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Original Article

Artigo Original

Tinnitus in adolescents: the start of the vulnerability of the auditory pathways

Zumbido em adolescentes: o início da vulnerabilidade das vias auditivas

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Keywords

Tinnitus
Adolescent
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ABSTRACT

Introduction: Although tinnitus is an increasingly common symptom, few studies have assessed its prevalence or incidence among adolescents. **Purpose:** To assess whether the presence of tinnitus in adolescents is associated with minimal hearing damage, evaluated through high-frequency audiometry (HFA), otoacoustic emission (OAE), and loudness discomfort level (LDL). **Methods:** The sample comprised 168 adolescents of a private school (61.3% boys; mean age 14.1 years old; standard deviation=2). All of them completed a questionnaire about tinnitus and hypersensitivity to sounds (sound intolerance), and then underwent otoscopy, pure-tone audiometry, HFA, LDL, transient and distortion product otoacoustic emissions (TOAE and DPOAE), and tinnitus pitch/loudness matching (the latter only in those with tinnitus). Participants were later divided into three groups: with no tinnitus (n=73, 43.4%), with sporadic tinnitus (n=47, 28%), and with constant tinnitus (n=48, 28.6%). **Results:** No significant difference was observed between the groups regarding audiometry thresholds in frequencies from 0.25 to 16 kHz, or TOAE and DPOAE. However, the LDL in adolescents with constant tinnitus was significantly lower than that in other groups, suggesting hypersensitivity to sounds. **Conclusion:** There was no evidence of minimal hearing damage in the audiometry and OAE. Nonetheless, the decreased LDL in adolescents with constant tinnitus suggests that their auditory system is more sensitive. Therefore, this may be the first sign of vulnerability to sounds. Future medium- to long-term monitoring of these students may show whether they will begin a process of functional impairment, altering hearing thresholds, and OAE.

Descritores

Zumbido
Adolescente
Audiometria
Hiperacusia

RESUMO

Embora o zumbido seja um sintoma cada vez mais comum, poucos estudos avaliaram sua prevalência ou incidência entre adolescentes. **Objetivo:** Avaliar se a presença de zumbido em adolescentes está associada a lesões auditivas mínimas, avaliadas por audiometria de altas frequências (AAF), emissões otoacústicas (EOA) e limiar de desconforto a sons (LDL). **Métodos:** Participaram da amostra 168 alunos adolescentes de uma escola particular, sendo 61,3% do gênero masculino e com média de idade de 14,1 anos (desvio padrão=2). Todos responderam a um questionário sobre zumbido e hipersensibilidade auditiva (intolerância a sons) e foram submetidos à otoscopia, audiometria tonal convencional e de frequências acima de 8.000 Hz, LDL, EOA transientes (EOAT) e produto de distorção (EOAPD) e acufenometria (esta apenas naqueles com zumbido). Em seguida, foram divididos em três grupos: Sem Zumbido (n=73; 43,4%), Zumbido Esporádico (n=47; 28%) e Zumbido Constante (n=48; 28,6%). **Resultados:** Não houve diferença significativa entre os grupos em relação aos limiares da audiometria nas frequências de 250 a 16.000 Hz, nem nas EOAT ou EOAPD. Entretanto, o LDL dos adolescentes com zumbido constante foi significativamente menor do que o dos demais grupos, sugerindo hipersensibilidade auditiva. **Conclusão:** Não houve evidência de alterações auditivas mínimas na audiometria e EOA. Entretanto, a diminuição do LDL em jovens com zumbido constante sugere que suas cócleas sejam mais sensíveis. Portanto, esse pode ser o primeiro sinal de vulnerabilidade a sons, mas o acompanhamento desses adolescentes a médio prazo poderá demonstrar se tais regiões entrarão em processo de comprometimento funcional, alterando os limiares audiométricos e as EOA.

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INTRODUCTION

Although tinnitus is an increasingly prevalent symptom in the world population and in clinical assessments, few studies have evaluated its prevalence or incidence among adolescents. The results found in literature have varied widely (from 3.5 to 69%), but suggested that it is more common than expected[1-7]. Still, professionals with experience on the subject rarely treat adolescents complaining of tinnitus, which suggests the existence of some natural mechanism of adaptation to the complaint.

However, young people, in general, tend to put their ears at risk during leisure activities, often due to lack of information. Brazilian adolescents enjoy loud music, in particular the one reproduced in personal media players[2], and do not worry about prolonged exposure or excessive sound volume. These behaviors expose them to early and irreversible cochlear damage[4]. In the Netherlands, 70% of the young people reported attending nightclubs and 24.6% are at risk for hearing loss by estimated exposure to 100 dBA for more than an hour a week, without the use of hearing protection[8].

