https://doi.org/10.23925/2176-2724.2023v35i1e57675

ARTICLES

Masking Level Difference and Auditory Brainstem Response In Normal Hearing Adults With Tinnitus

Limiar Diferencial de mascaramento e potencial evocado auditivo de tronco encefálico em adultos normo-ouvintes com zumbido

Umbral de enmascaramiento diferencial y potencial evocado auditivo del tronco encefálico en adultos con audición normal y tinnitus

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Abstract

Introduction: Tinnitus is a conscious auditory illusion, a sound perception unrelated to any external stimulus source. **Objectives:** To characterize the Acuphenometry, Masking Level Difference, the quality of life questionnaire Tinnitus Handicap Inventory and Auditory Brainstem Response in normal hearing adults with tinnitus, with the purpose of comparing the findings. **Method:** Twenty female and male individuals, between 20 and 60 years of age, normal hearing with complaints of tinnitus, underwent Acuphenometry, Masking Level Difference, Tinnitus Handicap Inventory and Auditory Brainstem Response. **Results:** The Acuphenometry showed the average pitch was 4.3 KHz to the right ear and 4.6 KHz to the left ear. The average loudness was 21.7 dBSL to the right ear and 23.5 dBs to the left ear. The average Masking Level Difference was altered. The average Tinnitus Handicap Inventory corresponded to the classification of mild grade. Auditory Brainstem Response showed parameters within normal range

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Authors' contributions:
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Received: 14/03/2022
Accepted: 13/04/2023

bilaterally. **Conclusion:** It was found that normal hearing adults with tinnitus complaints have bilateral acute pitch tinnitus with a slight impact on quality of life, appropriate conduction of auditory pathways to the brainstem and impaired identification of sounds in the presence of noise, demonstrating that tinnitus can have repercussions on central auditory skills.

Keywords: Tinnitus; Brainstem Auditory Evoked Potentials; Perceptual masking; Hearing tests; Adult.

Resumo

Introdução: O zumbido é uma ilusão auditiva consciente, uma sensação sonora não relacionada com uma fonte externa de estimulação. **Objetivos:** Caracterizar a Acufenometria, Limiar Diferencial de Mascaramento, o questionário de qualidade de vida Inventário de Desvantagem do Zumbido e Potencial Auditivo de Tronco Encefálico em adultos normo-ouvintes com zumbido, com a finalidade de comparar seus achados. **Método:** Vinte indivíduos do sexo feminino e masculino, entre 20 e 60 anos de idade, normo-ouvintes com queixa de zumbido, foram submetidos ao Acufenometria, Limiar Diferencial de Mascaramento, Inventário de Desvantagem do Zumbido e Potencial Evocado Auditivo de Tronco Encefálico. **Resultados:** A Acufenometria revelou *que o pitch médio foi* de 4,3 KHz à orelha direita e 4,6 KHz à orelha esquerda. O *loudness* médio foi de 21,7 dBNS à orelha direita e 23,5 dBNS à orelha esquerda. O Limiar Diferencial de Mascaramento médio mostrou-se alterado. O Inventário de Desvantagem do Zumbido médio correspondeu à classificação de grau leve. O Potencial Evocado Auditivo de Tronco Encefálico apresentou parâmetros dentro da normalidade bilateralmente. **Conclusão:** Constatou-se que adultos normo-ouvintes com queixa de zumbido apresentam zumbido de *pitch* agudo bilateral com discreto impacto na qualidade de vida, condução adequada das vias auditivas até o tronco encefálico e comprometimento na identificação de sons na presença de ruído, demonstrando que o zumbido pode ter repercussões nas habilidades auditivas centrais.

Palavras-chave: Zumbido; Potenciais Evocados Auditivos do Tronco Encefálico; Testes Auditivos; Mascaramento Perceptivo; Adulto.

