Annals of Otology, Rhinology & Laryngology
1–9

DOI: 10.1177/0003489418805766
journals.sagepub.com/home/aor
SAGE

Polysomnographic Findings in Patients With Chronic Tinnitus

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Abstract

Objectives: Tinnitus is an auditory sensation in the absence of any external stimulus. It has a negative impact on quality of life and interferes with concentration, sleep, social activities, and even emotional stability. The aim of this study was to compare sleep architecture in patients with and without chronic subjective tinnitus.

Methods: This was an observational, noninterventional, and prospective study. The sample consisted of 50 individuals of both sexes aged 20 to 60 years. Twenty-five patients with tinnitus constituted the study group, and for comparison, a control group consisting of 25 patients without reported tinnitus was formed. The patients underwent polysomnography and were administered the Epworth Sleepiness Scale, Tinnitus Handicap Inventory, and visual analog scales.

Results: The group with tinnitus had higher mean values in sleep stages 1 and 2, and lower mean values in stage 3 and in rapid eye movement (REM) sleep, compared with the control group, and this difference was significant only for REM sleep ($P = .031$). This demonstrates that patients with tinnitus remained longer in shallow sleep and spent less time in deep sleep (stage 3) and REM sleep.

Conclusions: This study shows that patients with tinnitus have significant alterations in REM sleep latency as well as the REM sleep phase.

Keywords

sleep, Tinnitus Handicap Inventory, Epworth Sleepiness Scale, obstructive sleep apnea syndrome, tinnitus, otology, otolaryngology

Introduction

Tinnitus is an auditory sensation in the absence of any external acoustic stimulus and is frequently related to auditory loss.[1,2] It is a common disorder, with variable prevalence rates.[1] Statistics from epidemiologic and clinical studies in Germany, the United Kingdom, and the United States suggest that about 35% to 45% of adults have experienced tinnitus at some point in their lives.[3] Within the totality of patients with tinnitus, 2.4% have severe tinnitus, significantly compromising their quality of life.[4]

Many approaches have been developed to quantify tinnitus. Besides the psychometric values of tinnitus or intensity values of minimum masking, visual analog scales (VASs) and numeric scales for tinnitus have been used. Different standardized questionnaires to evaluate the disadvantages related to tinnitus have also been developed, validated, and translated into various languages.[5] VASs are a subjective, one-dimensional method, easy to apply, that can be used to measure the level of intensity and the inconvenience of tinnitus. They are rapidly administered, and patients can assign grades of 1 (least intense) to 10 (most intense).[6] The VAS approach to scaling tinnitus uses a straight line (the visual analog for such continua as the loudness or the severity of tinnitus), without any numbers. The standard length of the line is 10 cm, and there should be verbal anchors at each end of the line to indicate the intended range of values. The respondent receives instructions to mark the line clearly at the point that best corresponds to his or her tinnitus. It has traditionally been felt that VASs provide maximum precision compared with other types of scales, but there is considerable evidence that they are difficult for some patients to

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respond to, in particular the elderly or those with some degree of physical or visual impairment.[7]

The Tinnitus Handicap Inventory (THI) is a validated questionnaire broadly used to evaluate the impact of tinnitus on daily life. The THI is also frequently used to document the results of tinnitus treatment, though this is not its original purpose.[5] The THI consists of 25 items, each with the options "yes" (4 points), "sometimes" (2 points), and "no" (0 points). The sum of the points resulting from the questions ranges from 0 (all responses are negative, when tinnitus has no impact on the patient's life) to 100. According to the classification proposed by McCombe et al[8] (18-36%) is light (38-56%)is moderate, (58-76%)is severe and (78-100%) is catastrophic.[9]

A series of studies have found that sleeping was listed as the most difficult activity for patients with tinnitus. Insomnia was classified as the main problem in 50% of patients with severe tinnitus, and the severity of tinnitus was correlated to the occurrence of sleep disorders.[10,11] The sensation of tinnitus can occur before sleep because of the diminished masking effect resulting from the reduction of external noise, causing an increase in the perception of tinnitus. Moreover, anxiety due to tinnitus and concern regarding tinnitus before falling asleep or after waking up during the night can prolong the time required to fall back asleep.[12]

The approach to patients with sleep disorders follows the usual medical evaluation and the application of various questionnaires, such as the Epworth Sleepiness Scale (ESS), as well as examinations such as polysomnography (PSG).[13,14]

The ESS is a subjective method widely used to assess excessive daytime sleepiness. It is a self-administered questionnaire that assesses the likelihood of falling asleep in 8 situations involving daily activities. The punctuation indicated in all situations investigated is summed up and analyzed. Results between 0 and 10 points indicate no drowsiness between 10 and 16 points, mild drowsiness; between 16 and 20 points, moderate drowsiness; and between 20 and 24 points, severe somnolence.[6,13,15]

PSG is the gold standard for the diagnosis and classification of the severity of respiratory sleep disorders and analysis of the structure and quality of sleep. However, PSG is not always available in day-to-day clinical practice, as it requires time for analysis and is an expensive examination.[16] The discovery that respiratory disorders related to sleep are common greatly contributed to the application of PSG as a tool to diagnose sleep disorders.[17]

Methods

This observational, noninterventional, and prospective study took place at Instituto Brasiliense de Otorrinolaringologia do Distrito Federal, with the help of Instituto do Sono da Asa Norte. All patients treated provided written consent authorizing their participation in the study. The study was approved by Comitê de Ética em Pesquisa do Hospital das Forças Armadas (Research Ethics Committee of the Army Hospital), under protocol 55725916.9.0000.0025.

