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Original articles

Influence of different aspects on psychoacoustic measurements of patients with chronic tinnitus

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ABSTRACT

Purpose: to verify the sex, age, tinnitus location, presence or absence of hearing loss, its degree, and the psychoacoustic measurements (pitch, loudness, minimum masking level [MML], and residual inhibition [RI]) of patients with chronic tinnitus and their relationships.

Methods: the study included subjects of both sexes, aged 25 to 85 years, with complaints of chronic tinnitus, followed up at the health service where the research was conducted. They were submitted to medical history survey, basic audiological assessment, and pitch, loudness, RI, and MML research. The following statistical tests were used: chi-square test, Fisher's exact test, Wilcoxon-Mann-Whitney U test, Kruskal-Wallis test, and Spearman's correlation coefficient. The significance level was set at 5% ($p \leq 0.05$).

Results: the type of tinnitus was associated with the presence or absence of hearing loss (HL), degree of HL, MML, and loudness; age was associated with the presence or absence of HL and its degree. There was a directly weak proportional correlation between loudness and MML, whereas the correlations between pitch and loudness, pitch and MML, and RI and MML were weak and inversely proportional.

Conclusion: both the affected subjects and their tinnitus characteristics were heterogeneous. The results indicate that some variables influence one another, which also happens between psychoacoustic measurements.

Keywords: Hearing; Psychoacoustics; Tinnitus

INTRODUCTION

Tinnitus is a symptom that can be characterized as an unpleasantly experienced auditory sensation with no external sound stimuli[1]. It can be uncomfortable and persistent due to the difficulty of detecting its etiology[2]. It can be also associated with emotional issues, directly affecting the quality of life of those who have it[3]. With advancing age, the severity of tinnitus and its psychological symptoms tend to increase[4]. Hence, these individuals must be treated in health services specializing in the problem to ensure improvement from the condition, consequently, providing a better quality of life.

The prevalence of tinnitus differs between the available epidemiological studies, especially regarding study populations and variables. They indicate that tinnitus can manifest in all age groups for different reasons[5-7].

Its clinical manifestation may vary in terms of location and laterality and can even be perceived in different ways[8]. It can be persistent, intermittent, orpulsatile[9].Moreover, tinnitus can be classified in different ways, namely: primary or secondary; chronic; rhythmic or non-rhythmic; and subjective or objective[2,10].

Since it is auditorily perceived by the patient, measuring and characterizing it is a complex task, with little possibility of objective assessments. Therefore, psychoacoustic measurements are used (tinnitus pitch and loudness matching, minimum masking level [MML], and residual inhibition [RI]). These measurements in combination with other variables (e.g., sex, age, tinnitus location, and so forth) are essential to enable more adequate intervention. Thus, they also help understand the effects of external sounds on this symptom, as some tinnitus therapies use noise generators.

Hence, this study aimed to verify the sex, age, tinnitus location, presence or absence of hearing loss, its degree, and psychoacoustic measurements (pitch, loudness, MML, and RI) in patients with chronic tinnitus and their relationships.

METHODS

This project was submitted to and approved by the institution's Research Ethics Committee of the Clinic Hospital of Porto Alegre, Brazil, under number 06-027. It is a cross-sectional, retrospective, quantitative study. The analysis sample comprised adults and older adults with complaints of chronic unilateral or bilateral tinnitus (diagnosed with otorhinolaryngological and speech-language-hearing assessments). They were followed up at a specialized outpatient center at the Hospital de Clínicas de Porto Alegre (HCPA).

The inclusion criteria were as follows: complaints of chronic tinnitus, followed up at the health service where the research was conducted, being above 18 years old, and signing an informed consent form. The exclusion criterion was the failure to perform all examinations proposed in the study. Individuals who met the inclusion criteria participated in the research.

Participants were submitted to medical history survey approaching various aspects, including sex, age, and tinnitus location. Basic audiological assessments were performed to identify whether they had hearing loss (HL) and, if so, its type and degree. The degree of hearing loss was classified based on the four-frequency mean, using 500 Hertz (Hz), 1000 Hz, 2000 Hz, and 4000 Hz, following the guidelines of the World Health Organization (2020)[11].

