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Original articles

Electroacoustic evaluation of the olivocochlear efferent pathway in subjects with tinnitus complaint

Avaliação eletroacústica da via eferente olivococlear em indivíduos com queixa de zumbido

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ABSTRACT

Purpose: to investigate the suppressive effect of transient-evoked otoacoustic emissions in subjects with tinnitus complaint and normal audiometry and to analyze the relation to age, gender, laterality of tinnitus and its degree of discomfort.

Methods: we assessed 60 subjects, 14 males and 46 females, aged between 20 and 59 years, 30 with tinnitus (experimental group) and 30 without tinnitus complaint (control group). The suppression of transient-evoked otoacoustic emissions was investigated with contralateral white noise at 50 dBHL at the frequency bands of 700, 1000, 1400, 2000, 2800 and 4000Hz.

Results: the mean value for the suppression of transient-evoked otoacoustic emissions in the experimental group ranged from 2.14 to 4.38. In the control group, the mean value for suppression of transient-evoked otoacoustic emissions ranged from 2.27 to 4.88.

Conclusion: suppression values of otoacoustic emissions were similar in subjects with and without tinnitus, although the results of the tinnitus group were lower, suggesting worse performance of the Superior Olivary Complex.

Keywords: Tinnitus; Hearing; Hearing Tests; Hair Cells, Auditory, Outer; Signal-To-Noise Ratio

RESUMO

Objetivo: investigar o efeito supressor das emissões otoacústicas por estímulos transientes em indivíduos com queixa zumbido e audiometria normal e analisar sua relação com as variáveis idade, sexo, lateralidade do zumbido e grau de incômodo.

Métodos: foram avaliados 60 sujeitos, 14 do gênero masculino e 46 do gênero feminino, entre 20 e 59 anos de idade, sendo 30 com queixa de zumbido (grupo experimental) e 30 sem zumbido (grupo controle). Foi realizada a pesquisa da supressão das emissões otoacústicas por estímulos transientes, para ruído branco de 50 dBNA, na condição contralateral nas bandas de frequência de 700, 1000, 1400, 2000, 2800 and 4000Hz. **Resultado:** no grupo experimental, a supressão das emissões otoacústicas transientes média variou de 2,14 a 4,38. No grupo controle o valor médio da supressão das emissões otoacústicas transientes variou de 2,27 a 4,88.

Conclusão: os valores de supressão das emissões otoacústicas foram semelhantes nos indivíduos com e sem zumbido, embora o grupo com o sintoma tenha tido resultados menores, sugerindo pior desempenho do Complexo Olivar Superior.

Descritores: Zumbido; Audição; Testes Auditivos; Células Ciliadas Auditivas Externas; Razão Sinal-Ruído

INTRODUCTION

Tinnitus is defined as the perception of a sound in one or both ears, as well as in the head, generated in the absence of an external sound stimulus, and it may be the first indication of a number of diseases that endanger health and well-being of individuals[1,2].

Also called *acouphène*, this symptom may or may not be associated with hearing alterations, varying in intensity and quality from person to person and can be perceived as a high-pitched sound, like a bell, or even a low-pitched sound, such as an engine[3]. It ranges from a mild discomfort to a complete incapacity[1,4].

This complaint is still unclear in many aspects, especially concerning its origin and production. According to researchers[5], the lack of knowledge about the pathophysiology of tinnitus conducted to the development of many theories that attempt to explain the origin of this symptom. It is known that there is the possibility of involvement of more than one mechanism in the same individual.

One of the hypotheses for the occurrence of tinnitus would be a dysfunction in the efferent auditory system, specifically in the medial superior olivary complex (MSOC) region.

The medial olivocochlear tract modulates the movement of the outer hair cells by the release of acetylcholine in the synaptic cleft, causing a hyperpolarization, which is opposed to the depolarization induced by sound stimuli. This hyperpolarization can be quantified by the decrease in the amplitude of otoacoustic emissions in the presence of noise in contralateral ear[6,7].

Some studies have shown a decrease in the amplitude of otoacoustic emissions in the presence of contralateral noise, which is called suppression effect, in individuals with tinnitus complaints[8,9]. However, other studies have found similar findings when comparing the suppression effect of otoacoustic emissions in individuals with and without tinnitus[10,11].

Although otoacoustic emissions are useful to investigate the medial olivocochlear tract, methodological problems affect the interpretation of academic findings. Many studies use a probe stimulus to produce the otoacoustic emission and an eliciting stimulus to evoke the efferent activity, changing, therefore, the otoacoustic emissions. Little attention has been given to the possibility of the probe stimulus evoke the efferent activity. Besides, many studies use contralateral elicitors and do not include measures to discard the influence of stapedius muscle contractions[12,13].