Patients treated in the otorhinolaryngology ambulatory of Instituto Brasiliense de Otorrinolaringologia do Distrito Federal with tinnitus and sleep-related symptoms were oriented to undergo PSG at Instituto do Sono da Asa Norte. Indications for the examination included the presence of 1 or more sleep-related symptoms, such as snoring, exhaustion, agitated sleep, insomnia, obstructive sleep apnea syndrome, interrupted sleep, or sleepiness during the day (group 1). Patients with sleep disorders without tinnitus constituted group 2 (control). The fact that both groups presented symptoms related to sleep was important to ensure that both shared similar characteristics.

After enrollment, patients were distributed in 2 groups, 1 with tinnitus and 1 without. Patients with tinnitus constituted the study group, and for comparison, a control group was formed consisting of patients without reported tinnitus. The sample was made up of 50 individuals of both sexes (25 in each group), 20 to 60 years of age. The only difference between the study and the control groups was the absence of tinnitus in the control group. Besides the examination, the group with tinnitus was administered the ESS, the THI, and the VAS for tinnitus annoyance. Patients in the control group also underwent PSG and were administered the ESS. When arriving at Instituto do Sono da Asa Norte to take the examination, each patient answered the questionnaires and then underwent PSG. The results of PSG were blindly read, as the physicians responsible for reporting the examinations were unaware of the study.

Inclusion Criteria

The following patients were included in the study: those with sleep disorders, both female and male, who also had tinnitus over a period longer than 6 months, between 20 and 60 years of age, able to undergo PSG. The control group was submitted to the same criteria but did not experience tinnitus.

Exclusion Criteria

The following patients were excluded from the study: patients under psychotropic or sleep medication, those using continuous positive airway pressure, those with bruxism, those with substance abuse, shift workers, those with obstructive sleep apnea syndrome, those with restless leg syndrome, those with diagnosed neurologic diseases, those with body mass index values greater than 40 kg/m^2, and those younger than 20 or older than 60 years of age. Patients with obstructive sleep apnea syndrome were excluded after undergoing PSG.

Statistical Analysis

The χ^2 test was used to verify the similarity of data behavior between the control group and the study group, considering a significance level of $P < .05$. This was done using the data analysis plugin for analysis of variance in Excel (Microsoft, Redmond, WA).

Standard deviation and average rates were measured for each sample parameter to assess the dispersion of the groups. For the study group, the parameters for the VAS and THI were also compared with the ESS score.

Another statistical value measured was the Pearson correlation coefficient, which indicates if there is a direct influence in the behavior between the variables, valued between −1 and 1.

Results

With regard to gender, the tinnitus group had 13 female patients and 12 male patients. The control group was made up of 9 female patients and 16 male patients. The difference between the groups was not statistically significant ($P = .392$) (Figure 1).

Regarding age, we found similar mean ages in the 2 groups, 36.08 years in the control group and 41.56 years in the tinnitus group. This difference was not statistically relevant ($P = .075$) (Figure 2).

The patients were asked the following question: "How intense is your tinnitus most of the time?" Response options were mild (scores of 0.1-2), moderate (scores of 3-7), and severe (scores of 8–10). This was recorded on the VAS. The majority of patients had tinnitus of moderate intensity (63%); 12% considered their tinnitus mild, and 25% considered it severe. These data are shown in Figure 3.

To assess the degree of annoyance of tinnitus, patients responded to the THI. The results of this questionnaire showed that no patient had tinnitus considered catastrophic. Patients with slight and mild tinnitus accounted for 66% and those with moderate and severe tinnitus for 34%. These results are shown in Figure 4.

We used the ESS to assess daytime sleepiness. The results could be analyzed statistically, considering that both groups answered this questionnaire. Scores on this questionnaire can vary from 0 to 24 points, and no patient scored higher than 21. There was no significant statistical difference between the study and control groups regarding this scale ($P = .122$). The data are shown in Figure 5.

After analyzing the results of all questionnaires answered by the tinnitus group, the data were compiled in a graph to evaluate a distribution tendency. As the values of the ESS went up, there was also an increase in the results of the other scales (VAS and THI). The results of this analysis are shown in Figure 6.

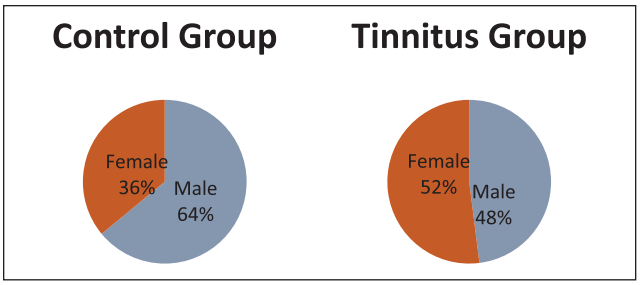

Figure 1. Percentage distribution by gender.

