Original Article

Tinnitus and Underlying Theoretical Mechanism: The Key and Lock?

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Abstract

Background and Aim: To evaluate the association between psychoacoustical characteristics of tinnitus and audiogram configurations and reveal which theoretical mechanism dominates tinnitus. **Materials and Methods:** The medical charts of 110 adult participants' 164 ears with tinnitus were retrospectively reviewed. Audiological results, edge frequency, and psychoacoustical characteristics of tinnitus were assessed. Participants were divided into two groups as follows: normal hearing (NH) and sensorineural hearing loss (SNHL). **Results:** No significant relationship was observed between age, gender, tinnitus pitch, and loudness between the two groups. In the SNHL group, there was a weak positive correlation between tinnitus pitch and frequency of maximum hearing loss (FMHL), and a strong positive correlation between the mean tinnitus loudness at the tinnitus pitch and FMHL. Besides, the edge frequency was positively and weakly correlated with the tinnitus pitch and FMHL. No statistically significant difference was observed between the groups regarding the tinnitus pitch. However, tinnitus loudness was statistically higher in the NH group. No relationship was observed between the audiogram shapes and tinnitus timbre, pitch, and FMHL. In addition, the most likened tinnitus timbre was found to be tonal/whistle in both groups. A moderate positive correlation was observed between the tinnitus pitch and edge frequency in the gradual slope audiograms. **Conclusions:** The findings obtained in this study supported homeostatic plasticity theories for the SNHL group, and hidden hearing loss for the NH group.

Keywords: *Edge frequency, tinnitus, tinnitus mechanisms, tinnitus pitch*

Introduction

Tinnitus is a common and distressing otologic symptoms of which pathogenesis has still not been entirely illuminated.[1,2] The observations such that the majority of patients with tinnitus also suffer from various degrees of hearing loss and the increase in the severity of tinnitus as hearing deteriorates emerge the hypothesis that the hearing loss may be a potential trigger for tinnitus.[3,4] Psychoacoustic assessment of tinnitus can be used to evaluate the mechanisms of tinnitus generation. Many studies have investigated the relationship between the psychoacoustical characteristics of tinnitus and audiometric characteristic of hearing loss for decades and theorized several mechanisms, but the results have some controversial issues.[5-11] However, it has not been clarified yet whether there is a relationship between the tinnitus pitch and the audiometric edge,[4-7,10,12-14] which remained to be investigated.

Objective

This study aimed to evaluate the association between the psychoacoustic parameters of tinnitus and audiological data and reveal which mechanism is responsible for the emergence of tinnitus.

Materials and Methods

Ethical considerations and study design

This retrospective nonrandomized clinical research was approved by Dokuz Eylül University, Ethical

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Committee (protocol number: 2019/17-15). In this study, all interventions involving human volunteers were also in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Study size, setting, participants, and eligibility

The medical charts of the patients who experienced tinnitus for at least 3 months and were admitted to the department of Otorhinolaryngology, from January 1, 2016, to December 31, 2019, were reviewed (n = 256). The exclusion criteria were fluctuating hearing loss, conductive hearing loss, stapedial otosclerosis, retrocochlear pathologies, history of otological surgery, head trauma, ototoxicity, neurological disorders, presence of external, middle and inner ear infections, any abnormalities in otomicroscopic examination, other results than Type A tympanogram in 226 Hz tympanometry (Madsen Zodiac Type 1096, GN Otometrics, Denmark), and aged under 18 years. Patients with pulsatile and objective tinnitus were not eligible to participate in this study and therefore did not include. Finally, eligible 110 participants were enrolled in the study. The participants were divided into two groups as follows: normal hearing (NH) and sensorineural hearing loss (SNHL). None of the patients had unilateral SNHL.

Data sources and variables

The initial audiological evaluation was comprised air and bone conduction hearing thresholds at 250–16000 Hz, word recognition score, and speech reception thresholds (Interacoustics AC40, Otometrics, Denmark). Pitch and loudness matching were also performed using a multifrequency clinical audiometer (Interacoustics AC40, Otometrics, Denmark). The means of air conduction (AC) hearing thresholds at 500, 1000, and 2000 Hz; 1000, 2000, and 4000 Hz; and 500, 1000, 2000, and 4000 Hz were defined as PTA_1, PTA_2, and PTA_3, respectively. The NH was defined as having a pure-tone average at 500, 1000, 2000, and 4000 Hz thresholds better than 25 dB HL.

