

Association between sleep disorders, hyperacusis and tinnitus: Evaluation with tinnitus questionnaires

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Abstract

Patients with tinnitus are heterogeneous and several factors influence the impact of this symptom on the quality of life. The aim of the study is to evaluate the relationship between age, gender, sleep disorders, hyperacusis and tinnitus annoyance and to demonstrate the utility of tinnitus questionnaires as screening tools for sleep disorders and hyperacusis in patients with tinnitus. 37 consecutive patients (18 males and 19 females) with subjective tinnitus lasting over 3 months were evaluated with a complete interview, otological examination, pure tone audiometry, Italian version of tinnitus sample case history (TSCH) and tinnitus handicap inventory (THI). Statistical analysis was performed with the Wilcoxon's rank sum test, the Spearman's rho non-parametric correlation and the logistic regression analysis. THI grades were slight (16%), mild (32%), moderate (30%), severe (19%) and catastrophic (3%). Based on the answers to TSCH 20 patients reported sleep disorders (54%) and 20 patients reported hyperacusis (54%). 11 patients (30%) reported sleep disorders and hyperacusis. No significant correlation was found between the severity of tinnitus and patients' age and gender. Significant correlation was found between sleep disorders ($P = 0.0009$) and tinnitus annoyance and between hyperacusis ($P = 0.03$) and tinnitus annoyance. TSCH and THI may be considered as screening tools in the clinical practice to evidence sleep disorders and hyperacusis in patients with tinnitus.

Keywords: Hyperacusis, sleep disorders, tinnitus

Introduction

Tinnitus is defined as a perception of a sound in the head without an external acoustic source and it has an adverse effect on the quality of daily life.^[1] Tinnitus has been classified in several ways and many studies have investigated the origin of tinnitus even if many hypotheses have not yet been proven.^[2-6] Tinnitus can be also accompanied by sleep disorders and hyperacusis with a high impact on tinnitus perception. It is still uncertain whether the hearing loss is only a trigger for the onset of tinnitus or is strictly related to tinnitus loudness and quality because tinnitus can be also present in patients with a normal audiogram. Schaeffe *et al.*^[7] reported that, in subjects with tinnitus and a normal audiogram, auditory brainstem responses show a significantly reduced amplitude of the wave I potential (generated by primary auditory nerve fibers) but normal amplitudes of the more centrally generated wave V. This provides direct physiological evidence of "hidden

hearing loss" that manifests as reduced neural output from the cochlea and consequent renormalization of neuronal response magnitude within the brainstem. Employing an established computational model, they demonstrated how tinnitus could arise from a homeostatic response of neurons in the central auditory system to reduced auditory nerve input in the absence of elevated hearing thresholds. Based on the scores obtained in tinnitus questionnaires^[8-10] no correlation can be found between audiometric results and the quality of tinnitus. Hyperacusis is defined as a condition of over sensitivity to loud and even moderately loud sounds with a discomfort level for pure tones lower than normal. The mechanism involves the auditory pathways^[11] and it's probably linked to a hyperactivity of the central auditory system. Hyperacusis and tinnitus in many cases coexist: 40% of patients with tinnitus show a decreased sound tolerance while 86% of patients with hyperacusis report the presence of tinnitus^[12] but this relationship between tinnitus and hyperacusis is still obscure. Hyperacusis can be an isolated problem and in many cases there is no relationship with hearing threshold.^[13] Insomnia comprehend a range of sleep related complaints such as insufficient sleep duration and effectiveness for difficulty falling asleep, early morning wakefulness and difficulty in maintaining sleep, with a prevalence that range from 25% to 60%. Insomnia is one of the most common problems reported by patients with tinnitus.^[14-17] The prevalence of sleep disorders in tinnitus sufferers is variable from 25% to 77%. Many factors influence the different values of prevalence

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	DOI: 10.4103/1463-1741.110287

as the onset of tinnitus, comorbidities associated to tinnitus, the use of subjective sleep studies with questionnaires rather than objective sleep studies with polysomnography.^[18,19]

Although tinnitus is not a specific sleep antagonist, when the environmental noise is lower in the night time, tinnitus awareness is higher with the arising of unhelpful thoughts, mood changes and physical reactions, which can lead to a vicious cycle with anxiety, increased arousal and distress. It is important to remember that sleep disorders can lead to consequences like mood disturbance and cognitive impairment, which play an important role in tinnitus therapy selection criteria and individual assessment. The aim of this study is to assess the relationship between genders, age, sleep disorders and hyperacusis with the tinnitus induced annoyance.

