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Auditory skills in young adults with and without tinnitus perception: a comparative study

Habilidades auditivas em adultos jovens com e sem percepção de zumbido: um estudo de comparações

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ABSTRACT

Purpose: Objective: To analyze auditory information processing responses in young adult subjects with tinnitus disorder. **Methods:** A descriptive and quantitative study was conducted, involving 36 subjects aged between 19 and 35 years. The subjects were divided into two groups: Group 1 (20 subjects with chronic tinnitus) and Group 2 (16 subjects without tinnitus). All participants underwent medical history assessment, Visual Inspection of the External Auditory Canal, Pure-Tone Audiometry, Speech Audiometry, Acoustic Immittance Measures, and used Behavioral Central Auditory Processing Tests as an evaluation tool - Dichotic Digits Test (TDD), Frequency Pattern Test, Speech in Noise, Masking Level Difference, and Gap in Noise (GIN). **Results:** Statistically significant differences were found between the groups for TDD responses in the left ear and for GIN in both ears. **Conclusion:** Young adults with chronic tinnitus exhibit impairments in binaural integration and temporal resolution skills.

Keywords: Tinnitus; Auditory processing; Hearing; Adults; Brain

RESUMO

Objetivo: analisar as respostas do processamento das informações auditivas em sujeitos adultos jovens com transtorno do zumbido. **Métodos:** estudo de caráter descritivo e quantitativo. Participaram do estudo 36 sujeitos, com idades entre 19 e 35 anos, divididos em dois grupos: Grupo 1 (20 sujeitos com zumbido crônico) e Grupo 2 (16 sujeitos sem zumbido). Todos os indivíduos foram submetidos à anamnese, inspeção visual do meato acústico externo, audiometria tonal liminar, logoaudiometria, medidas de imitância acústica e, como instrumentos de avaliação, os testes comportamentais do processamento auditivo central - Teste Dicótico de Dígitos, Teste Padrão de Frequência, Teste de Fala no Ruído, *Masking Level Difference* e *Gap in Noise*. **Resultados:** existiram diferenças estatisticamente significativas entre os grupos para as respostas do Teste Dicótico de Dígitos na orelha esquerda e para o *Gap in Noise* em ambas as orelhas. **Conclusão:** adultos jovens com zumbido crônico apresentam prejuízo nas habilidades de integração binaural e resolução temporal.

Palavras-chave: Zumbido; Processamento auditivo; Audição; Adultos; Cérebro

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INTRODUCTION

Tinnitus refers to the perception of a sound in the absence of any external sound source[1,2]. The multifactorial nature of the factors that can trigger and influence tinnitus makes each individual unique. Therefore, for the intervention process to be effective, an individualized treatment program is necessary[2]. It is not uncommon for tinnitus to be associated with complaints of difficulty understanding speech in noisy environments and cognitive impairment, which can lead to problems with attention, concentration, sleep, anxiety and depression[1-4].

Tinnitus disorder has been widely studied, but there is still much to unravel, since there is evidence that the symptom can be generated by different mechanisms[1,2]. It is now known that the triggers of tinnitus may be located in the primary auditory cortex, as well as in the auditory and non-auditory processing centers in the cortical region, and that the message will then be encoded with the support of adequate cognitive performance[5]. In view of these aspects, investigation of the peripheral and central auditory nervous systems is essential, because damage can occur in various areas within the auditory pathway.

Researchers have reported that the presence of tinnitus seems to resemble the presence of a competing background noise, which can negatively influence the processing of auditory information. In addition, there is evidence that tinnitus disorder may be related to neuroplastic changes in the central auditory nervous system (CANS)[4]. Impairment in the processing of auditory information can occur in various types of auditory skills, such as figure-ground, auditory closure, integration and temporal resolution[6,7]. Changes in auditory skills can lead to a disorder in the perception of verbal and non-verbal sounds, which will directly involve acoustic, phonemic and linguistic processing. In addition, inadequate sound perception can hinder functional auditory capacity and can influence the well-being and quality of life of each individual[4,6-8].

Studies investigating tinnitus disorder are related to diverse populations that present cognitive alterations, attentional alterations, neurological alterations or even include the aging process[1,9]. However, there is a need for studies with populations considered typical, i.e. those with only tinnitus disorder, but without other associated aggravating factors that could negatively influence auditory information processing responses, measuring the real performance of this population.