After basic audiological assessments, tinnitus pitch and loudness matching was used to measure patient-reported tinnitus pitch (frequency sensation) and loudness (intensity sensation)[12]. Besides these measurements, MML and RI were also investigated to verify the influence of the variables analyzed in this study. Regarding symptom laterality, both unilateral and bilateral tinnitus were surveyed ipsilaterally.

To measure the pitch, patients were exposed to pure tone, warble, or narrowband noise, according to the type of tinnitus perceived by the individual. The stimuli were presented 10 decibels hearing level (dBHL) above the hearing threshold – i.e., 10 decibels sensation level (dBSL) at the frequencies tested in audiometry. Patients

were instructed to raise their hands when they noticed the sound was being presented at a similar frequency to that of their tinnitus.

Loudness was surveyed by presenting stimuli at the frequency reported by the subject when the pitch was surveyed, 10 dBHL below the hearing threshold; the intensity was progressively increased by 1 dBHL at a time. Patients were instructed to raise their hands when they noticed an intensity similar to that of their tinnitus. The intensity was recorded and subtracted from the subject's hearing threshold to quantify it in dBSL. If a patient stated that none of the presented sounds was similar to their tinnitus, they were excluded from the study.

MML was surveyed with the patient's hearing threshold for narrowband noise at the tinnitus frequency, previously detected in the pitch survey. Then, the intensity was progressively increased by 1 dBHL at a time until the individuals indicated they were not perceiving the tinnitus[13].

RI was surveyed by presenting the masking noise to the ear ipsilateral to the tinnitus, 10 dBHL above the masking level, for 1 minute. Then, the noise was stopped, and the individual was instructed to raise their hand when they perceived the tinnitus had returned[13]. Hence, the time the patient remained without perceiving the symptom was quantified in seconds (s). If the tinnitus continued after the noise presentation, it was quantified as 0 seconds.

After collecting this information, a bank was created with the data of 106 patients of both sexes, aged 25 to 85 years, who met the criteria. Of these, 53 had bilateral tinnitus and 53 had unilateral tinnitus, totaling 159 ears with tinnitus.

Quantitative data were analyzed both per person and per ear. Sex, age, and tinnitus location were described per person. Data per ear (only those in which the patients reported having tinnitus) were used to analyze tinnitus and cross this information with the other variables (tinnitus laterality, absence or presence of HL, its degree, four-frequency mean, and psychoacoustic measurements).

Some categories of variables were grouped for statistical analysis because they had little representativity in the sample. Regarding the types of tinnitus, warble (WB) and pure tone (PT) were grouped into one, which was then called "WB/PT". In terms of the degree of HL, moderately severe and severe were joined into one group called "moderately severe or severe".

The distribution of psychoacoustic measurements was assessed in the histograms, and none had a normal distribution. Therefore, the median was used to describe the variables, and nonparametric tests were used for data crossing.

The following tests were used to test the hypotheses, compare statistics, and correlate variables: chi-square test, Fisher's exact test, Wilcoxon-Mann-Whitney U test, Kruskal-Wallis test, and Spearman's correlation coefficient. The significance level was set at 5% ($p \leq 0.05$).

RESULTS

The study sample comprised 106 individuals of both sexes (predominantly females), aged 25 to 85 years. Half of them had unilateral and the other half had bilateral tinnitus, totaling 159 ears with this symptom. The left ear was the most affected one. The most prevalent types of tinnitus were those that resembled warble or pure-tone stimuli. As for peripheral hearing, most patients had HL, predominantly mild. The median pitch was at a higher frequency (Table 1).

Table 1. Sample characterization

Variable– per person	n=106
Sex	**n (%)**
Females	62 (58.49)
Males	44 (41.51)
Medianage (IQR) –years	66 (11.5)
Location	**n (%)**
Unilateral	53 (50)
Bilateral	53 (50)
Variable–per ear	n=159
Side	**n (%)**
Right ear	75 (47.16)
Left ear	84 (52.83)
Type of tinnitus	**n (%)**
Narrowband	36 (22.64)
Warble orpure tone	123 (77.36)
Presence or absence of HL	**n (%)**
WithoutHL	31 (19.49)
With HL	128 (80.51)
Degree of HL	**n (%)**
Mild	70 (44.03)
Moderate	41 (25.79)
Others (moderately severe or severe)	17 (10.69)
Median psychoacoustic measurements	**Median (IQR)**
Pitch – Hz	6.000 (5.000)
Loudness –dBSL	7 (7)
RI– s	0 (13.5)
MML–dBSL	10 (10.5)
FFM –dBHL	42.5 (27.05)

Captions: n = absolute number; IQR = interquartile range; HL = hearing loss; RI = residual inhibition; MML = minimum masking level; FFM = four-frequency mean; % = percentage

There was no difference in the influence of sex on the other variables analyzed in the study. Hence, it cannot be stated whether their values differ according to the person's sex (Table 2).