The clarification of the mechanisms involved in the production of tinnitus is necessary and essential to propose effective measures, which aim to the permanent relief of this symptom[14].

Knowing that the efferent system plays a key role in the modulation of active cochlear process, is there a decrease of noise suppression effect on otoacoustic emissions in individuals with complaint of tinnitus?

Therefore, this study aimed to investigate the suppression effect of transient-evoked otoacoustic emissions (TEOAEs) in individuals with complaint of tinnitus, as well as analyze its relation to the variables age, gender, laterality of tinnitus and level of discomfort.

METHODS

This study was approved by the Research Ethics Committee of the Postgraduate Studies Program in Speech Therapy at Pontifical Catholic University of São Paulo (PUC/SP) REC/PUC-SP.

, under the number 0015/2004 and all individuals signed an informed consent to participate in this study. The same proceedings were done in a private specialized clinic in the municipality of São Paulo.

This is a descriptive, experimental and comparison group study, and quantitative analysis were adopted.

The convenience sample was composed of 60 individuals, including male and female genders, with a mean age of approximately 37 years, ranging from 20 to 59 years. Both the experimental group (EG) and the control group (CG) were formed by 30 individuals, 23 women and seven men. Individuals who reported tinnitus composed the EG, while those who did not report this symptom remained in CG.

Inclusion criteria consisted in: complaint of constant or intermittent tinnitus, unilateral or bilateral for EG; hearing thresholds within the normal range, i.e., less than or equal to 25 dB HL in the frequencies of 250 kHz up to 8 kHz and TEOAEs in both ears for EG and CG. We excluded individuals who have reported outer and/or middle ear alterations and neurological changes, as well as those who have already undergone treatment with ototoxic medications and/or are in drug treatment for tinnitus.

All individuals were submitted to: audiological anamnesis, questionnaire about tinnitus characteristics[15], pure tone audiometry, transient-evoked otoacoustic emissions (TEOAEs) and research of TEOAEs suppression.

In order to measure TEOAEs, were used non-linear clicks with regular pulses during 80 microseconds

(µs), with rarefied polarity, presented in a series of 260 stimuli in eight clicks blocks each, with pulse repetition frequency of 50 cycles per second. Concerning the spectrum of emissions, the standard stimulus contains energy distributed in the frequency bands of 0.7; 1.0; 1.4; 2.0; 2.8 and 4 kHz[16].

The collection of emissions started with the right ear. For the measurement of transient-evoked otoacoustic emissions (TEOAEs), it was used the cochlear analyzer *Ero Scan*, produced by Maico Diagnostics Company, in a soundproof booth.

The technique used to record the suppression of TEOAEs followed the aforementioned procedures, added to the presence of white noise[17] in the opposite ear. The noise was provided by the audiometer *Interacoustic* AC 40, through TDH 39 phone with intensity of 50 dB HL[18]. This measure has always been performed after recording without contralateral stimulation for both ears, in order to not change the placement of the probe during the two measurements[16]. Therefore, the measurement was initiated in the right ear, after collection without contralateral stimulation, and after the left ear was evaluated with and without contralateral stimulation.

In the analysis of results, the otoacoustic emissions were classified as present or absent according to the following criteria: emissions were considered present when the value of S/N (signal-to-noise ratio) was greater than or equal to 7 dB in at least three frequencies.

The following criteria[17] were used to classify TEOAEs suppression as present or absent: the suppression value of the olivocochlear system was obtained from the measurement of the difference of the values obtained in the conditions with and without contralateral stimulation in each ear. It was considered that the suppression occurred when the value was positive (greater than or equal to 1) and it was considered that there was no suppression of the amplitude of TEOAEs when the value was zero or negative.

In order to compare the results in the suppression of transient-evoked otoacoustic emissions (TEOAEs) concerning the variable age (if it influences or not), the experimental group was divided by age – less than or equal to 37 years and over 37 years, and the division parameter was the average age (paired between groups).

The severity of tinnitus was analyzed by visual analogue scale (VAS). Following this method, we ask individuals to give a score from 1 to 10 concerning tinnitus, considering that 1 would be a mild tinnitus while 10, the worst tinnitus they could imagine. The scores were classified as the following: 1 to 3 - mild tinnitus; 4 to 6 - moderate tinnitus, and 7 to 10 - severe tinnitus[19].

After analyzing the scores attributed to the severity of tinnitus, the individuals were divided into three subgroups: Group 1 - mild tinnitus; Group 2 - moderate tinnitus; Group 3 - severe tinnitus.