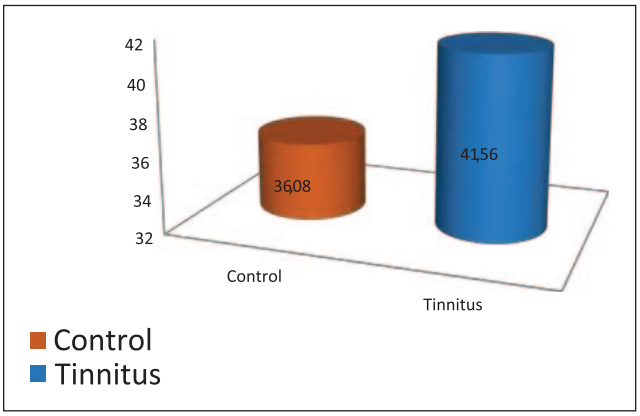

Figure 2. Average age between groups.

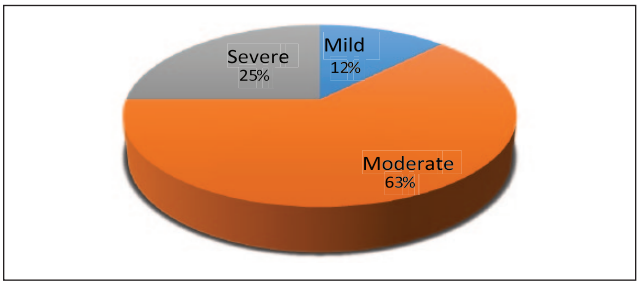

Figure 3. Visual analogic scale.

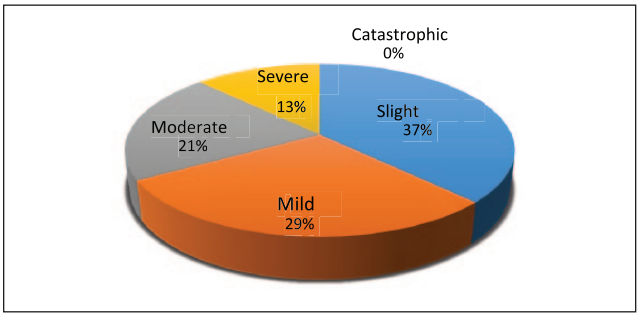

Figure 4. Distribution according to Tinnitus Handicap Inventory.

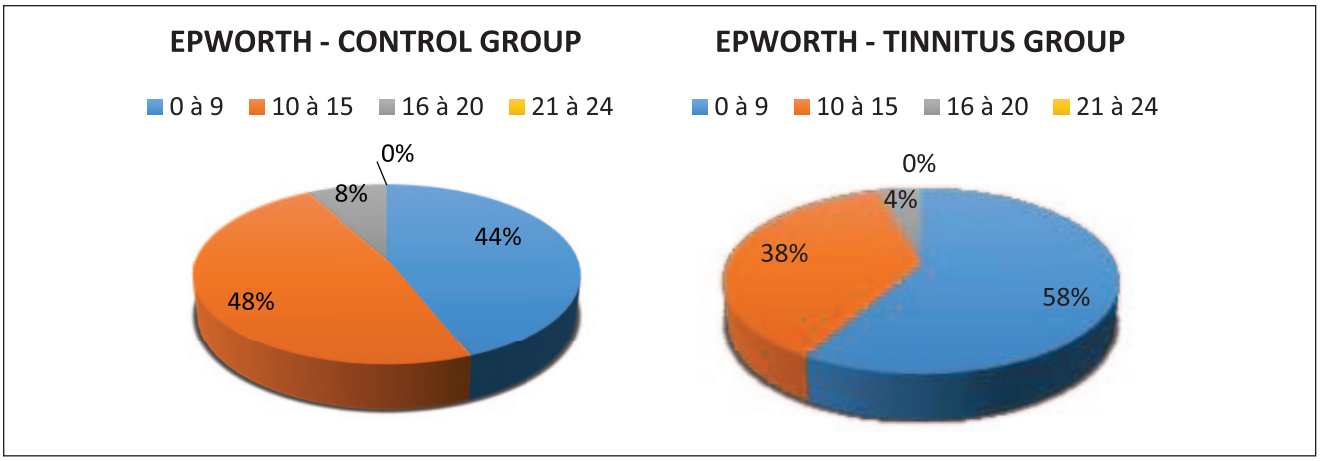

Figure 5. Epworth Sleepiness Scale: comparison between groups.