The hearing threshold test results were classified according to seven different audiometric configurations as follows: flat, high-frequency gradual slope (HFGS), high-frequency steep slope (HFSS), notched, low-frequency hearing loss (LFHL), inverted U-shape, and the others [Figure 1].[6]

The difference between the maximum and minimum hearing threshold was equal or higher than 50 dB Hearing Level (HL) in the HFSS [Figure 1a-left ear], and <50 dB HL in the HFGS types [Figure 1b-right ear], respectively. The difference between low-frequency (the mean of 250, 500, and 1000 Hz) and high-frequency (the mean of 2000, 3000, 4000, 6000, and 8000 Hz) hearing thresholds was defined to be equal or more than 15 dB HL in the LFHL type [Figure 1a-right ear]. The difference between the maximum and minimum hearing thresholds was <25 dB HL in the flat type [Figure 1b-left ear]. The notch type had a notch at any frequency between 3000 and 6000 Hz. The notch had to be at least 25 dB worse than the threshold at 1000 Hz [Figure 1c-left ear]. The hearing threshold at mid-frequency (1000 and/or 2000 Hz) had to be at least 20 dB HL lower than the hearing thresholds at low (250 and 500) and high (4000–8000 Hz) frequencies in the Inverted U-shape [Figure 1c-right ear].

The edge frequencies of the notch, gradual slope, and steep slope audiograms were determined according to two criteria. According to the first criterion, if the difference between the thresholds at consecutive two octave or half octave frequencies is 15 dB or more, the first of these frequencies is considered as the edge frequency. According to the second criterion, if the threshold difference of the first and third frequencies from three consecutive frequencies is 25 dB or more, the first frequency is defined as the edge frequency [Figure 2].

The side of the tinnitus ear was decided by asking in which ear the participant felt tinnitus most frequently and loudest. In the case of bilateral symmetrical tinnitus perception, better hearing ear were assigned to be tinnitus-ear. Moreover, in the case of bilateral symmetrical hearing loss with similar tinnitus perception, the side decision was left to patient preference. Participants were assured to fully understand what pitch and loudness represent. The sound most similar to tinnitus, either pure tone or narrow-band noise, was initially presented one-octave frequency below the predicted tinnitus pitch. Interoctave frequencies were also utilized to provide exact pitch matching when needed. Tinnitus pitch matching was performed at 250–16000 Hz (Interacoustics AC40, Otometrics, Denmark). Tinnitus loudness matching was assessed by presenting an initial sound stimulus 10 dB above the AC hearing threshold at the individual's tinnitus pitch. When required, the threshold of the stimulus was decreased in 5 dB steps and increased in 1 dB steps.[13] To determine tinnitus timbre, patients were administered a tinnitus questionnaire form, in which they were asked to declare the most resembled tone with their tinnitus among six different sounds, including whistle, cicada, engine, wind, water boiling, and the others.

Statistical analysis

The statistical analysis was carried out using the SPSS 24.0 (IBM, Armonk, New York, USA) software. The numerical results were expressed as mean ± standard

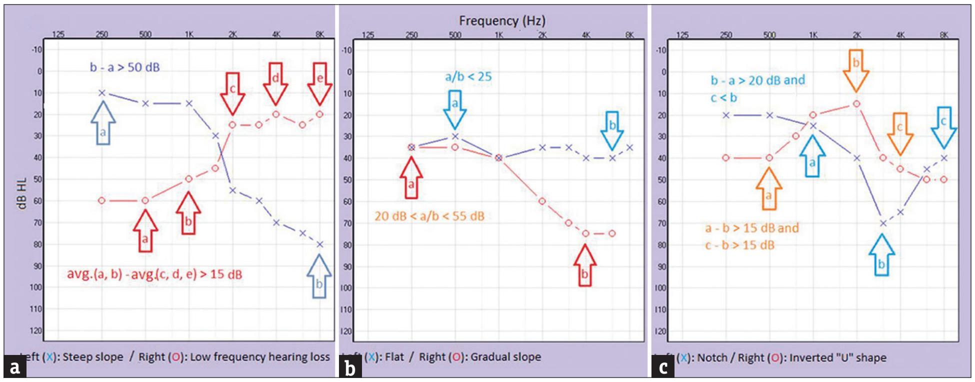

Figure 1: The definition of the audiogram configurations. Steep slope (a-left ear), low frequency hearing loss (a-right ear), flat type (b-left ear), gradual slope (1b-right ear), notch type (c-left ear) and inverted U-shape (c-right ear)