Health regulators suggest that new research on tinnitus be carried out in young individuals with adequate cognitive stimulation[1,10]. The premise is that by analyzing the auditory processing responses of these individuals, it would be possible to isolate other variables associated with tinnitus and thus understand which would be the most effective and reliable procedures for analyzing the processing of auditory information within an audiological investigation battery.

Therefore, the aim of this study was to analyze the behavioral responses of central auditory processing (CAP) skills in young adults with and without tinnitus perception.

METHOD

Study design

This is a descriptive and quantitative study, approved by the Research Ethics Committee of the Federal University of Santa Maria - UFSM, under the number 56038322100005346. It should be noted that this study complied with all the guidelines for research with human beings set out in Resolution 466/12 of the Brazilian National Health Council. All the subjects signed the Informed Consent Form (ICF), agreeing to take part in the study, and were informed of the risks and benefits of their participation. In addition, individuals who showed alterations in their hearing abilities were referred for auditory and/or cognitive training at the service and those who complained of tinnitus disorder were admitted to the institution's tinnitus outpatient clinic.

Sample composition

The sample for this study consisted of adults complaining of tinnitus disorder, which affects quality of life, a visual analog scale (VAS) of at least or more than 5 points, with onset six months ago and bilateral perception. The individuals had been seen at an audiology outpatient clinic and had been contacted through the social networks of the service, the teaching hospital and the researchers responsible. The eligibility criteria for both groups (G1 and G2) were:

- aged between 18 and 35;
- both genders;
- educated - more than twelve years of schooling;
- Brazilian Portuguese as a mother tongue;
- are not bilingual;
- right hand preference, due to changes in the functioning of the central auditory nervous system;
- non-musicians;
- hearing thresholds of up to 19 dBHL at frequencies between 250 and 8000 Hz;
- type "A" tympanometric curves and no history of hearing deprivation. - contralateral acoustic reflexes present bilaterally;
- without complaints or alterations in the Brief Neuropsychological Assessment Instrument-NEUPSILIN;
- do not have any diagnosed and/or evident neurological and/or psychiatric impairment;
- with and without tinnitus disorder;
- without complaints of dizziness or continuous exposure to noise.

The following inclusion criteria were adopted for G1 (study group):

- perception of only subjective tinnitus in both ears;
- individuals who were not undergoing any treatment for the symptom;
- time of tinnitus perception equal to or greater than six months;
- score on the Visual Analog Scale (VAS) equal to or greater than 4;
- degree of annoyance measured by the *Tinnitus Handicap Inventory* (THI) questionnaire, equal to or greater than 1.

Participants

A total of 71 individuals were seen during the data collection period, 35 of whom were excluded from the study for the following reasons: 15 for not being the maximum age, three for having a left hand preference, three for having hearing loss, ten for having altered their cognitive assessment and four for having altered their middle ear.

As a result of these exclusions, the total sample consisted of 36 subjects from a school clinic. Of the subjects, 25 were female and 11 male, aged between 19 and 35 years (average 23.8 years) and with an average schooling of 15.8 years. The participants were divided into two groups:

- Study Group (G1): made up of 20 subjects (7 men and 13 women), with bilateral tinnitus perception and ages ranging from 19 to 35 (average 24.6 years).
- Control Group (G2): made up of 16 subjects with no complaints of tinnitus (12 women; 4 men) aged between 20 and 30 years (average 22.8 years).

For a better methodological design, the procedures were divided into sample composition procedures and research procedures.

Procedures for sample composition

Semi-structured questionnaire: an anamnesis was carried out to find out about the hearing and general health aspects of each participant. Through this procedure, a diagnosis of chronic bilateral tinnitus was reached, based on the subject's self perception of the location of the symptom.

Visual inspection of the external acoustic meatus: carried out using a Mikatos model TK otoscope, in order to check for any alterations that would prevent the procedures from being carried out. If there were any alterations, the individual was referred for medical attention.

Pure tone audiometry (PTA): an Interacoustics AD229 audiometer, TDH 39 headphones and an acoustically treated booth were used. Hearing thresholds were considered to be within normal limits when up to 19 dBHL were present in the 250 Hz to 8000 Hz octaves, i.e. they were analyzed per frequency, since any alteration, even the slightest, can lead to impaired speech decoding[11].

