# IS THERE A RELATIONSHIP BETWEEN AUDIOGRAM SHAPE AND THE INTENSITY AND DURATION OF TINNITUS?

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# DA LI POSTOJI VEZA IZMEĐU IZGLEDA AUDIOGRAMA I JAČINE I DUŽINE TINITUSA

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## ABSTRACT

*Chronic tinnitus is often associated with hearing impairment, but it cannot be asserted that only hearing loss causes tinnitus. Audiograms of patients with tinnitus show that hearing loss occurred more often at high frequencies than at low frequencies.*

*The aim of this study was to analyse the audiogram shapes of patients with chronic tinnitus and to identify the relationship between the shape of the audiogram and intensity and duration of tinnitus.*

*This investigation was a cross case series study conducted at a general hospital in Kraljevo on patients with chronic subjective tinnitus. The study included 43 patients of both genders and of different ages. We used audiometry (measuring the threshold of hearing for frequencies from 250, 500, 1000, 2000, 4000 and 8000 Hz) and tympanometry. Each patient reported the intensity of tinnitus in each ear on a visual analogue scale (VAS[1]) and stated the duration of tinnitus for each ear.*

*Our research showed that patients with chronic tinnitus had a characteristic audiogram with progressive hearing loss to high frequencies. This difference was significantly increased starting from lower to higher frequencies, and the most hearing-decreased range ("edge") was between 2000 and 4000 Hz. We did not find a strong link between the tinnitus intensity measured by the visual analogue scale and tinnitus duration on one side and hearing loss in the studied patients and audiogram shape on the other side. The duration of tinnitus was most associated with hearing loss at 2000 Hertz, but even that was not significant.*

**Keywords**: *tinnitus, audiogram, visual analogue scale*

## SAŽETAK

*Hronični tinitus je često udružen sa oštećenjem sluha ali se se ne može tvrditi da samo oštećenje sluha uzrokuje zujanje u ušima. Na osnovu audiograma pacijenata sa tinitusom, češće se uočava oštećenje sluha za visoke nego za niske frekvencije.*

*Cilj ove studije je bio analiziranje izgleda audiograma pacijenata sa hroničnim tinitusom i ispitivanje povezanosti između izgleda audiograma i intenziteta i trajanja tinitusa.*

*Studija praćenja, rađena u Opštoj bolnici u Kraljevu kod pacijenata sa hroničnim subjektivnim tinitusom. U istraživanje je uključeno 43 pacijenta oba pola različite životne dobi (meren je prag sluha na oba uva na frekfencijama 250, 500, 1000, 2000, 4000 i 8000 Hz). Koristili smo audiomerijsko testiranje i timpanometriju. Pacijenti su se izjašnjavali o jačini tinitusa za svako uvo na vizuelno analognoj skali, kao i o dužini tinitusa za svako uvo.*

*Rezultati našeg istraživanja su pokazali da kod pacijenata sa hroničnim tinitusom postoji karaketrističan audiogram sa progresivnim oštećenjem sluha idući ka visokim frekfencijama sa najvećim padom u opsegu između 2000 i 4000 Hz. Ta razlika se statistički povećava idući od nižih ka višim frekfencijama. Nismo našli jaku vezu između jačine tinitusa merenog vizuelno analognom skalom i dužine tinitusa sa jedne strane i ukupnog gubitka sluha kod ispitivanih pacijenata i izgleda audiograma sa druge strane. Dužina tinitusa najviše je povezana sa gubitkom sluha na 2000 herca ali ni ona nije značajna*