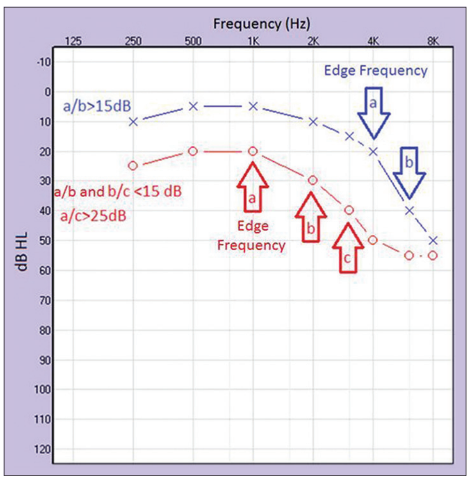

Figure 2: The definition of the edge frequency

deviation, minimum, and maximum values, and the categorical variables were presented as percentages. Kolmogorov–Smirnov normality test was used to check the distribution pattern of each variable. The psychoacoustic characteristic of tinnitus, demographic features, and audiological data of the patients were measured using descriptive statistics. The impact of age, gender, and audiological data on the psychoacoustic properties of tinnitus were calculated by Spearman's rank correlations, Kruskal–Wallis, and Mann–Whitney *U*-tests, separately. The minimum significance level $P = 0.05$, and the results were reported in 95% confidence interval.

Bias

The individuals' audiological test battery was achieved by a blinded clinical audiologist Selhan Gurkan (SG). The tinnitus assessment was made by another nonblinded clinical audiologist Serpil Mungan Durankaya (SMD). Data recording and statistical analysis were accomplished by blinded authors (ACC and BM).

Results

Participants and descriptive data

The study sample consisted of 110 patients' (70 (63.6%) male, 40 (36.4%) female) 164 ears with tinnitus. The distribution of age and gender is shown in Figure 3.

The demographical and audiological characteristics of the participants are demonstrated in Table 1.

Outcome data and main results

Audiological results

The mean age of the SNHL group was significantly higher than the NH group ($P = 0.000$). Furthermore, the Spearman's rank correlation test demonstrated significant and positive moderate correlations between age and PTA_1 ($r = 0.40$, $P = 0.000$), PTA_2 ($r = 0.38$, $P = 0.000$) and PTA_3 values ($r = 0.41$, $P = 0.000$), respectively. No significant relationship was observed between age, gender, and psychoacoustic characteristics of tinnitus (pitch and loudness) ($P > 0.05$).

The frequency-specific mean AC thresholds of the NH and SNHL groups are summarized in Figure 4.

Tinnitus characteristics and relevance to the audiological results and other analyses

The psychoacoustic characteristics of tinnitus and edge frequencies in seven different audiogram configurations in the SNHL and NH groups are indicated in Table 2.

In the SNHL group, the edge frequency was close to 2000 Hz where hearing loss begins [Figure 4]. Tinnitus pitch was 1.34 ± 0.8 octaves above the edge frequency ($P = 0.000$). There were weak positive correlations between edge frequency and the tinnitus pitch ($r = 0.27$ $P = 0.006$), and the frequency of maximum hearing loss (FMHL) ($r = 0.32$ $P = 0.001$), respectively. The mean pitch of tinnitus (6078 ± 2946 Hz) was approximate to the mean FMHL (5992 ± 1972 Hz, $P > 0.05$).