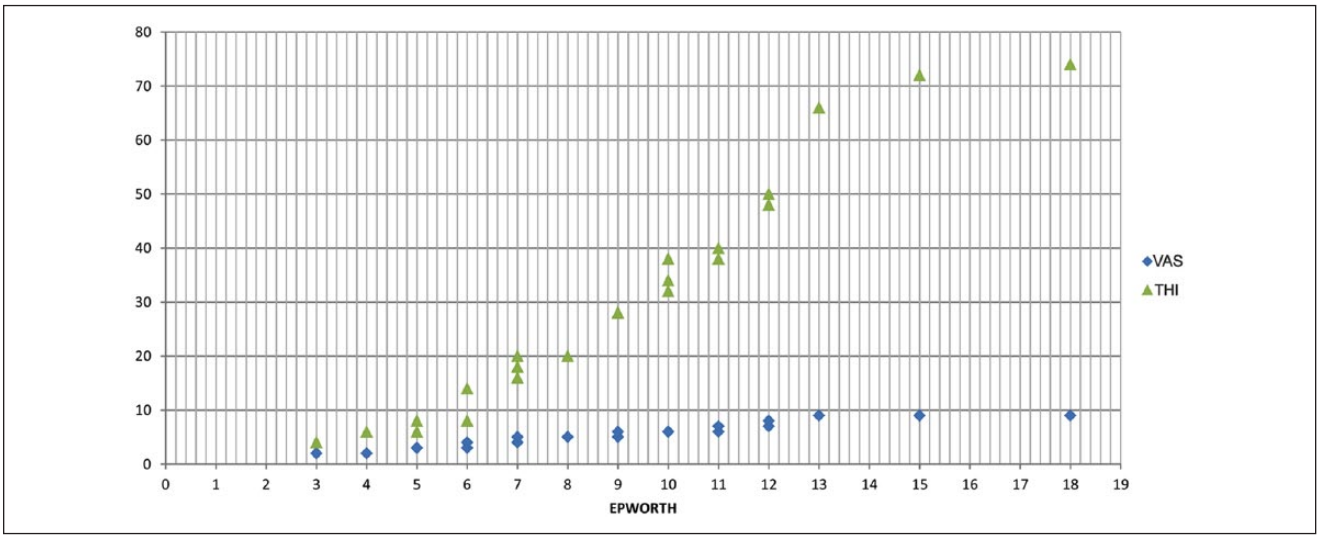

Figure 6. Correlation between the Epworth Sleepiness Scale, Tinnitus Handicap Inventory, and visual analogic scale.

A few parameters from PSG were chosen for analysis and further comparison between the groups. These parameters were stage 1, stage 2, stage 3, and rapid eye movement (REM) sleep; number of awakenings; time awake (wake time after sleep onset); and delay of REM sleep. In each group, percentages of patients with normal and abnormal results were calculated. In addition, an overlap of the graphs was done to improve comparison between the groups. Orange charts represent the tinnitus group, and blue charts represent the control group. Each parameter on PSG was evaluated separately, and each group was superimposed for better visualization. According to the Sleep Staging Manual, the normal percentages of each sleep stage are as follows: stage 1, up to 5%; stage 2, between 45% and 55%; stage 3, between 15% and 20%; and REM sleep, between 20% and 25%.

In stage 1 of sleep, values below 5% are considered normal and values above 5% abnormal. In the control group, 72% of patients had abnormal values, while in the tinnitus group, this number reached 80%. After analyzing the percentages of normal and abnormal results, the graph with the number of patients in each range of stage 1 was overlapped for better visualization (Figure 7). The comparison between the groups showed that the difference was not statistically significant ($P = .100$). In Figures 7 to 10, the vertical axis shows the frequency (ie, the number of patients), and the horizontal axis shows the percentage of each stage of sleep.

For stage 2 of sleep, the normal values are between 45% and 55%. Values that are either below 45% or above 55% are considered abnormal. The overlap of the results for each group is presented in Figure 8. The difference between the groups was not significant ($P = .253$).

For stage 3 of sleep, results are considered normal if they are between 15% and 20%. The overlap of these values can

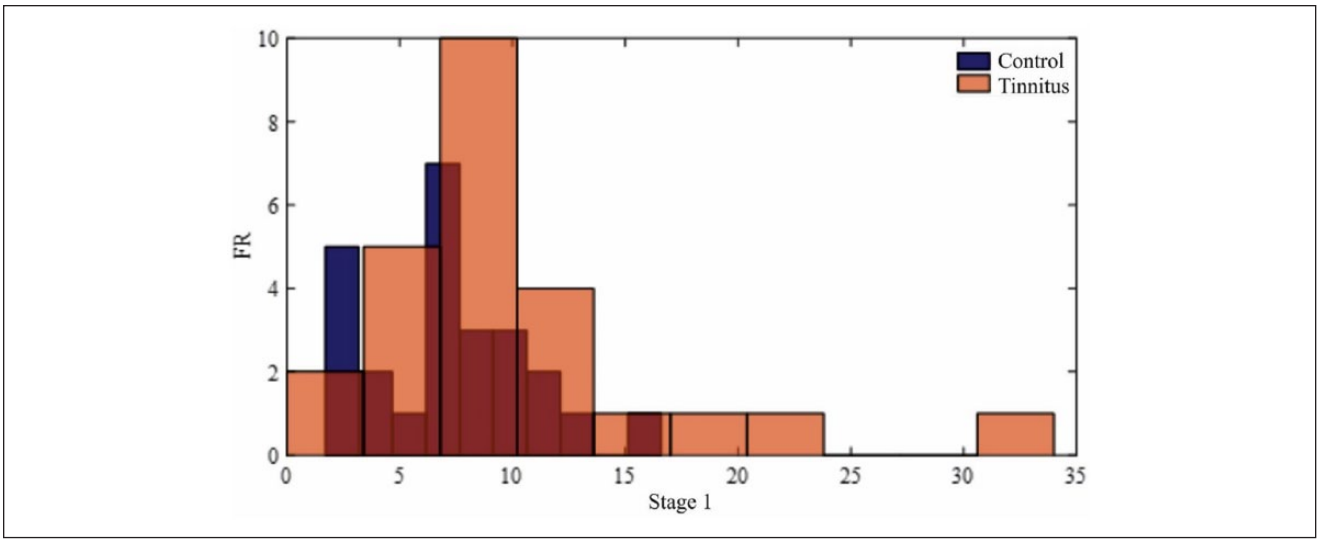

Figure 7. Overlap of results for each group for stage 1 sleep. FR, frequency or number of patients.