**Ključne reči:** *tinitus, audiogram, vizuelno analogna skala*

[1] VAS/ visual analogue scale

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## INTRODUCTION

Tinnitus is defined as a phantom sound perception, i.e., the perception of sound without appropriate acoustic or mechanical correlations in the cochlea (1). The American Tinnitus Association estimates that approximately 50 million Americans suffer from tinnitus and that 12 million people have sought medical help because of tinnitus (2). Approximately 15% of people experience tinnitus, and in persons over 65 years of age, the incidence of tinnitus reaches 30% (3). Within approximately 6 to 25% of affected persons, tinnitus causes a considerable amount of stress (4-6), which leads to a seriously impaired quality of life in approximately 2-4% of the population (7). Tinnitus can interfere with sleep, concentration, social contact and work (8). Persons with tinnitus have an increased prevalence rate of anxiety and depression (9-10). Many experts differ regarding subjective and objective tinnitus (11). Objective tinnitus is created in the body and can be spread to the ear. It is mostly generated in the vascular system and can be heard by another person. An individual with subjective tinnitus hears the sound although an external source of sound is absent. Subjective tinnitus is much more common and reflects some insufficiently known disorders of the auditory pathway. It can be of a different intensity and tonality, permanent or intermittent. The aetiology and pathogenesis are unclear. Tinnitus is accompanied by hearing loss, but not always. Hearing loss in aging is sometimes accompanied by tinnitus. Tinnitus is the first symptom of an acoustic neurinoma and persists after removal of the tumour. Numerous pharmacological agents, such as salicylates, diuretics, quinine, indomethacin, antidepressants, antihistamines, beta-adrenergic blocking agents, local anaesthetics, and corticosteroids, can cause tinnitus. There is often a vitamin B12 deficiency in patients with tinnitus (13). The mechanism of how these agents cause tinnitus is not well understood. In most patients, tinnitus is accompanied by hearing loss. However, contrary to expectations, tinnitus is not associated with total hearing loss but with the appearance of the audiogram (14,15). Recent studies indicate that hearing loss at high frequencies and a steeply sloping audiogram with reduced plasticity of the brain cause a phantom sound. A similar mechanism causes phantom pain. In the second part, we wanted to determine whether the intensity and duration of tinnitus correlated with the appearance of the audiogram. There are additional scales, mainly in English, that classify the intensity and severity of tinnitus, but there are no validated scales in the Serbian language that estimate the severity of tinnitus; therefore, we used a visual analogue scale and the tinnitus duration for each ear individually. We assumed that there is a link between these factors and the appearance of the audiogram. We have not found similar research in the literature. The existence of these links would be useful for further research on the deficiencies of domestic scales. Therefore, the aim of this study was to determine whether there is a specific audiogram for persons with chronic subjective tinnitus, and if so, whether there is a relationship to the tinnitus duration and intensity measured on the visual analogue scale.

## MATERIALS AND METHODS

This case series study, which was conducted on patients who appeared to have tinnitus in the ENT department of the general hospital in Kraljevo. The study was approved by the ethics committee of the general hospital (20-2/5-a, 28.9.2015.), and informed consent was obtained from all subjects. The study included only patients with subjective tinnitus and patients with tinnitus longer than six months, bilateral or unilateral. The study excluded patients with acoustic neurinomas and Meniere's disease as well as patients with objective or pulsatile tinnitus. The patients underwent audiometry (Amplaid A321 Twin channel) and certain thresholds of hearing for frequencies from 250 to 8000 Hertz, and the level of hearing loss in each ear and the total hearing loss were determined using Fowler-Sabin (FS) tables and tympanometry (Amplaid Tympanometer A756 Screening). All of the patients used a visual analogue scale (VAS) from 1 to 10 to report the severity of tinnitus for each ear; the visual analogue scale correlates with the tinnitus handicap index THI scores (16). We measured the tinnitus duration in each ear; every patient stated the continuance of tinnitus for each ear.

## STATISTICS

The study used the following statistical methods: the independent samples test and Mann-Whitney test, the correlation method and the regression model. We compared whether there was a statistically significant difference in hearing loss between adjacent frequencies in each ear (250 Hz and 500 Hz, 500 Hz and 1000 Hz, 1000 Hz and 2000 Hz, 2000 Hz and 4000 Hz, 4000 Hz and 8000 Hz). The second part showed that there was a link between the intensity of subjective tinnitus measured by the visual analogue scale (VAS) and the audiogram shape and hearing loss in the same ear (FS[2] table) as well as whether there was a link between the tinnitus duration and audiogram shape and hearing loss in this ear (FS table). We used the method of correlation analysis.

## RESULTS

Forty-three patients participated in the study. There were 23 male patients and 20 female patients. The average age (mean) of the patients was 63 years; the standard deviation (SD) was 11,163. The tympanogram was normal in all the patients (Type A). The audiogram indicated sensorineural hearing loss (41 patients) or was normal hearing (2 patients). The values of the hearing thresholds at different

[2] Fowler Sabine

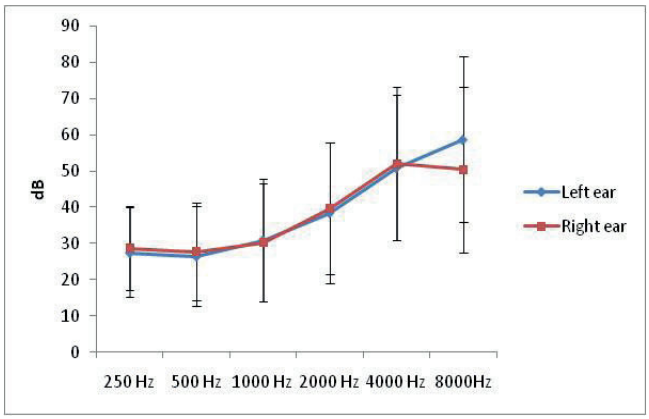



**Figure 1.** Values of hearing loss at different frequencies in the left and right ear. Each value is presented as the mean±SD. (* p<0,05)

frequencies for the left and right ear are shown in Figure 1. Each value is presented as the mean±SD.