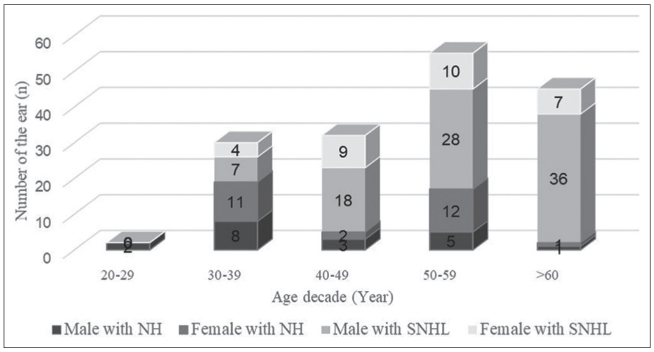

Figure 3: The distribution of the age and gender of the participants. SNHL: Sensorineural hearing loss, NH: Normal hearing

There was a weak positive correlation between the tinnitus pitch and FMHL (r = 0.31, P = 0.001). Furthermore, the mean tinnitus loudness at the tinnitus pitch (62.2 ± 16.6 dB HL) was close to the hearing threshold at the FMHL (56.6 ± 15.3 dB HL) with a strong positive correlation (r = 0.68, P = 0.000).

There was no statistically significant difference between the tinnitus pitch of the NH (5678 Hz) and SNHL (6078 Hz) groups (P = 0.747). However, the tinnitus loudness was statistically higher in NH (13.7 ± 8.0 dB SL) group compared to the SNHL group (9.7 ± 5.8 dB SL) (P = 0.001). A moderate negative correlation was observed between the hearing threshold at the FMHL and tinnitus loudness (dB SL) (r = −0.4 P = 0.000).

The most frequently likened tinnitus timbre was the tonal/whistle sound in both groups. The psychoacoustic features of tinnitus regarding tinnitus timbre are summarized in Table 3.

The tinnitus pitch was significantly higher in participants with tonal/whistle tinnitus timbre (P = 0.000) in both groups. No relationship was observed between the tinnitus timbre and the edge frequency (r = −0.9, P = 0.349) in both groups. No relationship was observed between the audiogram shapes and tinnitus timbre (r = 0.07, P = 0.400), tinnitus pitch (r = 0.05 P = 0.512) and the FMHL (r = −0.16 P = 0.083). However, a significant positive moderate correlation (r = 0.4, P = 0.003) was observed between the tinnitus pitch and the edge frequency in the gradual slope audiograms.

The distribution of the psychoacoustic parameters of tinnitus regarding laterality is shown in Table 4. Accordingly, there was no significant difference between the groups (P = 0.937). No significant difference was recognized regarding the tinnitus pitch, tinnitus loudness, edge frequency, tinnitus timbre, age, and gender between the right and left ears in both groups (P > 0.5 *for each*).

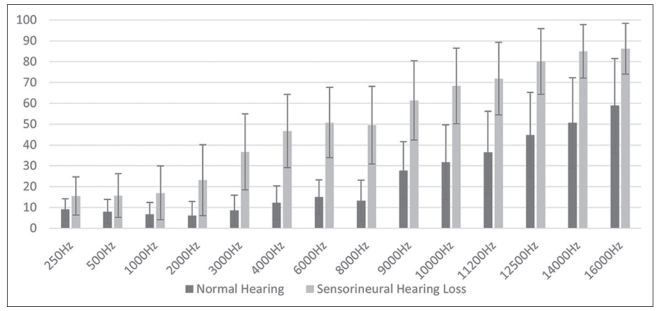

Figure 4: Frequency-specific hearing threshold averages in subjects with sensorineural hearing loss (n = 119) and normal hearing (n = 45)

Table 1: The demographical and audiological characteristics of the participants

	NH group	SNHL group
n (number of ears)	45	119
Age (years)	44.1±11.2	54.7±10.5
Gender, *n* (%)		
Male	19 (42.2)	89 (74.8)
Female	26 (57.8)	30 (25.2)
Tinnitus localization (*n*)		
Unilateral right	12	15
Unilateral left	11	18
Bilateral	22	86
Tinnitus frequency (Hz)	5678±2500	6078±2946
Edge frequency (Hz)	-	2285±1023
FMHL	15175±1579	5992±1972
PTA_1 (dB HL)	6.9±5.0	18.5±12.1
PTA_2 (dB HL)	8.5±5.5	28.9±12.4
PTA_3 (dB HL)	8.1±5.4	25.7±11.1

PTA: Pure tone audiometry average, dB HL: Decibel hearing level, NH: Normal hearing, SNHL: Sensorineural hearing loss, FMHL: Frequency of maximum hearing loss

Discussion

Key results

In this research, we aimed to assess and illuminate the predominant pathophysiological process underlying tinnitus. Since the tinnitus pitch in our SNHL group was near to FMHL, we can suggest the predominance of the homeostatic plasticity theory. On the other hand, our NH group can be explained by the hidden hearing loss theory.