Resumen

Introducción: El tinnitus es una ilusión auditiva consciente, una sensación de sonido no relacionada con una fuente externa de estimulación. **Objetivos:** Caracterizar la coincidencia de tono y volumen, el umbral de enmascaramiento diferencial, el inventario de minusvalía para acúfenos y el potencial auditivo del tronco encefálico en adultos normoyentes con acúfenos, con el fin de comparar sus hallazgos**. Método:** Veinte sujetos masculinos y femeninos, con edades entre 20 y 60 años, audición normal con tinnitus, fueron sometidos a acúfenos, Umbral de Enmascaramiento Diferencial, Inventario de Desventajas de Tinnitus y Potenciales Evocados Auditivos del Tronco Encefalico. **Resultados:** La combinación de tono y volumen reveló que el tono promedio era de 4,3 KHz en el oído derecho y de 4,6 KHz en el oído izquierdo. Mientras que el volumen medio fue de 21,7 dBNS para el oído derecho y de 23,5 dBNS para el oído izquierdo. Se modificó el umbral diferencial de enmascaramiento promedio. El Inventario de Desventajas de Tinnitus promedio correspondió a la clasificación de grado leve. El Potenciales Evocados Auditivos del Tronco Encefalico presentó parámetros dentro del rango normal bilateralmente. **Conclusión:** Se encontró que los adultos normooyentes con quejas de tinnitus presentan tinnitus de tono alto bilateral con leve impacto en la calidad de vida, conducción adecuada de las vías auditivas al tronco encefálico y deterioro en la identificación de sonidos en presencia de ruido, demostrando que Tinnitus puede tener repercusiones en las habilidades auditivas centrales.

Palabras clave: Tinnitus; Potenciales Evocados Auditivos del Tronco Encefalico; Testes Auditivos; Enmascaramiento perceptivo; Adulto.

Introduction

Tinnitus is a conscious auditory illusion, a sound perception unrelated to any external stimulus source. It affects more than 25 million Brazilians and may have negative consequences on their quality of life[1.] It usually results from peripheral and/or central changes in the auditory pathway of patients with various degrees of hearing loss. Only 8 to 10% of people with tinnitus have normal pure-tone audiometry[1]. Tinnitus has different origins and intensities, to the point of being seriously incapacitating in its severe form, sometimes even leading the patient to the extreme attitude of attempting suicide[2]. When tinnitus is generated within the auditory system, its cause may be otologic, cardiovascular, metabolic, neurological, pharmacological, odontogenic or psychogenic. Oftentimes, the tinnitus etiology cannot be precisely identified[3].

Tinnitus has been the subject of numerous studies involving neurophysiological, audiological, therapeutic, psychological and pharmacological aspects. Health professionals are increasingly involved in the search for an accurate assessment of the patient, in addition to efficient and definitive therapeutic alternatives[4,5,6,7,8].

The differential diagnosis of tinnitus can be established with various hearing and complementary assessments. For instance, the pure-tone audiometry, speech audiometry, and acoustic immittance verify the hearing sensitivity and, if there is a hearing loss, establish its type and degree. Acuphenometry, in its turn, measures the tinnitus, showing to the patient that their tinnitus is real, thus helping advise the patient and establish a sound therapy prognosis. Quality of life questionnaires that assess and quantify tinnitus and its consequences to the patient's life are also frequently employed. The electrophysiological and electroacoustic examinations aid in the treatment of patients with a complaint of tinnitus as they investigate the causal factor and help understand the physiopathological mechanisms involved[9.]

As shown in the literature, it was found that the population affected by chronic tinnitus presented a mild degree for the Tinnitus Disadvantage Inventory and the average of the sensation of intensity of the Acuphenometry in the right ear of 20 dBSL and in the left ear of 17 dBSL. As for the type of stimulus, the most common was the continuous pure tone. The sensation of frequency, in the largest number of cases, was 6.000 Hz[5].