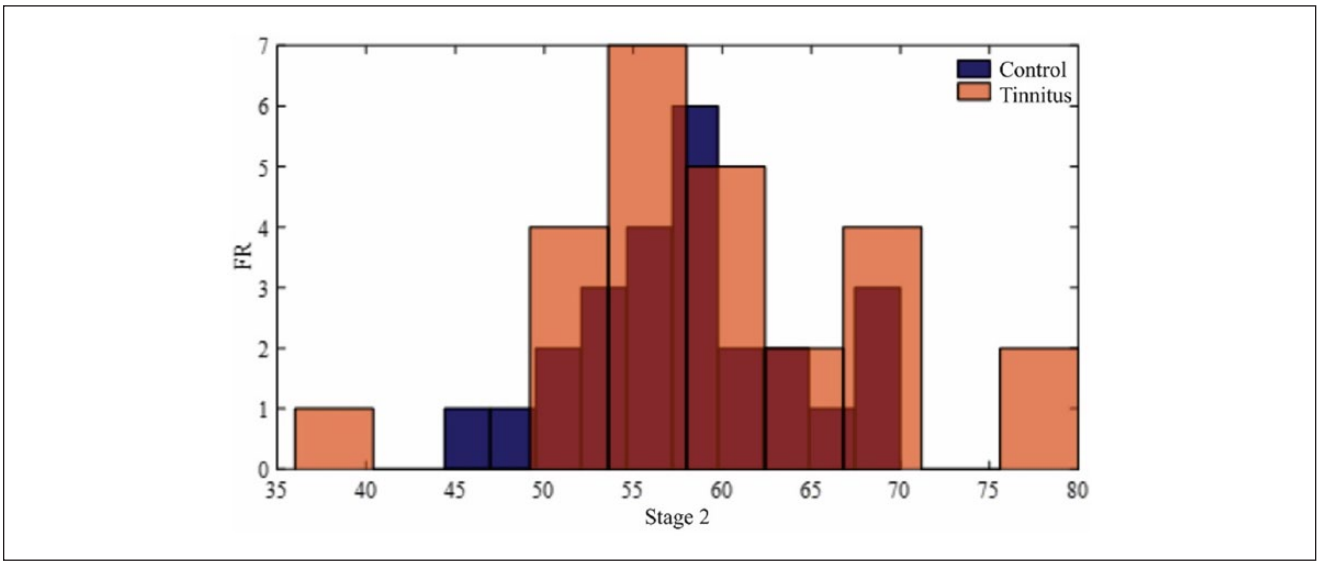

Figure 8. Overlap of results for each group for stage 2 sleep. FR, frequency or number of patients.

be seen in Figure 9. The difference between the groups was not statistically significant ($P = .377$).

In relation to REM sleep, values between 20% and 25% are considered normal. The difference between the groups was considered statistically significant ($P = .0375$). The overlap is presented in Figure 10.

The results related to the number of awakenings per hour of sleep in each group are presented in Figure 11. The difference was not significant ($P = .108$). For young adults, a number lower than 16 is considered normal.

The time awake (in minutes) in each group, and its overlap, is shown in Figure 12. The difference between the groups was not statistically relevant ($P = .252$).

The last evaluated parameter was latency for REM sleep, which is the time needed to reach REM sleep. This latency is considered normal for values between 70 and 120 minutes. The difference between the groups was considered significant ($P = .0477$). Figure 13 shows these results.

Discussion

The prevalence of tinnitus has been investigated in many other population studies, with the biggest ones being conducted in Europe, the United States, and Japan. A Japanese study evaluated 14,423 adults and observed a higher percentage of occurrence in men (13.2%) than in women