Logoaudiometry: this was carried out on the same equipment as the ATL and consisted of two stages: the speech recognition threshold test, adding 30 dBHL above the tritonal mean, using the descending-ascending technique, considering the individual's threshold when 50% of the four presentations were repeated correctly. In addition, the Percentage Speech Recognition Index (PSRI) test was carried out, to which 40 dBHL above the tritonal mean was added, at a fixed intensity, or one that was more comfortable for the subject. For the test, 25 words were presented to the subject, who had to repeat them, with each hit corresponding to 4%[10].

Acoustic immittance measurements were taken using an *Interacoustics* AT235 device and TDH-39 headphones. The criteria already proposed were used to classify the tympanometric curves and acoustic reflexes[10].

Brief Neuropsychological Assessment Instrument - NEUPSILIN: was carried out with the aim of characterizing the individual's neuropsychological profile. It is a test that aims to verify the preservation or impairment of neuropsychological abilities through eight main cognitive functions: temporal-spatial orientation, concentrated auditory attention, visual perception, memory, arithmetic skills, language, praxis and executive functions. Using this test, it is possible to establish cognitive normality in the different skills mentioned above. For this study, the total score for each task was considered, taking into account previously proposed values[12].

For participants with *tinnitus* , the Visual Analog Scale (VAS) and the *Tinnitus Handicap Inventory* (THI) questionnaire were applied, both used to assess the impact of tinnitus on the individual's quality of life, as well as the eligibility criteria.

Research procedures

To assess CAP, the tests were selected with the aim of covering the minimum suggested battery, according to the recommendations of the *American Speech Language-Hearing Association* - ASHA[13] . All the behavioral tests were carried out in an acoustically treated booth, using supra-aural headphones, model TDH39, brand *Telephonics,* a two-channel audiometer, model AD629B, brand Interacoustics, connected to a *notebook to* guide the evaluations.

In all the tests, 40 dBNS above the tritone average was added to the application intensity, applied alternately, so as not to influence the results as a result of the individual's fatigue. It should be noted that all the tests could be carried out at the intensity mentioned above, given that regulatory bodies suggest the possibility of 40 dBNS above the tritonal mean, the same technique as the IPRF, which should be reviewed when individuals have reduced peripheral hearing acuity[10] . The tests were applied in a single session, but rest breaks were taken when necessary. Lower performance in at least one of the tests applied was considered a change in hearing abilities[13].

The analysis was carried out according to the guidelines for each test below: **Dichotic Digits Test (DDT):** the test was used to assess figure-ground auditory ability for verbal sounds in stages of binaural integration. The individual was instructed to repeat the four numbers presented simultaneously, two in each ear, at the end of each sequence, regardless of the order.

To analyze the final percentage of correct answers per ear, the number of correct answers was added up and multiplied by 2.5%. Hits equal to or greater than 95% were considered normal[14].

Frequency Pattern Test (FPT) - Auditec: The test was applied to assess the auditory ability of temporal ordering for non-verbal sounds. The individual was instructed to listen to the three stimuli presented and then repeat the sequence in which they heard the frequency, i.e. whether it was a fine or coarse sound (for example: fine-fine coarse). To analyze the final percentage of correct answers, results equal to or greater than 86.6%[15] were used as normal values.

***Masking Level Difference* (MLD):** The test was used to assess the auditory ability of binaural interaction and selective attention. Subjects were asked to answer "no" when they heard only the noise/whistle and "yes" when they heard the whistle. To analyze the final percentage of correct answers, normal values of 8 dB or more were used as a reference[15].

Speech in Noise (SR): The test was applied to assess auditory closure ability for verbal sounds. Each ear was presented with 25 monosyllable words in ipsilateral white noise, at a signal-to-noise ratio (S/N) of 5 dB, i.e. the speech was 5 dB more intense than the noise. The subject was instructed to ignore the noise and repeat the words they heard. The standard of normality used was 70% correct in both ears[14].

***Gap in Noise* (GIN):** The test was used to assess auditory temporal resolution ability. The individual was instructed to raise their hand every time they perceived silence. In order to analyze the final percentage of correct answers, the *gap* detection threshold was considered to be the smallest *gap* perceived by the individual at least 50% of the time it was presented, with 6 ms being considered the standard for normality[16]. Only track 1 was used, in both ears, due to the need to optimize time.

Statistical analysis of data

To obtain the statistical data, the variables were analyzed for normality using the Shapiro-Wilk test. Then, the Mann-Whitney non-parametric U test was selected to analyze the homogeneity of the age, education and gender variables, as well as to compare the groups, with a p-value of <0.05 (5%) as the level of significance.