Methods

We studied 37 consecutive patients, selected with unilateral or bilateral subjective tinnitus lasting over 3 months as their primary complaint. A complete clinical otorhinolaryngological and audiological examination was made with pure tone audiometry (125-8.000 Hz), impedenzometry and distortion-product otoacoustic emissions. Exclusion criteria were acute or chronic pathology of the external auditory canal or middle ear, Eustachian tube dysfunction, sleep breathing disorders like obstructive sleep apnea syndrome, neurological disorders and abuse of caffeine (more than three cups of tea/coffee per-day).

All patients were evaluated with the Italian version of tinnitus sample case history (TSCH) and tinnitus handicap inventory (THI).^[20,21] TSCH is a standardized questionnaire with items on background (age, gender, family history of tinnitus), tinnitus history (initial onset, associated events, pattern, site, loudness, pitch, percentage of awake time aware of tinnitus, previous tinnitus treatments, modifying influences, hyperacusis, alteration by movements, effect of nocturnal sleep, effect of stress, effect of medications) and related conditions (hearing impairment, noise annoyance, headaches, vertigo/dizziness, mandibular joint disorder, neck pain, psychiatric problems).^[22] Relevant questions of TSCH about sleep and hyperacusis are: “Is there any relationship between sleep at night and your tinnitus during the day?”; “Do you have a problem tolerating sounds because they often seem much too loud?”; “That is, do you often find too loud or hurtful sounds which other people around you find quite comfortable?”. When a sleep problem was reported by the patient, we asked to specify if the problem was difficulty falling asleep, waking in the night or too early in the morning.

THI is a 25-item questionnaire with “yes” (4 points), “no” (0 points) or “sometimes” (2 points) answers. The scores are added to yield a classification of tinnitus annoyance: Slight (0-16), mild (18-36), moderate (38-56), severe (58-76) or catastrophic (78-100). Relevant question of THI about sleep

is: “Because of your tinnitus do you have trouble falling asleep at night?”

Data are presented as means ± SD. The Wilcoxon’s rank sum test was performed to evaluate the differences between mean THI scores in subjects with and without hyperacusis and sleep disorders. Spearman’s rho non-parametric correlation was applied to evaluate the correlation between age and the THI scores. Logistic regression analysis was performed to evaluate the association between sleep disorder and four independent co-variates (sex: Female, age: >56, THI: >56 and hyperacusis). The confidence intervals for the regression parameters and the confidence intervals of odds ratios were estimated using the profile likelihood function. All statistical analyses were performed using SAS statistical software (Statistical Analysis System Institute, Inc., Rel. 9.2, 202-2008, Cary, North Carolina). The study was conducted according to the guidelines on biomedical research involving human subjects (Declaration of Helsinki). Informed consent was obtained from each patient.

Results

In this study 37 patients were included, 18 males (48.6%) and 19 females (51.4%). Age ranged from 34 to 81 years (mean 57.2 ± 14.1 years).

Based on the answers to TSCH 20 patients (54%) reported sleep disorders and 20 patients (54%) reported hyperacusis. Of these, 11 patients (30%) reported sleep disorders and hyperacusis [Table 1].

Based on THI score these 11 patients were classified as two mild (one with moderate high frequencies hearing loss and one with normal hearing), four moderate (one with mild high frequencies hearing loss, one after viral upper airways infection, one after sudden hearing loss, one with normal hearing), four severe (three after sudden hearing loss, one with severe high frequencies hearing loss), one catastrophic (post-stapedotomy).