On the other hand, there were differences in the types of tinnitus and their association with the presence or absence of HL and its degree. This variable was also associated with MML and loudness. Thus, MML and loudness are different between the types of tinnitus, as the medians of both were higher in individuals with other types of tinnitus (warble or pure tone). There was no difference in the p-value of RI, pitch, or four-frequency mean (Table 2).

Table 2. Influence of sex and type of tinnitus on the variables analyzed

Variable	Sex		p-value	Type of tinnitus		p-value
	Females (n=90)	Males (n=69)		Narrowband (n=36)	Others (warble or pure tone) (n=123)	
Type of tinnitus[1]						
Narrowband	23 (63.89%)	13 (36.11%)	0.417***	-	-	-
Others (warble orpure tone)	67 (54.47%)	56 (45.53%)		-	-	-
Presence or absence of HL[1]						
Without HL	18 (58.06%)	13 (41.94%)	1***	0 (0)	30 (97)	0.008***
With HL	73 (56.59%)	56 (43.41%)		36 (27.91)	93 (72.09)	
Degree of HL[1]						
Without HL	18 (58.06%)	13 (41.94%)	0.702**	1 (3.23)	30 (96.77)	0.016**
Mild	42 (60%)	28 (40%)		19 (27.14)	51 (72.86)	
Moderate	20 (48.78%)	21 (51.22%)		11 (26.83)	30 (73.17)	
Mod. severe or severe	10 (58.82%)	7 (41.18%)		5 (29.41)	12 (70.59)	
MML[2]	10 (9.75)	10 (12)	0.596*	8 (5.5)	12 (12)	0.003*
RI[2]	0.5 (18.5)	0 (11)	0.513*	1 (20)	0 (11.5)	0.525*
Pitch[2]	6.000 (5.000)	6.000 (6.000)	0.478*	4.000 (6.125)	6.000 (5.000)	0.8*
Loudness[2]	7 (6.75)	6 (7)	0.776*	4.5 (6)	8 (9)	0.011*
FFM[2]	475 (2.580)	425 (2.815)	0.733*	425 (2.811.25)	425 (2.585)	0.345*

***Chi-square test
**Fisher's exact test
*Wilcoxon-Mann-Whitney U test
[1]Statistics presented: n (%)
[2]Statistics presented: median (IQR)
Captions: HL = hearing loss; mod. severe = moderately severe n = absolute number; % = percentage; MML = minimum masking level; RI = residual inhibition; FFM = four-frequency mean

Concerning the analysis of its influence, age did not correlate with psychoacoustic measurements (pitch, loudness, MML, and RI) (Table 3), and neither was there any difference with the type of tinnitus (p = 0.585). It can be stated that the median age differs in patients with the presence or absence of HL (p=0.007); the median age of patients with HL is higher (67 years) than that of patients without it(61 years). Also, there was no difference between degrees of HL (p=0.039).

Loudness had a directly weak proportional correlation with MML. There were also inversely weak proportional correlations between pitch and loudness, pitch and MML, and RI and MML. There were no statistical differences in the other crossings (Table 3).