RESULTS

Statistical analysis of the sample

With regard to the G1 individuals, i.e. those who perceived chronic bilateral subjective tinnitus, there was an average VAS score of 6.05, a THI of 2.6 for the degree of tinnitus and an average onset time of 5.82 years.

In the analysis of the homogeneity of the sample, no statistical differences were observed for the means of age and schooling in years or for gender between the groups, ruling out the influence of these variables on the findings. Hearing thresholds were not analyzed due to the normality required for peripheral hearing acuity for both groups (Table 1).

The descriptive data to better visualize the scores between the groups is shown in Table 2.

As for the comparisons between the groups in terms of performance on the DDT, by ear, statistically significant differences were found for the responses from the left ear (Figure 1).

When comparing the performance of the RF test per ear between the groups, no significant differences were observed between subjects with and without tinnitus disorder (Figure 2).

The comparison between the groups for the TPF test, where no significant differences were found, is shown in Figure 3.

The comparison between the groups for the MLD test, with no significant differences, is shown in Figure 4.

When comparing the average performance in the GIN, by ear, between the groups, it could be seen that there was a statistically significant difference for the test in both the right (RE) and left (LE) ears (Figure 5).

Table 1. Analysis of the variables gender, age and schooling between the groups

VARIABLES	GROUP	N	AVERAGE	SD	VALUE of P
GENDER	G1	20	13M - 7H	-	0.523
	G2	16	12M - 4H	-	
AGE	G1	20	24.65	4.41	0.296
	G2	16	22.87	2.94	
SCHOOLING	G1	20	16	1.98	0.947
	G2	16	15.5	1.36	

Subtitle: N = Number of participants; SD = Standard deviation; G1 = Group with tinnitus; G2 = Group without tinnitus; M = Women; H = Men.

Table 2. Presentation of descriptive data to visualize scores between groups

TEST	GROUP	N	AVERAGE	SD	VALUE of P
DDT RE	G1	20	95.75	6.07	0.094
	G2	16	98.28	1.76	
DDT LE	G1	20	96.25	4.48	**0.006***
	G2	16	99.38	1.12	
SR OD	G1	20	81.4	15.48	0.712
	G2	16	85.5	9.11	
SR OE	G1	20	85.4	11.48	0.383
	G2	16	89.25	6.96	
GIN RE	G1	20	5.05	1.23	**0.008***
	G2	16	4.19	0.4	
GIN LE	G1	20	4.95	1.6	**0.024***
	G2	16	4.06	0.57	
FPT	G1	20	82.97	19.95	0.166
	G2	16	93.92	4.76	
MLD	G1	20	12.6	3.56	0.769
	G2	16	13	2.07	

*statistical significance

Subtitle: N = Number of participants; SD = Standard deviation; G1 = Group with tinnitus; G2 = Group without tinnitus; DDT RE = Digit dichotic test in the right ear; DDT LE = Digit dichotic test in the left ear; SR RE = Speech in noise in the right ear; SR LE = Speech in noise in the left ear; GIN RE = *Gap In Noise in* the right ear; GIN LE = *Gap In Noise in the* left ear; FPT = Frequency standard test; MLD = *Masking Level Difference*