Furthermore, it was observed that there are divergences in the findings regarding the Auditory Brainstem Response (ABR)[6]. There is a study demonstrating that there are no significant differences for ABR latencies and amplitudes of individuals with and without tinnitus[7]. As well as, there is a study that pointed out that the group of individuals with tinnitus had significantly delayed latencies of waves I, III and V, in addition to significantly reduced amplitudes of waves I and III when compared to individuals in the control group[8].

Observed in clinical practice, there is an increasing incidence of complaints of tinnitus in patients with normal auditory thresholds, in whom it is an even more evident symptom. As it is not associated with a peripheral change, its diagnosis and treatment are further complicated by the hypothetical nature of its cause.

Hence, studies on auditory processing are justified, as well as the analysis of the integrity of the auditory pathways to research the differential diagnosis of tinnitus etiology. Therefore, this study aimed to characterize and compare the Acuphenometry, the Masking Level Difference, the Tinnitus Handicap Inventory, and the Auditory Brainstem Response in normal hearing adults with tinnitus.

Materials and methods

This is an analytical descriptive study. The work was carried out in the of Speech-Language-Hearing Sciences Department in cooperation with the Department of Otorhinolaryngology of the Universidade Federal de São Paulo/Escola Paulista de Medicina. The research began after being approved by the Research Ethics Committee of the of Universidade Federal de São Paulo under CAAE certificate number: 14409818.6.0000.5505 and Evaluation Report Number: 3.584.418. All the participants were informed of the procedures to be performed and, having agreed to participate in the research, signed the Informed Consent Form (ICF).

A total of 20 female and male volunteers participated in this study. They were recruited in an active search in the Clinical Audiology and Otorhinolaryngology Outpatient Centers of the Universidade Federal de São Paulo, based on the following inclusion criteria:

- Age between 20 and 60 years;
- Having normal audibility thresholds (≤ 25 dBHL between 250 Hz and 8 kHz);
- Having a tympanometry type A curve (normal);
- Having complaints of tinnitus;
- Not presenting middle ear changes or conductive impairment;
- Not having syndromes nor being under genetic investigation;
- Not taking medications that cause tinnitus;
- Not having evident cognitive changes.

At first, the individuals were submitted to Acuphenometry research, which consists of a behavioral assessment used to measure the sensory characteristics (sensation of frequency and intensity) of tinnitus. This measure has diagnostic importance because it furnishes a quantitative value to monitor tinnitus deterioration or improvement and classify the type of tinnitus. Moreover, it furnishes a more significant psychoacoustic measure than some of the discomfort caused by tinnitus[5]. The Acuphenometry was conducted in a sound booth with the Interacoustics audiometer (AD229b). They were instructed to raise their hand when the tone presented was similar to their tinnitus pitch[10]. The tone stimuli were presented at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, 8000 Hz, and 10500 Hz. When the person indicated a frequency similar to their tinnitus pitch, the frequency was fixed and the presentation level (intensity) was increased every 5 dB, based on the pure-tone threshold obtained in the audiometry. The tinnitus loudness level was obtained from the difference between the pure-tone threshold and the presentation level indicated by the subject as being similar to their tinnitus loudness and then presented in dBSL (sensation level).