In the analysis of results, the Mann-Whitney Test and the Kruskal-Wallis Test were used with significance level of $p < 0.05$; as well, it was performed a descriptive critical analysis of the variables: age, sex, severity and location of tinnitus.

RESULTS

The study sample consisted of 30 individuals in each group studied, 23 (76.7%) women and seven (23.3%) men, with an average age of 37 years for the experimental group and 36.2 years for the control group. There was no statistically significant difference between the groups regarding average age ($p = 0.753$).

In relation to the severity of tinnitus, there was an occurrence of 86.65% for moderate or severe tinnitus, while 13.35% for mild tinnitus.

Concerning the symptom laterality, 56.65% of the individuals reported bilateral tinnitus, whereas 43.35% informed unilateral tinnitus, considering that 23.35% reported this complaint in the right ear and 20% in the left ear.

The descriptive analysis of TEOAEs amplitude suppression, by frequency on the right and left ears, is shown in Table 1 and Table 2, respectively, in the control and experimental groups, and the answers were compared through the Mann-Whitney test, not finding significant differences.

Table 1. Descriptive analysis of TEOAEs amplitude suppression, by frequency on the right ear, in the Control Group (CG) (n=30) and in the Experimental Group (EG) (n=30).

Frequency / Group	TEOAEs amplitude suppression					*p*
	Average	SD	Median	Minimum	Maximum	
			700 Hz			
CG (n=8)	4,88	3,09	4,5	1	9	0,062
EG (n=7)	2,14	1,46	2,0	1	5	
			1000 Hz			
CG (n=17)	4,41	2,53	5	1	8	0,983
EG (n=13)	4,38	2,02	5	1	8	
			1400 Hz			
CG (n=14)	3,21	1,48	3,5	1	5	0,676
EG (n=12)	3,67	1,92	3,0	1	7	
			2000 Hz			
CG (n=11)	3,09	1,64	3	1	6	0,209
EG (n=13)	2,31	1,49	2	1	5	
			2800 Hz			
CG (n=11)	2,27	1,10	2,0	1	4	0,613
EG (n=12)	2,75	1,71	2,5	1	6	
			4000Hz			
CG (n=7)	3,14	1,77	3	1	6	0,650
EG (n=10)	2,80	1,62	3	1	6	

Mann-Whitney Test

Legend: TEOAEs– Transient-evoked otoacoustic emissions CG – control group; EG – experimental group SD – standard deviation; n –number of individuals Hz - *Hertz*

Table 2. Descriptive analysis of TEOAEs amplitude suppression, by frequency on the left ear, in the Control Group (CG) (n=30) and in the Experimental Group (EG) (n=30).

Frequency / Group	TEOAEs amplitude suppression					*p*
	Average	SD	Median	Minimum	Maximum	
			700Hz			
CG (n=7)	4,57	3,46	5	1	9	0,872
EG (n=9)	4,11	3,02	3	1	9	
			1000Hz			
CG (n=15)	2,93	1,71	3	1	6	0,655
EG (n=13)	4,15	3,81	2	1	13	
			1400HZ			
CG (n=16)	2,44	1,83	2,0	1	8	0,735
EG (n=12)	2,92	2,31	2,5	1	8	
			2000Hz			
CG (n=12)	2,92	2,02	2,5	1	8	0,515
EG (n=9)	3,67	2,45	3,0	1	8	
			2800Hz			
CG (n=13)	3,15	2,12	3	1	8	0,063
EG (n=12)	2,17	1,90	1	1	6	
			4000Hz			
CG (n=5)	3,00	1,00	3	2	4	0,377
EG (n=4)	2,25	1,50	2	1	4	

Mann-Whitney test
Legend: TEOAEs– Transient-evoked otoacoustic emissions CG – control group
EG – experimental group SD – standard deviation
n –number of individuals Hz - *Hertz*

The distribution of the presence of TEOAEs suppression, by frequency and by ear, in individuals in the experimental group according to age (less than or equal to 37 and greater than 37 years) showed no significant differences using Mann-Whitney test (Table 3).

In tables 4 and 5, there is the presence of TEOAEs suppression by frequency and by ear, according to the variable severity (mild, moderate and severe) and laterality of tinnitus (right unilateral, left unilateral left or bilateral) respectively. It was observed that there were no significant differences in the comparisons performed using the Kruskal-Wallis test.

Table 3. Presence of TEOAEs suppression by frequency and by ear, according to the variable age (years), in the experimental group (n=30).