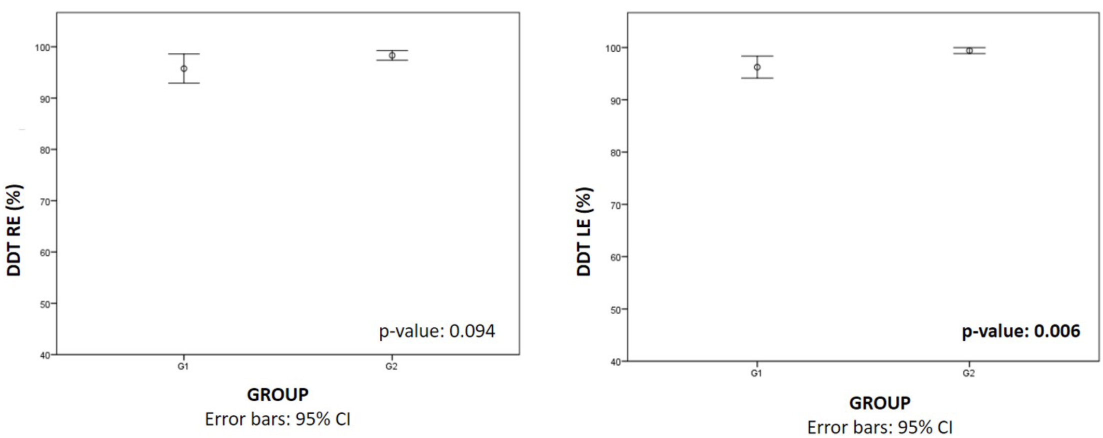

Figure 1. Comparison of the Dichotic Digits Test by ear between the groups
Subtitle: % = percentage; DDT RE = right ear dichotic digit test; DDT LE = left ear dichotic digit test; G1 = subjects with tinnitus; G2 = subjects without tinnitus; CI = confidence interval

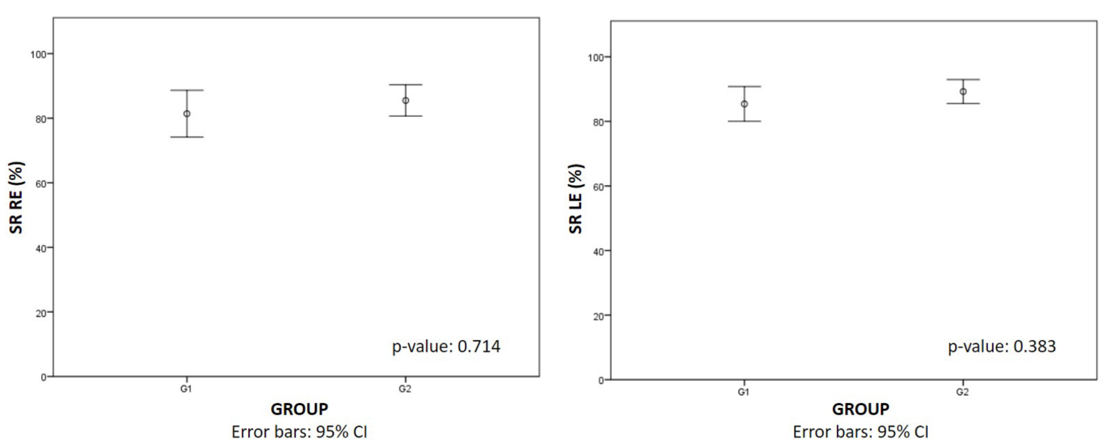

Figure 2. Comparison of the Speech in Noise Test between the groups
Subtitle: % = percentage; SR RE = speech in noise in the right ear; SR LE = speech in noise in the left ear; G1 = subjects with tinnitus; G2 = subjects without tinnitus; CI = confidence interval

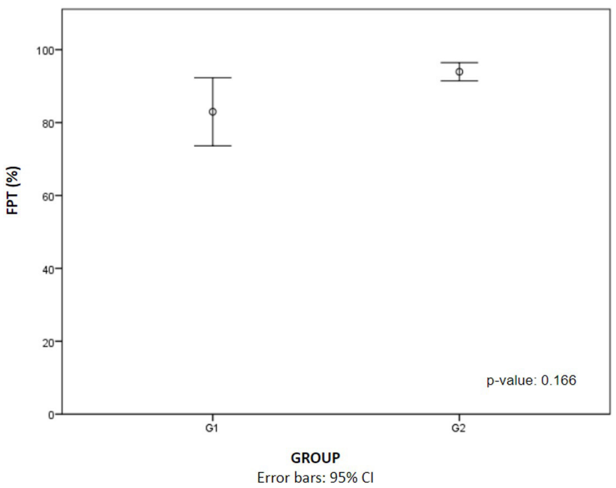

Figure 3. Comparison of the Frequency Standard Test between the groups, with no statistically significant differences
Subtitle: % = percentage; TPF = Standard Frequency Test; G1 = Subjects with tinnitus; G2 = Subjects without tinnitus; CI = Confidence Interval