Table 3. Correlation of psychoacoustic measurements of tinnituswith one another and with the subjects' ages

Variable	Estimated Spearman'sCorrelation	p-value
FFA vs. pitch	-0.043	0.583
FFA vs. RI	-0.122	0.125
FFA vs. MML	-0.146	0.067
FFA vs. loudness	-0.036	0.655
Pitch vs. RI	0.069	0.383
Pitch vs. loudness	-0.224	0.005*
Pitch vs. MML	-0.183	0.02**
Loudness vs. MML	0.448	< 0.001*
Loudness vs. RI	0.084	0.29
MML vs. RI	-0.156	0.049*
MML vs. age	-0.006	0.941
RI vs. age	0.0778	0.329
Pitch vs. age	-0.06	0.452
Loudness vs. age	-0.065	0.413
FFA vs. age	0.11	0.166

*Statistically significant values ($p<0.05$) – Spearman's correlation coefficient
Captions: FFM = four-frequency average; vs. = versus; MML = minimum masking level; RI = residual inhibition

Regarding the presence or absence of HL and its degree, there were no differences in the psychoacoustic measurements of tinnitus. Hence, it cannot be stated whether psychoacoustic measurements differ according to the presence of HL or between its various degrees (Table 4).

Table 4. Influence of the presence or absence of HL and its degree on the psychoacoustic measurements of tinnitus

Variable	Presence or absence of HL		P-value	Degree of HL				p-value
	Present (n=129)	Absent (n=31)		No HL (n=31)	Mild (n=70)	Moderate (n=41)	Mod. Severe or Severe (n=17)	
MML[1]	10 (9.25)	12.5 (13.5)	0.193*	12 (13.5)	10 (9)	9 (10)	11 (11)	0.139**
RI[1]	0 (14.5)	0 (12.5)	0.961*	0 (12.5)	0 (19.25)	2 (20)	0 (3)	0.416**
Pitch[1]	6.000 (5.000)	5.000 (6.000)	0.625*	6.000 (5.000)	6.000 (4.750)	6.000 (5.000)	4.000 (7.000)	0.351**
Loudness[1]	6 (7)	8 (9)	0.195*	8 (9)	5 (6)	8 (7)	7 (8)	0.397**

*Wilcoxon-Mann-Whitney U test.
**Kruskal-Wallis test.
[1]Statistics presented: median (IQR).
Captions: HL = hearing loss; mod. severe = moderately severe; n = absolute number; MML = minimum masking level; RI = residual inhibition

There was no statistical indication proving that tinnitus laterality is associated with the type of tinnitus or degree of HL. There was likewise no evidence that psychoacoustic measurements differ according to the side affected by tinnitus (Table 5).

No relationship was found between tinnitus location and the type of tinnitus or degree of HL, and neither was there any finding that proved that psychoacoustic measurements are different between locations (Table 5).

Table 5. Influence of tinnitus laterality and location on the other variables

Variable	Tinnitus location		p-valor	Tinnitus laterality		p-value
	Unilateral (n=53)	Bilateral (n=53)		Right ear (n=75)	Left ear (n=84)	
Type of tinnitus[1]						
Narrowband	8 (30)	21 (70)	0.83***	16 (53.33)	14 (46.67)	0.584***
Others (warble or pure tone)	44 (34.11)	85 (65.89)		59 (45.74)	70 (54.26)	
Degree of HL[1]						
Without HL	10 (32.26)	21 (67.74)	0.378**	17 (54.84)	14 (45.16)	0.677**
Mild	22 (31.43)	48 (68.57)		32 (45.71)	38 (54.29)	
Moderate	12 (29.27)	29 (70.73)		17 (41.16)	24 (58.54)	
Mod. severe or severe	9 (52.94)	8 (47.06)		9 (52.94)	8 (47.06)	
MML[2]	11 (12)	10 (9)	0.434*	10 (10.5)	10 (11.25)	0.527*
RI[2]	0 (5)	0 (25)	0.339*	0 (11.5)	1 (15.25)	0.598*
Pitch[2]	6.000 (5.000)	6.000 (5.000)	0.109*	6.000 (5.500)	6.000 (6.000)	0.206*
Loudness[2]	8 (7)	5.5 (7)	0.394*	6 (7)	7 (7.25)	0.754*
FFA[2]	525 (2.325)	425 (2.830)	0.831*	1.375 (2.812.5)	375 (2.397)	0.135*

***Chi-square test
**Fisher's exact test
*Wilcoxon-Mann-Whitney U test
[1]Statistics presented: n (%)
[2]Statistics presented: median (IQR)
Captions: n = absolute number; % = percentage; HL = hearing loss; mod. severe = moderately severe; MML = minimum masking level; RI = residual inhibition; FFA = four-frequency average

DISCUSSION

The sample characteristics in this study show a predominance of females, which is similar to previous studies on the topic, whose percentage of individuals of this sex ranged from 58.27% to 60.3%[14,15]. There is no consensus in the current literature about the influence of sex on the prevalence of tinnitus - females predominate in some studies[15,16], whereas males predominate in others[17,18].