Interpretation

Tinnitus distributes in a wide spectrum regarding the audiogram configurations, pitch, loudness, and timbre.[3-10,12,14] Considering audiological properties, the vast majority of our SNHL group consisted of high-frequency hearing loss (gradual slope and steep slope), compatible with the literature.[15-18] Age and gender were not found to affect the psychoacoustic properties of tinnitus, as previously mentioned.[9,19] Our SNHL group was elder than the NH group, similar to previous studies, which indicated presbytinnitus.[15,16,20,21]

Table 2: The psychoacoustic characteristics of tinnitus and edge frequencies in seven different audiogram configurations in the sensorineural hearing loss (*n*=119) and normal hearing (*n*=45) groups

Audiogram shape	Number of ears, *n* (%)	Mean±SD (minimum-maximum)		
		Tinnitus pitch (Hz)	Tinnitus loudness (dB SL)	Edge frequency (Hz)
Flat (NH)	45 (24.8)	5678±2500 (1000-11,200)	13.7±8.0 (0-35)	None
Flat (SNHL)	14 (11.2)	5586±2741 (2000-11,200)	10.7±3.9 (5-20)	None
Gradual slope (SNHL)	60 (36.6)	5906±2723 (1000-14,000)	11.0±6.1 (0-26)	2536±1134 (1000-6000)
Steep slope (SNHL)	33 (20.1)	6777±3251 (1000-16,000)	6.2±4.7 (0-15)	2061±958 (500-4000)
Notch (SNHL)	10 (6.1)	5900±3658 (2000-12,500)	11.6±5.5 (5-21)	1900±316 (1000-2000)
Inverted 'U' (SNHL)	2 (1.2)	4000±0 (4000)	12.5±3.5 (10-15)	2000±000 (2000)

SD: Standard deviation, NH: Normal hearing, SNHL: Sensorineural hearing loss, dB SL: Decibel sensation level

Table 3: The distribution of timbre, pitch, and loudness of tinnitus in the sensorineural hearing loss (*n*=119) and normal hearing (*n*=45) groups

Tinnitus perception	Number of the ears		Mean±SD (minimum-maximum)			
			Tinnitus pitch (Hz)		Tinnitus loudness (dB SL)	
	NH	SNHL	NH	SNHL	NH	SNHL
Tonal/whistle	31	69	6291±2528 (1000-11,200)	6526±2928 (3000-16,000)	14.1±9 (0-35)	10.7±6.1 (0-26)
Cicada	1	33	4000	5997±2803 (1000-12,500)	15	8.0±4.8 (0-20)
Water boiling	7	8	4571±1902 (2000-6000)	4250±1165 (3000-6000)	12.9±5.7 (5-20)	6.9±6.5 (0-15)
Motor noise	5	4	4300±2335 (1500-8000)	4000±1633 (2000-6000)	12±5.7 (5-20)	12.5±2.9 (10-15)
Wind	1	4	3000	2750±1500 (1000-4000)	15	10±0
Other	0	1	-	14,000	-	10

SD: Standard deviation, NH: Normal hearing, SNHL: Sensorineural hearing loss, dB SL: Decibel sensation level

Table 4: The loudness, pitch, and edge frequency of tinnitus according to the side of tinnitus ear in the sensorineural hearing loss (*n*=119) and normal hearing (*n*=45) groups