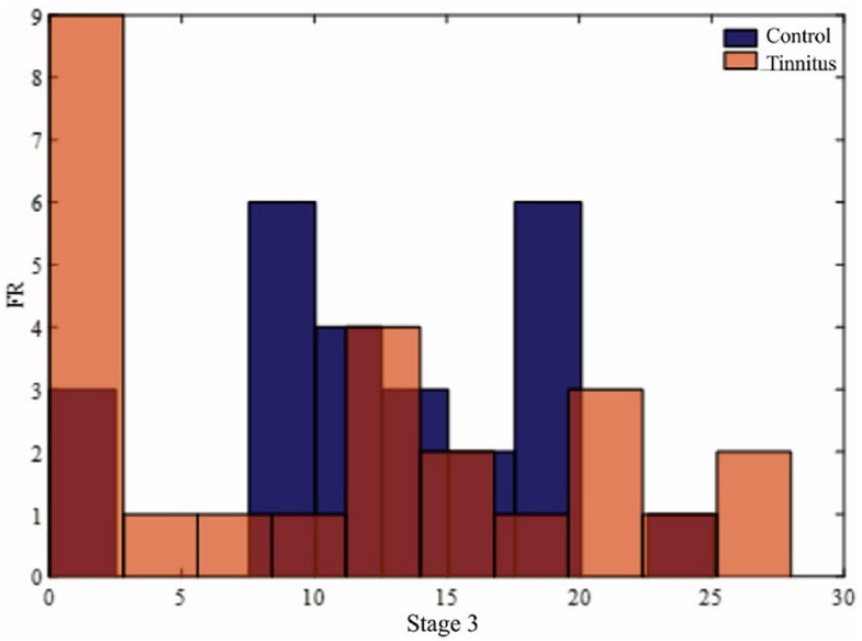

Figure 9. Overlap of results for each group for stage 3 sleep. FR, frequency or number of patients.

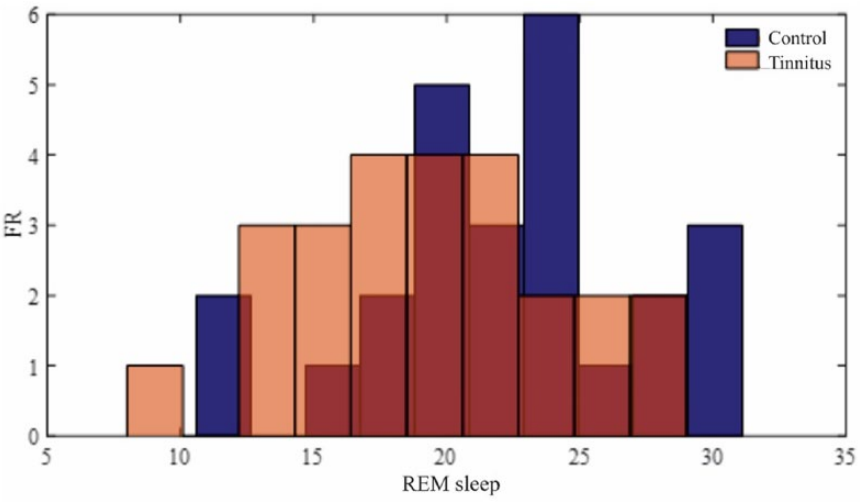

Figure 10. Overlap of results for each group for rapid eye movement (REM) sleep. FR, frequency or number of patients.

(10.8%).[18] Axelsson and Ringdahl[19] also reported a higher chance of tinnitus in men. A study of population prevalence in the United States evaluated 14,178 participants and found a larger number of women with tinnitus (52.1%) than men (47.9%).[20]

As it is, there is no consensus with regard to gender and tinnitus occurrence. Either way, women are more likely to report tinnitus and report its annoyance. A study conducted by Seydel et al[21] showed that regardless of age and tinnitus duration, women were more bothered by tinnitus and showed more stress signs than men.

In the present study, the result was similar to the aforementioned American study, but there was no statistical relevance ($P = .392$). The 3 scales administered to the group with tinnitus are correlated in Figure 6, and there is a clear tendency of increase of each scale, specially after number

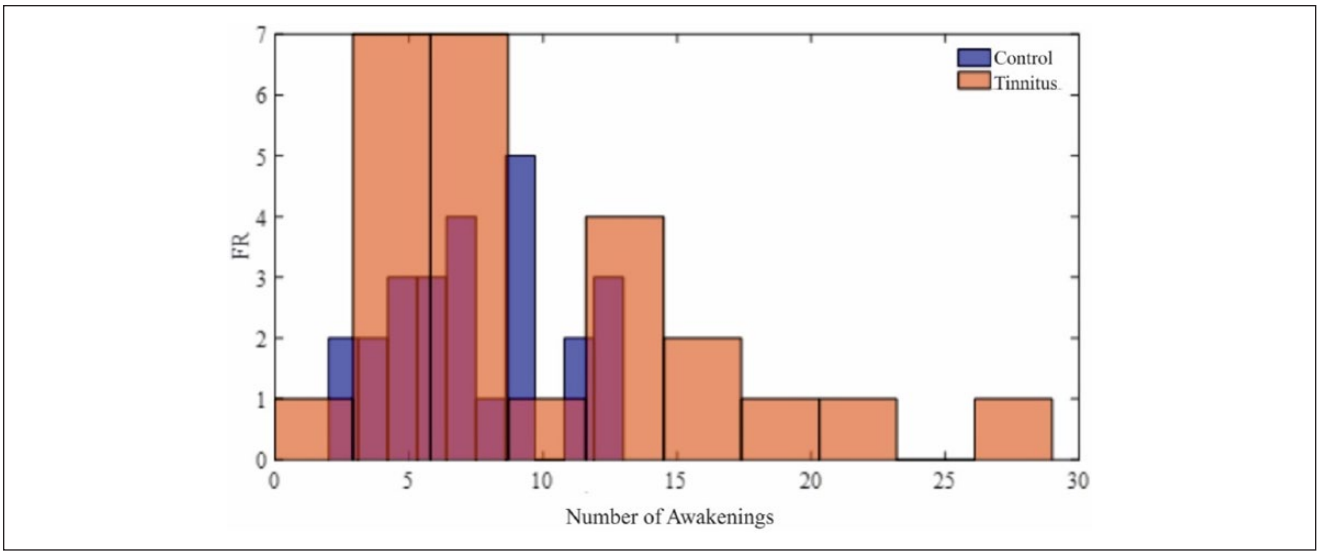

Figure 11. Overlap of each group in relation to the number of awakenings. FR, frequency or number of patients.

