date: March 8, 2019).

**Informed Consent:** Informed consent was obtained from the patients who agreed to take part in the study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept –Z.L., X.Z.; Design – Z.L., X.Z.; Supervision – Z.L., X.Z.; Resources – X.Z.; Materials – Z.L.; Data Collection and/or Processing – M.Q., J.Z., T.H., S.Z., L.L.; Analysis and/or Interpretation – M.Q.; Literature Search – J.Z., T.H.; Writing – M.Q., Y.L., Z.L.; Critical Review – Z.L., X.Z.

**Declaration of Interests:** The authors have no conflict of interest to declare.

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