It is known that cochlear alterations — even if minimal — can lead to tinnitus[9] and hyperacusis[10], the latter also known as a type of hypersensitivity to sounds or sound intolerance. In fact, the association of the two is common and can reach 63 to 90% of the cases[11]. Both are subjective symptoms, usually evaluated through questionnaires, but tinnitus can be measured by tinnitus pitch and loudness matching (a measure of the frequency and intensity of tinnitus, as well as the minimum masking threshold) and hyperacusis, for the loudness discomfort levels (LDLs). The LDL are not often requested by otolaryngologists or performed in the speech-language pathologists' routine for clinical investigation, with the exception of the process of adaptation to hearing aids.

Thus, from a clinical point of view, both tinnitus and hyperacusis can be considered warning symptoms of early impairment of the peripheral auditory pathway, before any hearing loss is perceived by the patient or shown by conventional audiometry of 250 to 8,000 Hz. From the audiological perspective, two exams are considered to be more detailed for detecting slight hearing alterations: otoacoustic emissions (OAE) and audiometry of frequencies above 8,000 Hz.

The presence of OAEs indicates integrity of the preneural cochlear receptor mechanism to sounds and the specific evaluation through frequency provides information on different parts of the cochlea[12]. Several studies among adults with normal conventional audiometry have shown that the presence of tinnitus is often associated with changes in OAEs[13-16]. This reinforces that tinnitus may appear before hearing loss and that OAEs can detect minimal cochlear alterations in individuals with normal audiometry.

The high-frequency audiometry has taken a prominent role in the audiological diagnosis, as these frequencies are the first to be affected in most diseases that strike the inner ear[17]. Studies have shown worsening of high-frequency hearing thresholds in individuals with tinnitus before the characteristic alterations in the conventional frequency range[18-20].

Tinnitus in adolescents is a relatively unexplored subject in the scientific literature, and little valued in the professional routine of pediatricians, adolescent medicine doctors, otolaryngologists, and speech-language pathologists and audiologists. The possible verification that its presence in such an early age already suggests some fragility of the auditory system would have motivational power for obtaining more active attitudes from professionals, parents, teachers, and perhaps the adolescents themselves.

The objective of this study was to evaluate if the presence of tinnitus in adolescents is associated with minimal hearing damage, investigated by high-frequency audiometry, OAEs, and LDLs.

METHODS

Project and configuration

This study is part of the first stage of a three-phase "mother study" about tinnitus in adolescents, which is assessing the prevalence, the response to the treatment, and the long-term monitoring. It was approved by the Research Ethics Committee in the Plataforma Brasil (CAAE: 01734412.4.0000.0076) and has received funding from the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, 2011/18797-7).

Given the national socioeconomic distribution, we wanted to guarantee that the adolescents to be selected for the sample would have financial freedom to enjoy the leisure habits of their preference, so that the team could analyze them. Consequently, the study was conducted in a private school (Santa Cruz School, São Paulo), after a long discussion with the principal and the teachers, to protect the students as much as possible and avoid any interference in the schedule of school activities.

Selecting the sample

The school's principal and the researchers sent an invitation to the parents of 470 adolescent students, regularly enrolled, to participate in the research within the school's premises, requesting a formal written consent of parents or guardians, so that the adolescents could be part of the research with prior appointment. Of all the adolescents invited, 207 families authorized the participation of the students in the research, but only 168 adolescents attended. No exclusion criteria were previously applied, but participants with cerumen in the external auditory meatus, tubal pain or dysfunction due to ear, nose, and throat infections had their evaluation delayed until the normalization of the physical exams to minimize the influence on the results.

The final sample was then composed of 168 adolescents aged between 11 and 17 years old (mean age 14.1 years, standard deviation=2 years) and predominance of boys (61.3%).

Procedures

All adolescents were evaluated by the same professional team in a single session lasting 30 to 40 minutes. This team included two otolaryngologists and two speech-language pathologists, with clinical experience in tinnitus.

The otolaryngologists performed the following in all participants:

1. each adolescent was interviewed, with or without their parents, through a specific questionnaire developed for this study about the self-perception of hearing loss, tinnitus, and hypersensitivity to sounds (or sound intolerance). The individuals with tinnitus were asked to evaluate the discomfort on a visual analog scale from 0 to 10. The frequency of exposure to leisure habits with potential risk, such as headsets, music in evening events, and phone to the ear (excluding the use to type messages or access the Internet), was also evaluated;
2. physical examination focused on otoscopy (removal of cerumen and flaking whenever necessary);
3. final report with the results of all the exams to be presented to the adolescents, parents, and school principal.