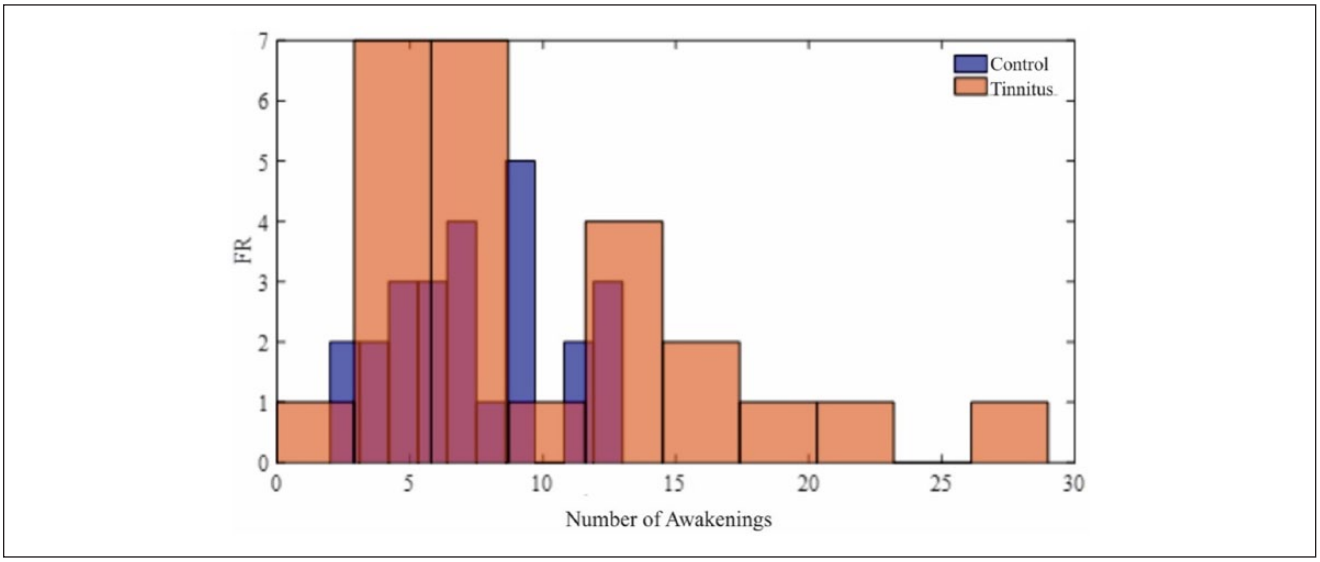

Figure 12. Overlap of each group with regard to time awake. FR, frequency or number of patients; WASO, wake time after sleep onset (minutes).

10 on the ESS. This shows that a greater intensity and annoyance of tinnitus lead to more daytime sleepiness. However, there is no clear explanation for how tinnitus can lead to a sleep disorder. One possibility is that when environmental noise lowers during the night, perception of tinnitus can increase, because of useless thoughts, mood swings, and physical reactions, thus leading to a cycle of anxiety, excitement, and anguish.[22]

The ESS was administered to both groups because it is a sleep evaluation scale. In the group with tinnitus, 42% had altered results. In the control group, 56% had altered results, but the difference was not significant ($P = .122$). This may have happened because the 2 groups both reported sleep disturbances. The results were different from other studies showing higher percentages of altered outcomes in patients with tinnitus. One study administered the ESS in 94 patients, and the results showed that the group without tinnitus deficiency had lower mean ESS than the tinnitus group, but there was also no significant difference, despite the higher mean values found in the group with tinnitus.[22]

Few studies have used PSG to analyze the sleep of patients with tinnitus. Besides being a difficult examination to prepare, it is expensive. For that reason, the majority of studies rely on sleep questionnaires because they are easier to handle and lower in cost.