Presence of TEOAEs amplitude suppression(**)		Age (Years)		*p*
Ear	Frequency	≤ 37 (n = 16)	> 37 (n = 14)	
Right	0,7kHz	3 (18,8%)	4 (28,6%)	0,533
	1,0kHz	6 (37,5%)	7 (50,0%)	0,498
	1,4kHz	5 (31,3%)	7 (50,0%)	0,304
	2,0kHz	8 (50,0%)	5 (35,7%)	0,439
	2,8kHz	6 (37,5%)	6 (42,9%)	0,769
	4,0kHz	6 (37,5%)	4 (28,6%)	0,611
Left	0,7kHz	4 (25,0%)	5 (35,7%)	0,530
	1,0kHz	5 (31,3%)	8 (57,1%)	0,160
	1,4kHz	8 (50,0%)	4 (28,6%)	0,240
	2,0kHz	5 (31,3%)	4 (28,6%)	0,875
	2,8kHz	5 (31,3%)	7 (50,0%)	0,304
	4,0kHz	4 (25,0%)	0 (0,0%)	0,068

Mann-Whitney test
(**) It was considered that the suppression occurred when the value was positive (greater than or equal to 1 dB).
Legend: TEOAEs– Transient-evoked otoacoustic emissions n –number of individuals kHz – *kilo Hertz*

Table 4. Presence of TEOAEs suppression by frequency and by ear, according to the variable severity of tinnitus (mild, moderate and severe) (n = 30).

Presence of TEOAEs suppression		Severity of tinnitus			*p*
Ear	Frequency	Mild (n = 4)	Moderate (n = 17)	Severe (n = 9)	
Right	0,7 kHz	1 (25,0%)	4 (23,5%)	2 (22,2%)	0,994
	1,0 kHz	1 (25,0%)	9 (52,9%)	3 (33,3%)	0,472
	1,4 kHz	1 (25,0%)	8 (47,1%)	3 (33,3%)	0,649
	2,0 kHz	0 (0,0%)	8 (47,1%)	5 (55,6%)	0,167
	2,8 kHz	0 (0,0%)	9 (52,9%)	3 (33,3%)	0,143
	4,0 kHz	0 (0,0%)	7 (41,2%)	3 (33,3%)	0,303
Left	0,7 kHz	0 (0,0%)	6 (35,3%)	3 (33,3%)	0,382
	1,0 kHz	1 (25,0%)	9 (52,9%)	3 (33,3%)	0,472
	1,4 kHz	1 (25,0%)	9 (52,9%)	2 (22,2%)	0,265
	2,0 kHz	2 (50,0%)	5 (29,4%)	2 (22,2%)	0,610
	2,8 kHz	1 (25,0%)	8 (47,1%)	3 (33,3%)	0,649
	4,0 kHz	0 (0,0%)	2 (11,8%)	2 (22,2%)	0,542

Kruskal-Wallis test
(**) It was considered that the suppression occurred when the value was positive (greater than or equal to 1 dB).
Legend: TEOAEs– Transient-evoked otoacoustic emissions n –number of individuals kHz – *kilo Hertz*

Table 5. Presence of TEOAEs suppression by frequency and by ear, according to the variable laterality of tinnitus (right unilateral, left unilateral left or bilateral) (n = 30).

Presence of TEOAEs suppression		Laterality of tinnitus			*p*
Ear	Frequency	Right ear (n = 7)	Left ear (n = 6)	bilateral (n = 17)	
Right	0,7 kHz	1 (14,30%)	3 (50,0%)	3 (17,65%)	0,585
	1,0 kHz	4 (57,15%)	3 (50,0%)	6 (33,3%)	0,234
	1,4 kHz	2 (28,55%)	3 (50,0%)	7 (41,15%)	0,245
	2,0 kHz	5 (71,40%)	2 (33,35%)	6 (35,30%)	0,709
	2,8 kHz	3 (42,85%)	3 (50,0%)	6 (35,30%)	0,141
	4,0 kHz	3 (42,85%)	4 (66,65%)	3 (17,65%)	0,248
Left	0,7 kHz	1 (14,30%)	2 (33,35%)	5 (29,40%)	0,532
	1,0 kHz	3 (42,85%)	2 (33,35%)	8 (47,05%)	0,561
	1,4 kHz	4 (57,15%)	3 (50,0%)	5 (29,40%)	0,115
	2,0 kHz	2 (28,55%)	2 (33,35%)	5 (29,40%)	0,572
	2,8 kHz	2 (28,55%)	2 (33,35%)	8 (47,05%)	0,245
	4,0 kHz	1 (14,30%)	2 (33,35%)	1 (5,90%)	0,143

Kruskal-Wallis test
(**) It was considered that the suppression occurred when the value was positive (greater than or equal to 1 dB).
Legend: TEOAEs– Transient-evoked otoacoustic emissions n –number of individuals kHz – *kilo Hertz*

DISCUSSION

The study sample consisted mostly of females (76.7%). Some authors[1,20] reported that women present a higher prevalence of tinnitus complaint. On the other hand, a national study[21] did not identify differences between the sexes; moreover, it was characterized by an average age of young adults (37 years), similar to the study of Fernandes and Santos[22], whose average age was 37.8 years.