The Masking Level Difference is a psychoacoustic test that identifies the auditory system's sensitivity to differences in time and amplitude of the signal and/or noise. Findings in the literature indicate that the Masking Level Difference corresponds to a behavioral measure of the binaural integration effect[11,12], which takes place at the brainstem level[13]. The Masking Level Difference was conducted in a sound booth with supra-aural earphones. The patient was asked to answer "yes" when they noticed a beep, even a weak one, amidst the noise, and "no" when they heard only noise. The Masking Level Difference used was the version by Auditec of Saint Louis (2002), played in a CD player attached to the audiometer. This Masking Level Difference version presents 33 narrow-band noise segments to both ears for at least three seconds, either in the presence or not of 500 Hz pure tone. Three different conditions were used: pure tone and narrow-band noise in phase, in both ears (homophasic signal/noise condition – SoNo); pure-tone in inverted phase in one of the ears, and noise in phase in both ears (antiphasic signal/noise condition – SπNo); noise without pure-tone (no tone – NT). The protocol of the test progresses from the most to the least favorable signal-to-noise relationship in the three conditions (SoNo, SπNo, and NT), randomized approximately in blocks of three. The test was conducted binaurally at 50 dBHL (hearing level). For the analysis, the total number of times the subjects indicated having heard the tone in each condition was converted into dB, following a table available in the test's manual. The final result was the difference in dB between the scores in the SoNo and SπNo conditions. The Masking Level Difference for normal hearing people ranges from 8 to 12 dB. For adults, the Masking Level Difference is considered normal at least 10[13]. The answers were noted in a record sheet developed for this purpose.

Then, the adapted Tinnitus Handicap Inventory questionnaire was applied. The Tinnitus Handicap Inventory is an easy-to-use and interpret questionnaire that assesses tinnitus and its emotional, functional, and catastrophic aspects[15]. The Tinnitus Handicap Inventory has been translated and culturally adapted to the Brazilian population, being named Brazilian Tinnitus Handicap Inventory. It is considered a reliable instrument to verify the loss caused by tinnitus on the patient's quality of life[16], which analyzes the quality of life of people with tinnitus, was administered. This questionnaire has 25 numbered questions – numbers 3, 6, 10, 14, 16, 17, 21, 22 and 25 assess the emotional aspect, questions 1, 2, 4, 7, 9, 12, 13, 15, 18, 20 and 24 assess the functional aspects, and questions 5, 8, 11, 19 and 23 assess the catastrophic aspect[16]. The participants' answer options in the questionnaire were "yes", "no", and "sometimes". The "yes" answers were given four points, the "no" answers scored zero points (0), and the "sometimes" answers scored two points. The maximum score is 36 points in the emotional aspect, 44 points in the functional aspect, and 20 points in the catastrophic aspect. The final score ranges from 0 to 100, with which the degree of interference of tinnitus on the quality of life can be analyzed, as follows: Degree 1: 0-16 (slight), Degree 2: 18-36 (mild**),** Degree 3: 38-56 (moderate), Degree 4: 58-76 (severe), Degree 5: 78-100 (catastrophic). In this study, the patients were handed the questionnaire to fill out while the assessor was at their disposal to answer any questions they might have. After it had been filled out, the assessor counted the points to classify the tinnitus degree of interference.

Posteriorly, the Auditory Brainstem Response (ABR) was captured. The ABR is an electrophysiological objective measure generated by the synchronicity of the structures of the auditory pathway, beginning in the auditory nerve, passing through the cochlear nucleus, superior olivary complex, and lateral lemniscus, up to the inferior colliculus. The presence or absence of responses, occurring within a given time (latency), makes it possible to evaluate the integrity of the auditory pathway up to the brainstem[17,18]. To the capture ABR with click stimulus was used the equipment manufactured by Intelligent Hearing Systems IHS - SmartEP. The patient's skin surface was cleaned with hydrophilic gauze and abrasive paste. Then, the silver surface electrodes were fixed with microporous medical tape and electrolytic paste to improve electrical conductivity. The ground electrode was placed on the frontal region and the other two electrodes were fixed onto the earlobes (A1 on the left ear and A2 on the right one), following the 10-20 international system. To obtain this potential in the neurologic protocol, the click stimulus was presented monaurally at 80 dBHL[19], using rarefaction polarity, a presentation rate of 19.1 stimuli per second, a high-pass filter at 100 Hz and a low-pass filter at 3000 Hz, stimulus duration 0.1 ms, 12.8-millisecond window, and rectangular envelope. The subjects were instructed to stay still and relaxed, with eyes closed to minimize myogenic artifacts. The means of two sweepings were calculated, ranging from 1500 to 2048 stimuli presented twice to each ear to analyze the reproducibility of the tracing. At the end of the collection, the presence of waves I, III, and V was verified. The absolute latencies of waves I, III, and V were marked and registered, as well as the interpeak intervals of I-III, III-V, and I-V for each ear. The integrity of the auditory pathway, considering the absolute latencies and interpeak intervals, was assessed based on the normal standards in the biological standardization of the equipment of the Department of Electrophysiology at Universidade Federal de São Paulo, as shown in Chart 1.