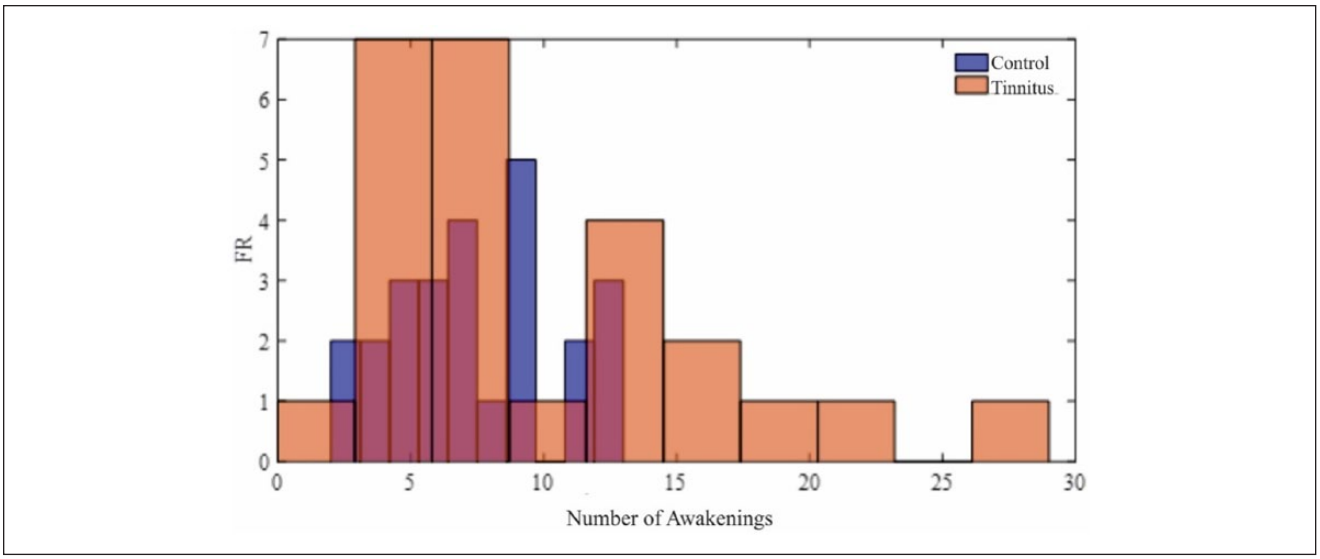

Figure 13. Overlap of each group with regard to the delay (latency in minutes) in reaching rapid eye movement (REM) sleep. FR, frequency or number of patients.

As for the percentage of patients with abnormal results, we can see that the majority of patients showed abnormalities in stages 1, 2, 3, and REM sleep. It is important to remember that the difference between the groups was significant only for REM sleep ($P = .031$).

Alster et al[23] evaluated the results of PSG in 10 patients with reported tinnitus and found a higher REM sleep delay (⩾70 minutes) in 6 patients. However, there was no control group for comparison.

With regard to the other PSG data, the average number of awakenings and rate of awakenings were higher in the tinnitus group (56.8 awakenings and 9.6 awakenings/hour of sleep) than in the control group (50.24 awakenings and 7.4 awakenings/hour of sleep). However, such differences were not statistically significant. The average of time awake during the examination was also higher in the tinnitus group (94.4 minutes) than in the control group (72.5 minutes). This shows that tinnitus patients were awake for longer periods of time, though this difference is not significant.

In a similar study, the stages of sleep and other variables were analyzed in 10 patients with tinnitus, who were compared with 20 patients with insomnia and 20 healthy control patients. In terms of to sleep continuity, patients with tinnitus showed reduced sleep efficacy, less time asleep, and a larger number of awakenings, all with significant results. Patients with tinnitus had a lower percentage of stage 2 sleep, a higher percentage of stage 1 sleep, and lower latency for REM sleep compared with the control group, though statistically not significant.[24]

In the present study, there was a longer time to reach REM sleep (normal values being 70-120 minutes) in the study group (average, 133 minutes). The control group needed an average of 103 minutes to reach REM sleep. This was an important piece of data, as it is statistically significant ($P = .047$).

A more recent work, from 2013, evaluated the results of PSG in 18 patients with chronic tinnitus and 15 control subjects, finding a statistical difference ($P < .001$) in stages 1, 3, and REM sleep.[25]

We observed that all studies that used PSG had small sample sizes, which shows the difficulty of using PSG in research studies, as it is costly.

When evaluating the results related to REM sleep, we can remember that there exists an interaction between the neural networks related to sleep and emotion. Insomnia includes the ascendant reticular formation and hypothalamus, the emotional regulatory system is located in the hippocampus, amygdala, and anterior cingulate cortex, and the cognitive system in the prefrontal cortex.[26] Aside from this correlation, neurons of the locus coeruleus show activity during REM sleep and awakenings and participate in auditory transmission. These anatomic analyses can explain the existence of a correlation between tinnitus and sleep, specially in its REM phase.

As for limitations of the study, we had a relatively small sample size, so some of the data showed no statistical significance. It also was not possible to find patients in a single clinic, because of difficulty finding a sufficient sample. We do not have data on otoacoustic emissions, tinnitus loudness, and audiometry, but this does not influence our results. Another limitation was the presence of a minority of patients with severe or catastrophic tinnitus, which could have shown a higher relevance in the parameters.

Even with these limitations, our work shows clinical relevance, as many patients with tinnitus frequently report difficulty in sleeping. With these results, we can orient ear,

nose, and throat physicians to evaluate these patients' sleep with more precision, if they show sleep-related symptoms.

Further studies will be necessary to evaluate treatments and solutions to improve sleep quality and overall quality of life for these patients. Furthermore, new studies with more patients could give more detailed information about this correlation between REM sleep and tinnitus.

Conclusion

This study showed that patients with tinnitus had significant alterations in REM sleep latency and in the REM sleep phase. This shows that PSG is useful in investigating patients with chronic tinnitus and reported sleep disturbances.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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