The results did not indicate any influence of sex on the psychoacoustic measurements, similar to another paper concerning the influence of pitch and loudness[19]. On the other hand, a study detected higher loudness values in males[20]. Apart from these, no studies were found in the consulted literature analyzing the influence of sex in the other psychoacoustic measurements (MML and RI).

The number of individuals in this research with unilateral and bilateral tinnitus was identical. However, this percentage differs in previous studies, as bilateral tinnitus prevails in some[21,22], and unilateral tinnitus prevails in others[7,23].

Most of the sample were older adults, 86.2% of whom had HL. The findings corroborate other studies, in which the prevalence of HL and tinnitus increased with age[16,24]. Moreover, one of these studies indicates that the peak of tinnitus complaints occurs in subjects above 65 years old, with three times the prevalence that is found in 18-to-25-year-old subjects. Also, tinnitus constancy (perceiving it every day) is up to three times greater with advancing age[16].

In this study, psychoacoustic measurements did not differ according to the subjects' ages or types of tinnitus. However, no studies were found in the consulted literature analyzing the association between these variables.

More than 80% of the sample had HL. According to a study by Oosterloo et al. 2021, individuals with HL are twice as likely to have tinnitus than subjects without HL[24]. Mild HL predominated, which is a similar result to that of another study on tinnitus[23].

The results of this research showed no difference in the median psychoacoustic measurements between the absence and presence of HL or between its degrees. On the other hand, a paper conducted by Benin et al. 2016[21], verified significantly higher pitch and more intense loudness in subjects with HL than in those without it.

The analysis showed that the median psychoacoustic measurements do not vary according to the side affected by tinnitus - all measurements had similar

results in both ears. However, the median pitch was 6000 Hz in both the right and left ears. Previous studies found the pitch more often at higher frequencies (4000 Hz – 8000 Hz)[22,25], although one paper indicates a prevalence of individuals identifying the pitch at lower frequencies[26].

The findings indicate that the types of tinnitus differ between subjects with and without HL and its degree, as well as loudness and MML. However, no studies were found in the literature with a similar analysis for comparison. The results of this research show a prevalence of tinnitus similar to warble or pure tone, which corroborates another study that found a slightly greater presence of pure tone (51%) than narrowband (49%)[27].

The results indicate that MML increases along with loudness – i.e., the greater the perceived intensity of tinnitus, the greater the minimum level needed to mask it. Pitch had inversely proportional correlations with loudness and MML – hence, the higher the pitch, the lower the perceived loudness and the lower the noise level needed to mask it. Lastly, there was also a significant relationship between RI and MML, though in reverse order, which indicates that the greater the intensity of the noise needed to mask the tinnitus, the lower the tinnitus RI. However, no literature has been found up to the present to corroborate these results – which makes it a differential of this study, as it aimed to analyze the mutual influence of psychoacoustic measurements.

The limitation of the present research lies in that most of the sample was older adults, even though it included people from 18 years old. Therefore, despite the considerable sample size, comparisons regarding age were limited. Age analysis results might have been different if the distribution between the various age groups had been more proportional.

Furthermore, comparisons with previous research were also limited, as most studies available in the literature analyze individual measurements, predominantly with information only on loudness and pitch. Hence, further research on the topic is evidently needed, such as the present study, which also aimed to analyze MML, RI, and the mutual influence of psychoacoustic measurements.

Future studies should comprise larger samples and analyze more variables – especially the psychoacoustic measurements, which are not much addressed in current research on the topic.

CONCLUSION

The type of tinnitus was associated with loudness and MML, and age was associated with the presence or absence of HL and its degree. Loudness had a directly weak proportional correlation with MML. There were also inversely weak proportional correlations between pitch and loudness, pitch and MML, and RI and MML. On the other hand, sex, the presence or absence of HL, degree of HL, and tinnitus laterality and location did not influence the other variables.

There was an important heterogeneity between the characteristics of tinnitus and the affected individuals. Given these results, it is concluded that some variables influence each other, which also occurs between psychoacoustic measurements.

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