In relation to the severity of tinnitus, it was evidenced similar results to the Brazilian academic literature in identifying the occurrence of moderate tinnitus in 86.65%[20]; 61.8%[13] and 57%[23] of cases. However, studies have reported that 72%[1] and 53.2%[24] of the population they have studied presented mild to moderate tinnitus. Perhaps the difference in values observed in these studies is due to the method used for data collection and analysis, as well as the difference between the populations studied.

Regarding the laterality of tinnitus, we verified 56.65% of bilateral and 43.35% of unilateral complaints, being 23.3% in the right ear and 20% in the left ear, similarly to the studies that reported 70%; 67% and 60% of patients with bilateral tinnitus and 30%; 33% and 25% with unilateral tinnitus, respectively[13,23,25]. However, other authors have reported higher incidence of unilateral tinnitus (left ear) (65%) in individuals with normal pure tone audiometryl[22].

The mean amplitude of TEOAEs suppression in this study ranged from 2.14 to 4.38 dB in the right ear and 2.17 to 4.15 dB in the left ear for the EG, and from 2.27 to 4.88 dB in the right ear and 2.44 to 4.57 dB in the left ear for the CG (Tables 1 and 2). Such values were higher than those found in the literature consulted (1.28 dB in the right ear and 1.25 dB in the left ear[26] and 1.29 dB in the right ear and 1.26 dB in the left ear)[4].

Therefore, despite the lack of a statistically significant difference, the mean amplitude of TEOAEs suppression were lower in patients with tinnitus (EG) than in individuals without the symptom (CG), similarly to another study that also compared the suppression effect between groups[9]. Although the difference is not statistically significant, this result suggests lower effectiveness of the medial efferent olivocochlear system concerning the EG[7,13.].

Numerical comparisons between studies are difficult, since there are methodological differences used to measure the suppression of TEOAEs, such as type and intensity of suppressive noise, intensity and polarity of the click, and the ear in which the masking was presented (contralateral/ipsilateral/bilateral) and the equipment used[27].

This study did not show statistically significant differences between the presence of suppression and age in the EG individuals (Table 3), although previous studies have demonstrated a reduction in the suppression effect according to age increases[28, 29].

There were also no differences in TEOAEs suppression according to the severity of tinnitus (Table 4). In the literature consulted, there were no studies that associate the presence of TEOAEs suppression to the variable severity of tinnitus in individuals with this symptom.

The association between laterality of tinnitus and the presence of TEOAEs suppression was also not significant (Table 5), in agreement with the international academic literature, a less efficient functioning of the MSOC in one ear does not necessarily imply that tinnitus is present in that ear, as some cases in which it is lateralized in the opposite side[10]. On the other hand, some studies have shown that the function of the MSOC is reduced in the tinnitus side[4,6,23].

Therefore, although the results related to the suppression of TEOAEs were similar in individuals with and without tinnitus, we observed a tendency to less suppression effect in patients with tinnitus. Thereby, further studies may support the understanding of the role of efferent pathways in cases of tinnitus and, especially, the assessment of the hypothesis of MSOC relation[10]. We suggest that these studies attempt to control confounding variables such as manual preference, since the efferent auditory system operates under lateral conditions, following the standards of hemispheric dominance and, thus, does not have the same suppression effects for the right and left ears in people right-handed and left-handed[6] and with tolerance to noise, since hyperacusis, which accompanies many cases of tinnitus, may increase the suppression effect of otoacoustic emissions[30].

In this context, even considering the inexistence of statistical significance, it is supposed the importance of the TEOAEs suppression for the tinnitus topographic diagnosis. However, it is necessary to standardize procedures and also normative values for clinical applicability.

CONCLUSION

Suppression values of otoacoustic emissions were similar in individuals with and without tinnitus, although the group with this symptom has presented lower results, suggesting a worse performance of the superior olivary complex. There were no significant differences between the presence of suppression and age, sex, laterality and level of discomfort of tinnitus.

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