The speech-language pathologists performed the following tests in all participants:

1. pure-tone audiometry from 250 to 16,000 Hz, using the two-channel audiometer Ziptom (Sancout) and Senheiser HDA 200 headphones, in the acoustic booth, researching pure-tone thresholds through the descending-ascending method. The research of the bone conduction pathway was carried out when some air conduction threshold was above 15 dB HL at the frequencies of 500 to 4,000 Hz.
2. LDL, with the two-channel audiometer Ziptom (Sancout) and Senheiser HDA 200 headphones, researching the discomfort thresholds at the frequencies of 500, 1,000, 2,000, and 4,000 Hz bilateral, within the acoustic booth.
3. transient otoacoustic emissions (TOAEs), in the frequencies of 1,500, 2,000, 2,500, 3,000, 3,500, and 4,000 Hz, and distortion product otoacoustic emissions (DPOAEs), at the frequencies of 2,000, 3,000, 4,000, 6,000, 8,000, 10,000, and 12,000 Hz, using the OtoRead (Interacoustics) apparatus. With the participant sitting in a silent room and as still as possible, the machine automatically monitored the level of noise, the stimulus' stability during the test and the proper placement of the probe. When one of these aspects was inadequate, the ear tip has been replaced or repositioned, and the evaluation restarted.

The adolescentes that experienced tinnitus in the moment of evaluation were also submitted to tinnitus pitch/loudness matching, including the research of the frequency and intensity more similar to the ones of the tinnitus and of the minimum masking levels (lower intensity of the narrowband stimulus necessary to mask the tinnitus).

Only from then on, 168 adolescents were divided into three groups, as shown in Table 1.

RESULTS

The data referring to the prevalence of tinnitus in the study participants were sent for separate publication[21]. Therefore, the results described here refer only to the comparison of the data between the three groups of adolescents (with no tinnitus, with sporadic tinnitus, and with constant tinnitus).

We evaluated the distribution of the sample in relation to gender, age, body mass index, discomfort with everyday sounds and leisure habits associated with headphones, loud music events (parties, nightclubs, concerts), and use of mobile phone in the ear. The epidemiological characteristics were similar, but there was a statistical trend of the participants with constant tinnitus being younger than those of the other groups ($p=0.06$), which was confirmed when comparing only the two groups with tinnitus ($p=0.04$). Individuals with constant tinnitus mentioned discomfort with everyday sounds in the anamnesis more frequently than those in the other groups ($p=0.02$). The exposure to habits potentially harmful to the ears was frequent in all groups, with no statistical difference. However, the sensation of manifestation or temporary worsening of tinnitus essentially associated with leaving noisy places (parties, concerts, nightclubs) was significantly more common in both groups with tinnitus ($p<0.001$).

Unlike what was expected, Table 2 shows there was no significant difference between tone levels obtained at all frequencies analyzed in the three groups. As a reinforcement point of this result, the analysis of the thresholds at the frequencies traditionally more affected by exposure to noise (3,000, 4,000, and 6,000 Hz) was extremely homogeneous between groups, reaching p-values ranging from 0.334 to 0.899. An exception was the frequency of 2,000 Hz, where the group of adolescents with constant tinnitus had the best results (lower thresholds, $p=0.02$).

For the OEAs, we made a descriptive analysis of the results of each frequency obtained in each ear using the mean, median, standard deviation, and minimum and maximum values. Table 3 shows that there was no significant difference in the intensity

Table 1. Criteria for the constitution of three groups of adolescents in the research, considering the responses to the questionnaire and tinnitus pitch/loudness matching

Group	Questionnaire: "Do you or did you have tinnitus in the last 12 months?"	Tinnitus pitch/loudness matching in an acoustic booth	Number of participants (%)
No tinnitus	No	No tinnitus	73 (43.45)
Sporadic tinnitus	Yes	Tinnitus absent at the moment	47 (27.98)
Constant tinnitus	Yes	Measured tinnitus	48 (28.57)

and signal-to-noise ratio of TOAE and DPOAE between the three groups (p>0.05).

We analyzed the correlations between pure-tone thresholds and the OAEs (TOAE and DPOAE) at the frequencies that are common to both exams (2, 3, and 4 kHz) and in each ear. For virtually all frequencies, the higher the threshold found in audiometry, the lower the value of the OAE for both parameters (TOAE and DPOAE) (r<0 and p<0.05). The exception was the frequency of 2,000 Hz in the right ear, although it followed the direction of the other results (p=0.084).

Regarding the LDLs, we performed a descriptive analysis of the results using the mean, median, standard deviation, and minimum and maximum values. Table 4 shows that the LDLs showed significant difference at all frequencies of both ears between the groups (p<0.001). In this analysis, we also made LDL comparisons between the groups (two by two). Table 5 clearly shows that, at all frequencies in both ears, the adolescents with constant tinnitus had statistically lower LDLs than the other adolescents (p<0.05). Thus, the adolescents with constant tinnitus have higher hypersensitivity to sounds (or sound intolerance) because their discomfort with sounds begins in weaker intensities than that of adolescents with sporadic tinnitus or without tinnitus.