The average hearing loss[3] in both ears of a given patient (43) was 20.68%. The average hearing loss in the right ear was 22.68% and in the left ear was 25.88%. The composed audiogram of hearing loss in the left and right ear is shown in Picture 1.

We compared the hearing threshold between the two neighbouring frequencies groups (43 thresholds per group) on the audiogram for each ear separately using the independent samples test and the Mann-Whitney test. The results of the statistical study are shown in Table 1).

The average values of the tinnitus intensity (VAS) and the tinnitus duration (years) for each ear are listed in Table 2).

The coefficient of correlation linking the hearing loss and its corresponding frequency for the left ear was 0,963 and for the right ear was 0,958. The regression curve for the left ear was y = 27,587 + 0,04x and for the right ear was y = 28,289 + 0,004x.

[3] Calculated by Fowler Sabine tab.

**Table 1.** Statistical values for comparing the hearing threshold between the two neighbouring frequencies for the left and right ear, separately. p<0.005, probability of the null hypothesis for the difference between frequency groups, MW - Mann-Whitney test

| Independent samples test and Mann-Whitney test | | | | | |
|---|---|---|---|---|---|
| frequency (Hz) | 250-500 | 500-1000 | 1000-2000 | 2000-4000 | 4000-8000 |
| p[§] for the left ear | 0,817 | 0,23 | 0,087 | 0,03 | 0,119[2MW] |
| p for the right ear | 0,89 | 0,57 | 0,007 | 0,006[MW] | 0,068[MW] |

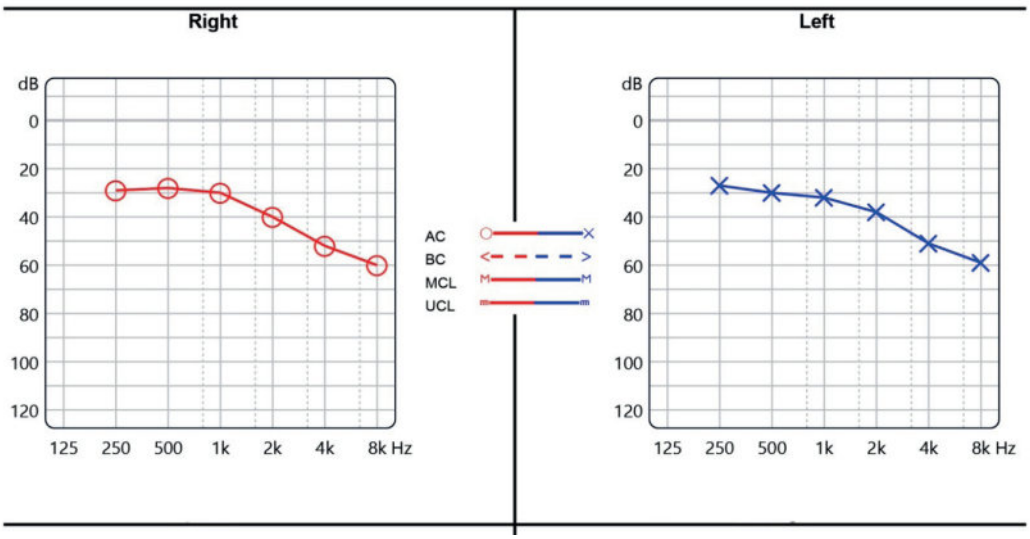
[§]p<0.005, probability of the null hypothesis for the difference between frequency groups
[MW]Mann-Whitney test

**Table 2.** Mean and median of the tinnitus intensity and duration. VAS, visual analogue scale;SD, standard deviation

| | | VAS[**] Left | VAS Right | Duration Left (years) | Duration Right (years) |
|---|---|---|---|---|---|
| N | Valid | 41 | 41 | 43 | 43 |
| | Missing | 2 | 2 | 0 | 0 |
| Mean (r) | | 5,24 | 4,83 | 4,298 | 3,942 |
| Median | | 5,00 | 5,00 | 2,000 | 2,000 |
| SD[4] | | 1,969 | 2,024 | 5,0710 | 4,7273[5] |