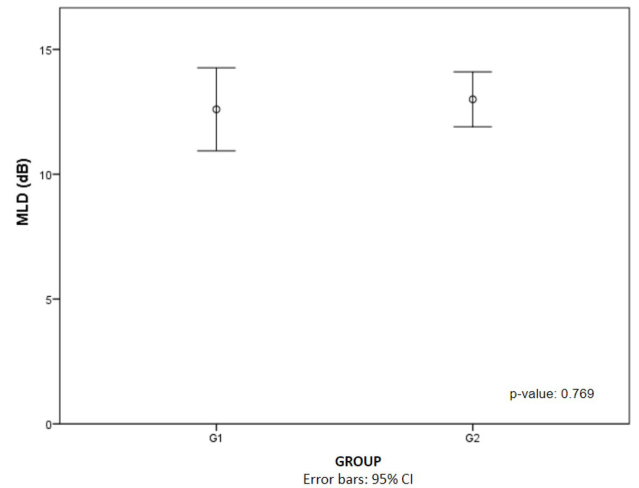

Figure 4. Comparison of *Masking Level Difference*, with no statistically significant differences
Subtitle: dB = decibels; MLD = *Masking Level Difference*; G1 = subjects with tinnitus; G2 = subjects without tinnitus; CI = Confidence Interval

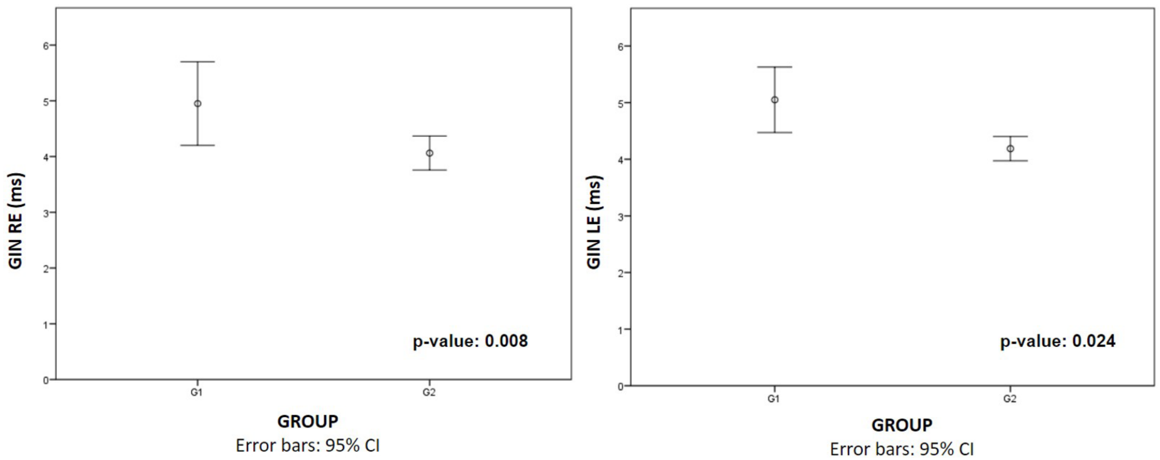

Figure 5. Comparison of the *Gap in Noise,* per ear, between the groups
Subtitle: % = Percentage; GIN RE = *Gap In Noise in* the right ear; GIN LE = *Gap In Noise* in the left ear; G1 = subjects with tinnitus; G2 = subjects without tinnitus; CI = Confidence Interval; ms = milliseconds

DISCUSSION

This study is in line with the specialized literature, since previous studies have shown the changes caused by the symptom of tinnitus in the CANS, which manifests itself in the functional capacity and, consequently, in the negative self-perception of these individuals, which may be correlated with speech decoding and comprehension(4,6,17-19). In addition, this study is pertinent due to the characteristics of the population studied, i.e. young adults, with no history of hearing deprivation, high education (incomplete or complete higher education) and cognitive normality, demonstrating the real performance of the subjects, without interference from these variables in the behavioral tests, with only the influence of the symptom on the processing of the acoustic signal.

Individuals with tinnitus disorder showed statistically significant differences when compared to individuals without tinnitus, with worse scores for OE TDD. These findings were found in other recent studies, which also showed lower binaural integration performance in this population, i.e. individuals with tinnitus have lower figure-ground auditory ability for verbal sounds(8,20). However, the difference between the samples in these studies and those in the present study, related to older age and altered peripheral auditory acuity, does not limit these assumptions, since these findings were also found in young adults with tinnitus.

It should be emphasized that the subjects in G1 obtained scores below normal for their age group, bilaterally, for the DPOA; however, this analysis was not carried out in this study due to the objective of the study. Thus, these alterations are justified due to cerebral perceptual asymmetry for processing auditory information, as a result of the significant differences for just one ear(20).