The statistical analysis used the Equality Test in Two Proportions and the ANOVA test. The Equality of Two Proportions Test compares whether the proportion of responses to two given variables and/or their levels is statistically significant. The ANOVA test consists of a parametric test that makes a comparison of means using the variance. In this paper, the p-value was set at ≤ 0.05 or 5%[20,21,22]. Also, all the confidence intervals throughout the paper were based on 95% statistical confidence. The statistically significant results are in bold type followed by an asterisk (*), whereas the results with a trend towards statistical significance are indicated with a sharp symbol (#).

Chart 1. Normative Auditory Brainstem Response values for clicks at 80 Decibels in Normal Hearing Level proposed in biological standardization of the Intelligent Hearing Systems equipment.

Waves and Interpeak intervals	Mean absolute latency values (ms)	Standard Deviation
I	1.65	0.06
III	3.80	0.15
V	5.67	0.16
I-III	2.15	0.16
III-V	1.86	0.12
I-V	4.01	0.17

Legend: ms = milliseconds

Results

Twenty normal-hearing individuals were evaluated that were selected from the routine attendance at the Clinical Audiology and Otorhinolaryngology outpatient clinic at Universidade Federal de São Paulo. The sample's mean age was 23.7 years, comprising two males and 18 females.

Concerning tinnitus laterality: 15% of the subjects had the symptom in the right, 10% in the left, and 75% in both ears.

Table 1, presents the characteristics of the sample in relation to the qualitative variables of tinnitus, containing the number, percentage and p-value.

Table 1. Distribution of the qualitative variables of the tinnitus characteristics

		Number	%	p-value
Tinnitus characteristic	High pitched	20	100%	-x-
Noise exposure	No	17	85%	**<0.001***
	Yes	03	15%	
Family history of hearing loss	No	14	70%	**0.011***
	Yes	06	30%	
Type of tinnitus	Continuous	07	35%	0.058#
	Intermittent	13	65%	
Dizziness	No	14	70%	**0.011***
	Yes	06	30%	
Self-reported degree of severity	Mild	13	65%	Ref.
	Moderate	06	30%	**0.027***
	Intense	01	05%	**<0.001***

Equality Test in Two Proportions - statistically significant p-value ≤ 0,05 or 5%
Legend: * = statistically significant p-value, # = p-value trending towards statistical significance.

Table 2 shows the results of the Acuphenometry's descriptive measures given in Hertz and dBSL (sensation level). The participants presented high pitched tinnitus, while the mean loudness was 25 dBSL above the audibility threshold in both ears.

Table 2. Descriptive measures of the acuphenometry in kilo-hertz and decibel's sensation level

Descriptive		Mean	Median	Standard deviation	Min.	Max.
Right ear	RE (dB)	24.0	20	18.3	5	70
	RE (Hz)	4.300	5.000	2.342	1.000	8.000
Left ear	LE (dB)	26.5	20	18.3	5	70
	LE (Hz)	4.200	5.000	2.215	1.000	8.000

Descriptive measures
Legend: RE = right ear, LE = left ear, dBSL = decibels sensation level; dB = decibel; Hz = Hertz; Min. = Minimum; Max. = Maximum.

In Table 3 are exposed findings of the descriptive measures of the Masking Level Difference and Tinnitus Handicap Inventory. The Masking Level Difference results proved to be changed, which corresponds to binaural integration difficulties. As for the Tinnitus Handicap Inventory, its mean score corresponded to a mild degree.