[**] SD, standard deviation

We compared the total hearing loss and hearing threshold for each frequency on one hand and the intensity of tinnitus (measured by the VAS) on the other side of each ear. We compared the average hearing loss and hearing threshold for each frequency on the one hand and the duration of tinnitus (expressed in years and months) on the other side of each ear. We used the method of correlation analysis. The research results are presented in Tables 3 and 4. Picture 2 shows a graphical schedule, the correlation




**Picture 1.** Composed audiogram of hearing loss in the left ear.

**Table 3.** Correlation analysis between the hearing threshold group and the tinnitus intensity and duration in the right ear. S - Spearman's correlation coefficient

| Pearson and Spearman's correlation coefficients for the right ear | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Hearing threshold** | **250 Hz** | **500 Hz** | **1000 Hz** | **2000 Hz** | **4000 Hz** | **8000 Hz** | **average** |
| Tinnitus intensity | 0,287$^{S}$ | 0,288$^{S}$ | 0,280$^{S}$ | 0,237$^{S}$ | 0,214$^{S*}$ | 0,169$^{S}$ | 0,342$^{S}$ |
| **Hearing threshold** | **250 Hz** | **500 Hz** | **1000 Hz** | **2000 Hz** | **4000 Hz** | **8000 Hz** | **average** |
| Tinnitus duration | 0,110 | 0,062 | 0,043 | 0,239 | 0,235$^{S}$ | 0,175$^{S}$ | 0,263 |

* Spearman's coefficient

**Table 4.** Correlation analysis between the hearing threshold group and the tinnitus intensity and duration in the left ear. S - Spearman's correlation coefficient

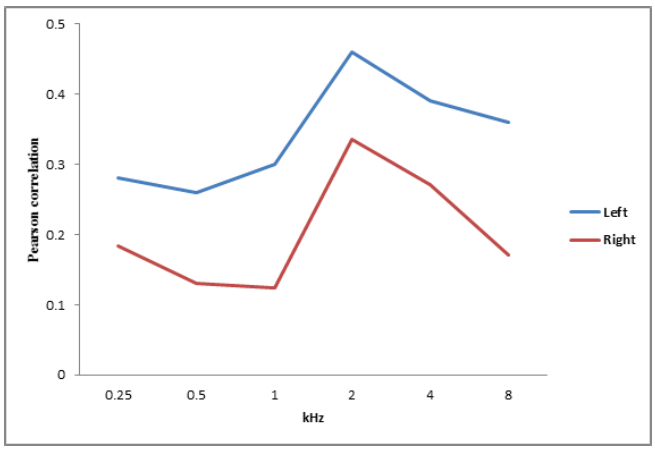
| Pearson and Spearman's correlation coefficient for the left ear | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Hearing threshold** | **250 Hz** | **500 Hz** | **1000 Hz** | **2000 Hz** | **4000 Hz** | **8000 Hz** | **Average*** |
| Tinnitus intensity | 0,225 | 0,262 | 0,289 | 0,356 | 0,245$^{S}$ | 0,257$^{S}$ | 0,312 |
| **Hearing threshold** | **250 Hz** | **500 Hz** | **1000 Hz** | **2000 Hz** | **4000 Hz** | **8000 Hz** | **Average** |
| Tinnitus duration | 0,207 | 0,241 | 0,3 | 0,388 | 0,347 | 0,415$^{S}$ | 0,294 |

* average hearing threshold calculated by the FS table

coefficient obtained by comparing the duration of tinnitus and hearing threshold at the measured frequencies.

## DISCUSSION

Tinnitus is a symptom with various aetiologies. Most likely, all levels of the nervous system in various degrees are involved in the tinnitus event (17, 18). The opinion has been posed that tinnitus is a result of an increased spontaneous discharge rate of individual auditory nerve fibres. This view has been encouraged by the fact that electrical stimulation of the cochlea mitigates tinnitus. Some diseases such as Meniere's disease accompanied by tinnitus are localized to the ear. However, hearing loss, which is often associated with tinnitus, is accompanied by hypoactivity of nerve fibres. Tinnitus is thought to be caused by hyperactivity of nerve fibres. Currently, cochlear damage is usually considered to be affected by the outer hair cells,




**Picture 2.** Graphical schedule. The correlation coefficient was obtained by comparing the tinnitus duration and hearing threshold at the measured frequencies.