Table 2 shows the final mean score and the standard deviation of THI results according to sex. There were no statistically significant differences in the THI scores according to sex with

Table 1: Patients with sleep disorder and hyperacusis based on the answers to tinnitus sample case history

Gender	Sleep disorder	Hyperacusis	Sleep disorder and hyperacusis
Females	12	10	6
Males	8	10	5

Table 2: Means and standard deviation for tinnitus handicap inventory in 37 patients differentiated for gender

Gender	n	THI (mean)	SD
Females	19	41.1	22.9
Males	18	34.7	21.7
Total	37	37.9	22.2

THI = Tinnitus handicap inventory

the Wilcoxon's rank sum test ($P = 0.36$). It was not possible to find any correlation between the annoyance of tinnitus and the age of the patients ($R = -0.006$; $P = 0.73$).

The classification of tinnitus annoyance in 37 patients based on THI scores is reported in Table 3.

Means and standard deviation for THI scores in 37 patients differentiated for the presence of sleep disorder and hyperacusis are reported in Tables 4 and 5 respectively. Based on the THI grading according to the presence of sleep disorder it was evidenced a frequent association between moderate and severe THI grading and sleep disturbance. Based on the THI grading according to the presence of hyperacusis it was found a frequent association between mild and moderate THI grading and the presence of hyperacusis.

The Wilcoxon's rank sum test revealed a statistically significant difference (P value = 0.03) between patients with hyperacusis (n value: 20) and tinnitus annoyance (mean THI: 45 ± 21.4).

In the logistic regression analysis, THI score >56 (n value: 8) was significantly associated with sleep disorders (P value = 0.0009; OR = 8.546; 95% CI 1.189-178.01) corrected for the effect of other independent co-variates (age: >56 , sex: Female and hyperacusis).

Discussion

The annoyance of tinnitus on patient's life may vary from

Table 3: Classification of tinnitus handicap in 37 patients based on tinnitus handicap inventory scores

THI grading	Patients (%)
Slight	6 (16)
Mild	12 (32)
Moderate	11 (30)
Severe	7 (19)
Catastrophic	1 (3)

THI = Tinnitus handicap inventory

Table 4: Grading of tinnitus handicap inventory, means and standard deviation for tinnitus handicap inventory in 37 patients differentiated for the presence of sleep disorder

Sleep disorder	n	THI (mean)	SD	THI score				
				Slight n	Mild n	Moderate n	Severe n	Catastrophic n
No	17	24.9	18.8	6	7	3	1	0
Yes	20	49	19	0	5	8	6	1

THI = Tinnitus handicap inventory

Table 5: Grading of tinnitus handicap inventory, means and standard deviation for tinnitus handicap inventory in 37 patients differentiated for hyperacusis

Hyperacusis	n	THI (mean)	SD	THI score				
				Slight n	Mild n	Moderate n	Severe n	Catastrophic n
No	17	29.6	20.8	5	6	4	2	0
Yes	20	45	21.4	1	6	7	5	1

THI = Tinnitus handicap inventory

slight to catastrophic if measured with the THI. A number of studies have been controversial in relating gender to the prevalence of tinnitus.^[23,24] According to the literature^[25,26] we find no difference in the level of annoyance due to tinnitus among males and females and in relation to the age on the basis of THI score.

Many studies have shown that the disability generated by tinnitus depends on primary psychological factors. The amount of worrying and attention that the patient devotes to it often resulting in a vicious circle in which the patient cannot deal. Moreover, a strong correlation is described between the severity of tinnitus annoyance and the presence of psychiatric conditions like depression and anxiety.^[27-31] Some authors reported a relationship between the severity of tinnitus and the degree of hearing loss.^[31-34] Other authors have suggested that the influence of hearing loss on tinnitus loudness still remains uncertain because no statistic correlation was found.^[26,35,36]