Table 3. Descriptive measures of the masking level difference test and tinnitus handicap inventory self-reported questionnaire

Descriptive	Mean	Median	Standard Deviation	Min.	Max.
Masking Level Difference	3.3	3	3.6	-4	12
Tinnitus Handicap Inventory	19.2	16	14.0	6	70

Descriptive measures
Legend: Min. = Minimum, Max. = Maximum.

Table 4 shows the descriptive measures for ABR latencies. The ABR findings demonstrated that the absolute latencies of waves I, III, V and the interpeak intervals I-III, III-V, and I-V meet the normal standards bilaterally in 100% of the cases, considering the normality criterion used (Chart 1).

Table 4. Descriptive measures for absolute and interpeak latencies of the auditory brainstem response

ABR	Waves and Interpeaks	Mean (ms)	Standard deviation	Min (ms)	Max. (ms)
Right ear	I	1.63	1.65	1.50	1.70
	III	3.80	3.80	3.50	3.98
	V	5.57	5.56	5.18	5.66
	I-III	2.16	2.22	1.83	2.25
	III-V	1.77	1.79	1.25	1.95
	I-V	3.93	3.93	3.53	4.08
Left ear	I	1.64	1.65	1.40	1.70
	III	3.80	3.80	3.27	3.91
	V	5.60	5.57	5.38	5.67
	I-III	2.15	2.19	1.67	2.25
	III-V	1.80	1.79	1.47	1.90
	I-V	3.95	3.95	3.68	4.08

Descriptive measures
Legend: ABR = Auditory Brainstem Response, Min. = Minimum, Max. = Maximum, ms = milliseconds.

In Table 5 there are compared mean results of Acuphenometry, Masking Level Difference and Tinnitus Handicap Inventory, distributed according to the degree of tinnitus severity self-reported in the anamnesis. No statistical significance was verified between the self-reported degree of severity and the Acuphenometry, Masking Level Difference and Tinnitus Handicap Inventory results.

Table 5. Comparison of the self-reported degree of severity with acuphenometry, masking level difference and tinnitus handicap inventory

Degree of severity		Mean	Median	Standard deviation	p-value
Acuphenometry RE (dB)	Mild	25.8	20	20.8	0.855
	Moderate	20.8	20	14.6	
	Intense	20.0	20	- x -	
Acuphenometry RE (Hz)	Mild	4.692	6.000	2.213	0.065#
	Moderate	2.833	2.000	1.835	
	Intense	8.000	8.000	- x -	
Acuphenometry LE (dB)	Mild	27.3	20	20.1	0.505
	Moderate	21.7	25	14.4	
	Intense	45.0	45	- x -	
Acuphenometry LE (Hz)	Mild	4.692	6.000	2.213	0.169
	Moderate	2.833	2.000	1.835	
	Intense	6.000	6.000	- x -	
Masking Level Difference	Mild	2.0	2	2.8	0.085#
	Moderate	5.7	4	4.3	
	Intense	6.0	6	- x -	
Tinnitus Handicap Inventory	Mild	19.1	16	16.4	0.558
	Moderate	17.0	15	7.2	
	Intense	34.0	34	- x -	

ANOVA Test - statistically significant p-value ≤ 0,05 or 5%
Legend: RE = right ear, LE = left ear, dB = decibel; Hz= Hertz; # = p-value trending towards statistical significance.

Discussion

The results' analysis of the present study found that the sample consisted predominantly of young female adults with bilateral tinnitus. Such results corroborate findings in the literature, which compared the characteristics of tinnitus and its interference in daily life in patients with and without hearing loss and pointed out that in both groups, tinnitus predominated in women and was bilateral and constant[23]. This finding in the literature suggests that there is a higher percentage of women among individuals with normal audiometry and bilateral tinnitus. Regarding tinnitus constancy, what the authors suggested differs of that of clinical impression. Thus, the authors concluded that in their study, the presence or absence of hearing loss did not influence the previously mentioned characteristics (gender, laterality and constancy)[23].