The specialized literature shows the effects of chronic tinnitus on speech recognition in noise, which can lead to difficulties in understanding speech in challenging listening situations(6,21,22,23). Thus, the recognition of stimuli in the presence of noise may be compromised or, at the very least, different from a healthy system. In this sense, although these networks can be addressed separately, using various auditory and cognitive tasks, they work together in real situations for speech recognition[21].

Research has reported a "central contribution" to speech comprehension, concluding that the effect of tinnitus may be particularly related to cognitive functions, which are potentially impaired when there is hearing loss[24]. Thus, in view of the cognitive assessment and hearing acuity of the population studied in this study, both of which were normal, the results are justified[25].

Thus, tinnitus in young adults with a high level of education does not seem to interfere with the RF test. However, despite these results, the possibility and warning of cognitive exhaustion in this population should be emphasized, considering that the effect of tinnitus as a factor detrimental to understanding the information received may have an effect similar to that of hearing loss in cognitive decline. Thus, the symptom as a distracting sound makes it difficult to recognize speech in noise and results in the depletion of cognitive resources due to excessive attention, resources which are extremely necessary for the proper processing of auditory information[25].

There were no differences between the groups in terms of binaural interaction ability, in agreement with another study[26]. Tinnitus causes changes in the distal portion of the vestibulocochlear nerve, and we observed the possibility of the symptom not presenting wave I in the Brainstem Auditory Evoked Potential (BAEP), with no changes in the other elicited components[27] . In this sense, it is believed that there was no change in binaural interaction, since no changes are expected in the other brainstem structures, which respond directly to this ability. However, further studies are needed to ratify the findings here.

Temporal skills are of paramount importance for CAP, with temporal resolution being essential for the proper perception of phonemes, syllables and words, while temporal ordering skills are closely related to speech intelligibility[28] . Thus, it is important to understand these aspects in individuals with tinnitus disorder in order to measure the impacts of the perception of the symptom, since the analysis and understanding of temporal aspects are closely necessary within the process of speech perception, as they encompass acoustic, phonetic and linguistic processing, which are essential for auditory performance in the conditions of ideal listening (silence) and impaired listening (presence of noise).

In the present study, no significant differences were found for the temporal ordering ability, measured using the TPF. These findings confirm other studies that aimed to assess the auditory processing skills of normal-hearing individuals with and without chronic tinnitus[20,28] . In this sense, these results seem to be related to the low sensitivity of this test to abnormalities in structures below the level of the auditory cortex, since, given the mechanism of neural deafferentation and the neuroplastic changes that occur in the auditory pathway of these subjects, this justifies the fact that no alterations were found in the test[28].

With regard to temporal resolution ability, assessed using the GIN, the group with tinnitus disorder required longer times to detect the minimum intervals of silence in a sound stimulus, findings which have already been shown in the specialized literature[7,29,30]. Thus, additional explanations can be provided based on temporal desynchronization and deafferentation of the auditory nerve, taking into account that each afferent nerve fiber within the auditory nerve responds specifically to a certain sound (the receptor potential of the inner hair cell). In this sense, when there is cochlear impairment, not measured in conventional audiometry, there is an interruption in the coding of the neural waveform through desynchronization and/or temporal differentiation, causing a possible deterioration in auditory perception, impairing speech intelligibility in noise and reducing the speed of stimulus coding[29].

Finally, the symptom causes changes in the neuroplastic functioning of the auditory pathway, which can impair functional capacity, negatively impacting speech understanding in this population[4] . Understanding these findings is of paramount importance for the speech therapy clinic, in order to reduce the damage to quality of life caused by tinnitus disorder, as well as to clarify whether this disorder really causes such difficulties. According to the findings, we suggest the possibility of a new form of rehabilitation, through auditory training, using sound therapy, bearing in mind that if the symptom is caused by changes in the SNAC, reorganizing it can generate reduction and/or habituation, demonstrating auditory training as a possible treatment tool[20].

Limitations of the study

Other studies using the method employed in this study are needed to ratify the findings. There is also a need to include scales and/or questionnaires, such as the Central Auditory Processing Ability Self-Perception Scale, which measures young adults' self-perception of CAP and aspects related to quality of life.

CONCLUSION

Young adults with chronic tinnitus perform less well than those without tinnitus, especially in tests that assess the auditory skills of binaural integration, auditory closure and temporal resolution.

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