Our study is focused on the relationship between sleep disorder, hyperacusis and tinnitus annoyance. In the group of 11 patients with tinnitus associated with hyperacusis and sleep disorder, we found four patients affected by a sudden hearing loss, two patients with normal hearing and five patients with neurosensorial hearing loss. As reported by Katzenell and Seagal^[37] hyperacusis can be associated with different pathologies of the peripheral auditory system (Bell's palsy, Ramsay Hunt syndrome, post-stapedectomy, perilymph fistula), disease of the central nervous system (migraine, depression, post-traumatic stress disorder, head injury, multiple sclerosis) and infectious disease (Lyme disease) but in many cases, we cannot identify the origin of hyperacusis. In our study only one patient developed tinnitus and hyperacusis after stapedotomy and one patient was affected by depression. No significant difference in sex distribution was found in the group of patients with hyperacusis.

Hiller^[38] reported a severe tinnitus annoyance and intensity in older male patients with binaural tinnitus and hyperacusis, in line with our results. Many authors evidenced a major distress in patients with tinnitus associated with sleep disorders.^[18,39,40] Our study, which found sleep disorders in 54% of patients with tinnitus, has revealed with interview data of TSCH that difficulty in maintaining sleep was most predominant. As reported in the literature, we also found a prevalence of sleep disorders in females (12 of 20 patients with sleep disorders). Our subjective sleep study is based on the answers given to

TSCH and provides only limited information about the effect of tinnitus. It is a subjective test limit because many patients underestimate their effective quality of sleep. An objective technique, like the polysomnography with the study of the sleep structure, may better assess the patient's sleep. Even if it's not clear if sleep disorder is a consequence or a comorbid condition of tinnitus-sufferers, many patients think that sleep disorders are a consequence. Sleep disorders may occur more frequently in patients with recent onset tinnitus^[18] but the results of many studies on the relationship between tinnitus and sleep are contradictory. In our study, we also report a high association between sleep disorder and elevated THI score (>56), corrected for age (>56), sex (female) and hyperacusis.

In conclusion, high THI scores revealed elevated level of annoyance generated by tinnitus and may evidence a correlation with hyperacusis and sleep disorders. These last two parameters must be always considered to assess a correct therapy and a greater emphasis should be placed on improving sleep. Several questionnaires are used in the evaluation of sleep like the Pittsburgh sleep quality index (PSQI)^[41] and the Insomnia symptom questionnaire.^[42] After an interview about patient's experience with hyperacusis a specific questionnaire like Khalfa hyperacusis questionnaire^[43] may help to address severity of the hyperacusis. The assessment of specific audiological measures like the loudness discomfort level (LDL) is suggested to detect an abnormal sound-level tolerance. Gu *et al.*^[13] studied subjects with and without tinnitus and hyperacusis. The subjects were evaluated with behavioral tests (sound level tolerance questionnaire and tinnitus reaction questionnaire), LDL and functional Magnetic Resonance Imaging to measure sound-evoked activation of central auditory centers. Subjects with a decreased sound tolerance level presented a higher activation in the inferior colliculus, medial geniculate body compared with subjects without hyperacusis. These results may confirm the hypothesis that tinnitus and hyperacusis may arise from abnormal activation in the neural pathways. The major limit of our study was the very small sample size.

The most important strength of our study is the use of THI and TSCH to evaluate the relationship between tinnitus, sleep disorders and hyperacusis. Specific questionnaires like the PSQI and the Khalfa hyperacusis questionnaire and audiometric tests like LDL can be studied to better understand the relationship between sleep disorders and hyperacusis in tinnitus patients, preferably in a longer cohort study.

In conclusion we suggest that TSCH and THI can be considered as screening tools in the clinical practice to evidence sleep disorders and hyperacusis which subsequently will be investigated with specific questionnaires and clinical assessment.

Acknowledgments

We thank S. Necozone for assistance with data collection and statistical analysis.

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How to cite this article: Fioretti AB, Fusetti M, Eibenstein A. Association between sleep disorders, hyperacusis and tinnitus: Evaluation with tinnitus questionnaires. *Noise Health* 2013;15:91-5.

Source of Support: Nil, **Conflict of Interest:** None declared.

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