Table 1 showed that 85% of the individuals with tinnitus and normal auditory thresholds in this research were not exposed to noise, 70% did not have a history of hereditary hearing loss nor dizziness. Literature finding differs from the present study pointing out that only 7.4% of individuals with tinnitus have normal auditory thresholds, and the authors suggest that although tinnitus is a symptom often associated with the presence of hearing loss, this does not always occur[23]. Regarding exposure to noise, a study showed that individuals exposed to noise with normal hearing thresholds had tinnitus (71%), suggesting exposure to noise as a risk factor for the onset of tinnitus[24]. Another study pointed out that there was no significant association between normal auditory thresholds, tinnitus and vertigo (rotational dizziness), corroborating the result found in Table 1 of the present study[25].

In Table 2, it was observed that the tinnitus pitch was characterized as high and with an average loudness of 25 dBSL in relation to the hearing threshold in both ears. In this sense, it was found that the measurement of tinnitus frequency corresponded to self-reported by the individual, as shown in Table 1. Literature findings show a study on Acuphenometry in individuals with tinnitus and normal auditory thresholds in which the average intensity measured in the Acuphenometry evaluation in the right ear was 20 dBSL (SD = 14.63) and in the left ear it was 17 dBSL (SD = 14.96) and, thus, similar to that obtained in the present study, perhaps due to the fact that bilateral tinnitus was predominant. As for the type of stimulus, the most common was the continuous pure tone and the frequency at 6,000 Hz[5], coinciding with the results of the present study. The authors explain that Acuphenometry is important to quantify tinnitus due to its subjective characteristics (pitch and loudness)[5].

In Table 3, we visualized the damage that individuals with normal auditory thresholds and tinnitus presented in the auditory ability of binaural integration. The altered Masking Level Difference demonstrates that the individuals in this sample have difficulty of hearing in noise, which may contribute to communication difficulties. The literature on central auditory assessment in patients with tinnitus is scarce, so we did not find any studies in literature on the Masking Level Difference and tinnitus in different databases. However, we came across a study that evaluated auditory processing skills in normal hearing people with and without tinnitus, which corroborates the finding of the present study, demonstrating that normal hearing people with tinnitus have difficulty hearing in noise. The authors demonstrated that normal hearing people with tinnitus obtained significantly lower results in the Dichotic Listening Test and Gap Detection Threshold in the right ear. Thus, the authors suggested that patients with normal hearing and tinnitus may have auditory processing difficulties[26].

The total Tinnitus Handicap Inventory score in this study is similar to some findings in the literature. In the study, that compared the characteristics of tinnitus and its interference with daily living, the patients with tinnitus and normal auditory thresholds had similar characteristics (time of disease onset, localization, type, frequency of occurrence) to those of individuals with tinnitus and hearing loss. However, the interference provoked in concentration and emotional balance was significantly lower, which did not occur in relation to interference in sleep and social activity[1]. In other study found in the literature, it was observed that the frequency of responses in the Tinnitus Handicap Inventory was observed with a higher occurrence of the mild degree, similarly to the present study[5].