whose activity can be measured by otoacoustic emissions, as detected by Kemp (19). These emissions are rarely observed in patients with hearing impairments and much cannot be expected from them in the diagnosis of tinnitus. Patients with unbearable tinnitus have only discrete abnormalities on the BERA test. This is contrary to the assumption that tinnitus causes an increase in spontaneous activity of the auditory nerve fibres. Today, there is growing evidence that decreased activity of auditory nerve fibres leads to hyper-reactivity in the central auditory pathways. In animal experiments, ear injuries and removal of the cochlea cause increased activity of the lower colliculi and auditory nuclei (20), in contribution to the central mechanisms of the occurrence of tinnitus, which persists even after surgical resection of the auditory nerve in most experiments (21). Using NMR and SPECT in patients with tinnitus increases the activity of the associative auditory area for more than just the primary area (22). The limbic and autonomic nervous system exclusively determines each tinnitus event. There is much evidence about the role of stress in the pathogenesis of tinnitus. Stress in patients with tinnitus causes a sympathetic reaction (23).There is an increasing integration of the frontal cortex, hippocampus and other structures. The problem of tinnitus is much more complex than previously thought. In this paper, we aimed to study the audiological profile of people with chronic tinnitus and its relationship to the intensity and duration of tinnitus. More authors believe that the audiogram shape holds some answers to the aetiology of tinnitus. Most publications favour a steep audiogram in patients with tinnitus (14, 15). Our results are consistent with the assertions of Moller, Demeeseter and Konig (24, 14, 15). The difference in the hearing threshold, measured between the adjacent frequencies progressively increases with a higher frequency. The results are statistically significant for the left ear between 2000 and 4000 Hz ($p = 0.03$) and for the right ear between 1000 and 2000 Hz (p

= 0.007). Between 2000 and 4000 Hz (p=0,006), the analysed population in our study had a steeply sloping audiogram. Our audiogram had an audiometric edge between 1000 and 4000 Hz. The analysis included patients with tinnitus who had normal hearing. We did not separately analyse the patients who worked in noisy environments. This steeply sloping audiogram associated with reduced brain plasticity may be important for the aetiology of tinnitus (tonotopic reorganization theory) (25).

In the second part of our research, we did not find a strong link between the loudness of the tinnitus measured by VAS on one side and the average hearing threshold for each ear individually and the hearing threshold for each frequency measured on the other side. We started from the assumption that measured subjective tinnitus is associated with hearing loss or hearing loss at certain frequencies. This connection is weak (correlation coefficients less than 0.3) or medium (correlation coefficients less than 0.5 and greater than 0.3.). VAS is a subjective assessment volume and cannot fully indicate the severity of tinnitus but shows results for monitoring the therapeutic effect of a drug or therapeutic method. Currently, there are more scales that assess the intensity and severity of tinnitus, none of which have been validated in the Serbian language, for example: The Tinnitus Severity Scale (TSS) (26), the Tinnitus Handicap Questionnaire (THR) (27), the Tinnitus Handicap Inventory (THI) and the Tinnitus Questionnaire (TQ) (28). The work of certain authors shows a connection between the VAS and the THI (29).

We did not find a strong link in our research between the duration of tinnitus on one side and the average hearing threshold in each ear and the hearing threshold at each of the measured frequencies in the other ear (correlation coefficient of less than 0.5). The relationship between tinnitus duration and hearing threshold at each frequency was weak (correlation coefficient less than 0.3) or medium strong (correlation coefficients between 0.3 and 0.5). This relationship exhibited a certain regularity and was strongest at 2000 Hz and gradually decreased going towards both ends of the audiogram (Table 3, Table 4 and Picture 2). Notably, the greatest hearing decrease occurred at this frequency range (between 2000 and 4000 Hz), which had an audiometric edge. This is a very important frequency range in the pathogenesis of tinnitus. One zone in the auditory cortex is significantly less active than others. It creates a compensatory sound in the brain (phantom sound) with a frequency range between 2000 and 4000 Hz. The limitation of this research is that we did not separately assess different categories of chronic subjective tinnitus.

## CONCLUSION

Tinnitus and hearing loss are not related measures in persons with chronic subjective tinnitus, but tinnitus is associated with the audiogram shape. Hearing in people with tinnitus rapidly decreases with higher frequencies. The most hearing-decreased range is between 2000 and 4000 Hz. The severity of tinnitus experienced by the patient is not related to the degree of hearing loss and is not associated with hearing loss at some frequencies (audiometric shape). The relationship between tinnitus duration and hearing loss and audiometric shape is not strong. It is the strongest at 2000 Hz and decreases towards each end of the audiogram.

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