	Number of ears		Mean±SD					
			Pitch of tinnitus (Hz)		Tinnitus loudness (dB SL)		Edge frequency (Hz)	
	NH	SNHL	NH	SNHL	NH	SNHL	NH	SNHL
Unilateral	23	33	5426±2402	5963±3579	14.5±7.6	10.5±6.3	-	2172±1159
Bilateral	22	86	5941±2628	6122±2687	12.8±8.5	9.4±5.6	-	2330±967
Total	45	119	5678±2500	6078±2946	13.69±8.0	9.7±5.8	-	2285±1023

SD: Standard deviation, NH: Normal hearing, SNHL: Sensorineural hearing loss, dB SL: Decibel sensation level

Our results indicated that men tended to suffer from tinnitus more than women possibly because of higher vulnerability to occupational noise exposure, which has been detailed in the literature.[15,16,21-24]

The loudness of tinnitus was found as 9.7 and 13.7 dB SL in SNHL and NH groups in our cohort, respectively. According to some previous reports, tinnitus loudness was lower than 10 dB SL,[3,9,18,25] whereas in the others, it was found to be higher.[16,19,22,26] Our results demonstrated a negative correlation between the hearing threshold and tinnitus loudness. There are published results both supporting[22] and not supporting[27] our findings. Presumably, as the patient hears better, the tinnitus perceptibility may increase, and thus, tinnitus may become louder.[22] From our perspective, this might be the case in the NH group.

In contrast, hearing loss has not been shown to affect tinnitus severity according to several studies.[15,28] Searchfield *et al*., measured Tinnitus Severity Index for this purpose and did not find any significant correlation between the tinnitus severity and pure tone audiogram.[29] Similarly, a recent study[28] declared no correlation between tinnitus annoyance and Tinnitus Handicap Index results. However, the heterogeneity of the sample in these studies and the subjective nature of the questionnaires should also be considered while interpreting the results.[30]

Despite opponents,[15,22] some authors[30] advocate an association between tinnitus loudness and hearing loss. Even, tinnitus loudness was found to be lower in individuals with uni- or bilateral hearing loss compared to NH matches.[13] This finding was explained by the presence of loudness recruitment which is a typical consequence of outer hair cell dysfunction and manifested by an exaggerated increase in perceived loudness despite a slight increase in stimulus intensity.

The most reasonable mechanism underlying recruitment is the cochlear nonlinearity and it is not related to mood or level of anxiety.[13]

Concerning tinnitus timbre, the participants with tonal tinnitus had higher tinnitus pitch (6291 Hz for NH, 6526 Hz for SNHL), similar to previous data.[6,16,24] However, no relevance was observed between the configuration of the audiogram and tinnitus timbre, as previously mentioned.[6]

Recent literature has suggested that particularly in cases of tonal tinnitus, the tinnitus pitch should be close to an edge frequency, which corresponds to a boundary between a region of normal or near-NH and hearing loss.[4,6,7,9] The edge frequency reflects the transition zone between the damaged and undamaged region of the auditory system. It is typically approximate to where hearing loss begins,[14] consistent with our findings. The edge frequency (2285 ± 1023 Hz) identified in our research was 1.34 ± 0.8 octaves lower than the tinnitus pitch [Table 1]. According to the edge effect theory, because of the disconnected inputs of the tonotopic axis, an imbalanced lateral inhibition occurs in the boundary of the damaged and undamaged zone, which may lead to a cortical reorganization and over-representation of the edge-frequencies, and finally tinnitus.[10] The reason why the tinnitus pitch is within the hearing loss zone but far away from the edge frequency in our cohort may be explained by the existence of homeostatic plasticity rather than cortical reorganization and edge effect.[5,9,10,31,32]

As reported in the literature,[4-6,8,10,12,14,18,22,23] tinnitus pitch falls within high frequencies in audiogram and usually corresponds to the FMHL, which was also valid in our cohort [Table 1]. There are published results both supporting[10,15] and not supporting[6,22] our findings. The frequency proximity of maximum hearing loss to tinnitus pitch has been discussed by a theoretical model called homeostatic plasticity.[8,9,12,18,31-33] Homeostatic plasticity basically reflects the increased spontaneous fire rate and synchrony in the upper auditory pathway, rather than the temporal cortex which is caused by peripheral deafferentation. This process manifests in chronic tinnitus.[6] The tinnitus of our SNHL group can be explained by this theory. Even, it was proposed that this mechanism can be responsible for tinnitus in patients with NH, whose otoacoustic emissions (OAEs) are abnormal or absent.[34] However, the lack of OAEs in our cohort complicates to make an association between the tinnitus of the NH group and this theory. Homeostatic plasticity may also explain the somatosensorial alterations of tinnitus, since the dorsal cochlear nucleus and medial geniculate body have somatic and limbic inputs, respectively.[34-36] However, we did not assess such properties of tinnitus in our study. Nevertheless, we found weak correlations between both FMHL– tinnitus pitch and edge frequency– tinnitus pitch pairs. Hence, we can only interpret our data based on the numerical proximity of the tinnitus pitch and FMHL.