As seen in Table 4, the ABR revealed the response in all the expected generating sites with absolute latencies and interpeak intervals according to normal standards bilaterally. Such results were similar to findings in the literature which compared the ABR responses between two groups of people with normal auditory sensitivity, with and without tinnitus. As a result, they found no significant differences between the subjects with and without tinnitus. The ABR latency parameters were also in accordance with the normal limits bilaterally in both groups[7]. Thus, the authors suggest that tinnitus in normal hearing individuals does not reflect damage to the cochlea or auditory pathways up to the brainstem level. However, despite the ABR findings in individuals with tinnitus presenting latencies and amplitudes within normal limits, it was noted that in the qualitative assessment of the ABR there was an increase in the responses of the V/I ratio in the subjects with chronic tinnitus, thus, according to the authors, serving as a reliable metric to objectively identify tinnitus[7]. However, the present study and the aforementioned studies differ from another finding in the literature, which pointed out that in a comparative study of normal hearing individuals with and without tinnitus, the group of individuals with tinnitus presented significantly delayed latencies of waves I, III and V, in addition of significantly reduced amplitudes of waves I and III when compared to controls. Thus, the authors suggested the presence of binaural processing deficits in patients with tinnitus at different levels along the ascending auditory pathway[8]. Another study in the literature, with the same population cited in previous studies, suggested that ABR results are variable in patients with tinnitus, as they showed that there was no significant difference between individuals with and without tinnitus; however, some individuals with tinnitus had latencies abnormal prolonged absolutes, interpeak latencies and increased interaural latency difference of wave V[6].

Table 5 reveals no statistically significant associations between the self-reported tinnitus classification and Acuphenometry, Tinnitus Handicap Inventory, and Masking Level Difference assessment results, disagreeing with the literature finding that demonstrated the significant relationship between the Tinnitus Handicap Inventory and Acuphenometry in the assessment of tinnitus. The authors suggested that Acuphenometry and Tinnitus Handicap Inventory assessments present a proportional correlation with tinnitus, providing different dimensions of tinnitus and complementing each other[5]. No studies were found that associated Acuphenometry, Tinnitus Handicap Inventory and Masking Level Difference. However, findings in the literature suggest that tinnitus can cause auditory processing difficulties for normal hearing people[26].

Furthermore, in Table 5, although there was no statistical difference, those individuals who judged their tinnitus to be intense had a higher pitch. In addition, individuals with self-reported tinnitus as severe had higher scores on the Tinnitus Handicap Inventory, meaning worse quality of life.

Findings in the literature point out that the perception of Masking Level Difference with temporal cues and changes in the stimulus phase require binaural integration – and both take place in the superior olivary complex[12]. The cochlear nucleus, the trapezoid body and the superior olivary complex contribute to the formation of wave III, the lateral lemniscus and inferior colliculus reflect wave V of ABR with click stimulus[27,28].

Although the Masking Level Difference and ABR supposedly assess brainstem structures that contribute to binaural integration, this study's results did not coincide. Studies have demonstrated that people have concentration and attention difficulties due to tinnitus[29,30]. Thus, it can be inferred that the individuals in the present study, while performing the Masking Level Difference, could be less attentive, probably due to the presence of tinnitus, and, consequently, the reduced attention could have been a contributing factor to the increase in perception of the whistle in the middle of the noise in the behavioral assessment, even if the individuals had presented adequate integrity of the auditory pathway to the brainstem in the objective assessment. Thus, corroborating the findings in the literature that suggest that tinnitus has a masking effect on the acoustic signals presented to these individuals[30,31].

Given all the abovementioned findings of this study, it can be inferred that tinnitus should be measured with different assessments that complement each other. In addition, behavioral and electrophysiological tests are important in identifying physiological and neurophysiological aspects in individuals with tinnitus. Thus, being able to guide the treatment of tinnitus.

As a future perspective, new studies can be mentioned comparing individuals with or without tinnitus and normal auditory thresholds in other behavioral tests of central auditory processing.

Conclusion

Based on the findings, it was verified that normal hearing adults with a complaint of tinnitus present bilateral high pitched tinnitus (average of 4.3 KHz in the right ear and 4.6 KHz in the left ear); average loudness of 21.7 dBSL in the right ear and 23.5 dBSL in the left ear; slight impact on quality of life; adequate conduction of the auditory pathways to the brainstem and impairment in the identification of sounds in the presence of noise, demonstrating that tinnitus may have repercussions on central auditory abilities.

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