Another theory, hidden hearing loss, has been introduced by Schaette and McAlpine to identify the mechanism underlying tinnitus without hearing loss.[37] This theory assumes that tinnitus is related to a condition called cochlear synaptopathy, which is characterized by selective loss of synapses between inner hair cells and ribbon synapses.[11,17,32] Despite the lack of any prominent and clinically manifested hearing loss symptom, the patient may have a high-frequency (8–16 kHz) hearing loss, which may generally be overlooked by using a conventional audiometric test battery. This high-frequency hearing loss should be considered as the initial finding of the cochlear damage associated-hidden hearing loss and should alert the audiologist while measuring tinnitus in patients with normal conventional pure tone audiometry.[11,37,38] We assume that our NH group confirmed this theory.

Generalizability

The heterogeneity and subjectivity of tinnitus can often lead to complexity in studies on this subject, which may adversely affect their comparability. Even calculating the sample size can be challenging. Similarly, some series report cases only with a kind of tinnitus timbre. Sex distribution may vary in different studies. We would like to point out that the sample size in our study was similar to the articles we cited,[4,6-10,13-15,21] and additionally, unlike some of these studies, we included patients with both HL and NH. Similarly, the wide spectrum of the tinnitus timbre characteristics of our series and analyzing the data in all aspects can be considered the strength of this study, as well. Therefore, we believe in the reliability and comparability of our results. As known, some authors advocate that tinnitus is dominated by not only a single but also multifactorial pathogenesis, considering its complicated neural process and subjective nature that causes individual differences.[6,39] In fact, tinnitus is generated by increased auditory spontaneous neural activity and synchrony due to peripheral injury. This is the precondition that underlying both homeostatic plasticity and cortical reorganization theories. However, both of these theories have some limitations. First, it is not clear how spontaneous temporal nerve firing can be responsible for tinnitus. Because, if there was a direct relationship between the tinnitus pitch and temporal firing rate, the tinnitus pitch would be 100 Hz or lower, mimicking the firing rate of the temporal nerve.[6] Second, these theories can only be valid in chronic tinnitus. Because both necessitate time to exist. In addition, the audiogram configuration or the presence of hearing loss might not reflect the actual FMHL, edge frequency, and tinnitus pitch,[6,40] especially when there is a flat, low frequency, or a profound hearing loss. Our study did not reveal any relation between the audiogram shape and tinnitus pitch, as well. According to our point of view, a more complex and multifactorial mechanism involving the brain should play a role in tinnitus.[34,41,42] An elaborative evaluation should be performed on the patients with tinnitus considering all proposed theoretical mechanisms. We assume that the pathophysiology of tinnitus will be better understood in line with the data obtained from patients with the coexistence of different mechanisms, and thus new approaches can be developed for treatment.

Limitations

The primary limitation of this study was the lack of qualitative analysis and questionnaires to assess the individual characteristics of tinnitus perception. In addition, due to the retrospective design of this study, randomization and assessor-blinding were inapplicable. Furthermore, the lack of OAEs and somatosensorial features of tinnitus can be considered minor limitations.

Conclusions

This research provided evidence for homeostatic plasticity and hidden hearing loss in tinnitus. While the involvement of the tinnitus pitch within the hearing loss zone and close to the FMHL confirmed the presence of homeostatic plasticity, there was a weak correlation between the tinnitus pitch and FMHL, too. Hearing loss seen in high-frequency measurements in individuals with NH in conventional measurements supports the theory of hidden hearing loss/cochlear synaptopathy.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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