DISCUSSION

On the basis of our clinical and research experience with tinnitus in adults and its strong association with hearing loss, the planning of this first "mother study" with teenagers had suggested that we would find the following:

1. High prevalence of tinnitus among adolescents because of exposure to leisure habits with potential risk to the ears, such as use of headphones at high volume and for prolonged periods, going to venues with loud music (shows, parties, nightclubs, raves, etc.) and frequent use of cell phones in the ear. This item was actually confirmed and detailed in another article[21]. In summary, using the questionnaire created for the research, we have found that over 50% individuals answered "yes" to the question "Do you or did you have tinnitus in the last 12 months?", with the exception of one or two times and with duration of less than 5 minutes. These data are in agreement with other prevalence researches using questionnaire as an instrument for obtaining data[1,4,6]. In addition, when placed in an acoustic booth for the audiological tests, almost 30% of the total sample was able to identify the frequency and intensity of tinnitus through tinnitus pitch/loudness matching, whereas others

Table 2. Description of pure-tone thresholds of the three groups in all frequencies between 250 and 16,000 Hz

Ear	Frequency	Grup																		p-value
		No tinnitus						Sporadic tinnitus						Constant tinnitus						
		Mean	SD	Median	Min	Max	n	Mean	SD	Median	Min	Max	n	Mean	SD	Median	Min	Max	n	
Right	250 Hz	8.58	4.18	10	0	20	73	7.45	4.02	5	0	20	47	7.81	3.25	10	0	15	48	0.262
	500 Hz	8.49	4.62	10	0	20	73	7.66	4.41	5	0	20	47	6.87	3.67	5	0	15	48	0.318
	1 kHz	6.03	4.48	5	0	20	73	5.32	4.47	5	0	20	47	4.69	3.16	5	0	10	48	0.335
	2 kHz	5.48	6.08	5	0	40	73	5.96	4.50	5	0	15	47	5.00	4.84	5	0	25	48	0.386
	3 kHz	4.66	6.20	5	0	40	73	4.68	6.20	5	0	30	47	3.75	4.56	5	0	20	48	0.791
	4 kHz	3.29	5.73	0	0	35	73	3.09	5.17	0	0	25	47	3.12	4.33	0	0	20	48	0.892
	6 kHz	6.64	5.53	5	0	25	73	6.81	5.85	5	0	25	47	6.67	4.65	5	0	20	48	0.899
	8 kHz	6.30	5.07	5	0	25	73	5.11	5.57	5	0	25	47	5.10	4.44	5	0	20	48	0.221
	9 kHz	5.77	8.39	5	0	60	71	4.47	5.24	5	0	15	47	4.27	5.26	5	-5	25	48	0.653
	10 kHz	6.34	10.21	5	0	65	71	4.79	5.00	5	0	15	47	5.21	6.76	5	0	30	48	0.964
	11 kHz	5.77	8.93	5	0	50	71	5.53	6.36	5	0	20	47	5.21	6.19	5	0	25	48	0.923
	12 kHz	4.58	8.31	0	0	45	71	4.79	5.51	5	0	20	47	3.33	4.29	0	0	15	48	0.451
	14 kHz	2.25	5.53	0	0	35	71	1.91	4.37	0	0	20	47	1.46	3.71	0	0	15	48	0.517
	16 kHz	2.43	6.36	0	0	35	70	1.91	4.24	0	0	20	47	1.77	5.51	0	-10	20	48	0.694
Left	250 Hz	8.08	4.90	5	0	30	73	7.55	4.41	5	0	20	47	7.19	3.08	5	0	15	48	0.871
	500 Hz	7.74	5.07	5	0	25	73	7.45	4.88	5	0	20	47	6.67	3.32	5	0	15	48	0.650
	1 kHz	5.96	5.11	5	0	30	73	5.11	4.60	5	0	20	47	3.85	3.46	5	0	10	48	0.076
	2 kHz	4.73	5.65	5	0	35	73	5.21	4.66	5	0	15	47	2.92	4.10	0	0	20	48	0.020
	3 kHz	4.18	6.18	5	0	40	73	3.83	5.44	0	0	25	47	3.44	4.15	5	0	20	48	0.870
	4 kHz	3.77	6.91	0	0	45	73	3.94	4.77	5	0	15	47	2.60	4.12	0	0	20	48	0.334
	6 kHz	6.58	7.16	5	0	45	73	7.34	5.98	5	0	30	47	6.88	6.33	5	0	35	48	0.482
	8 kHz	6.58	5.13	5	0	25	73	5.85	4.70	5	0	15	47	6.56	6.03	5	0	25	48	0.826
	9 kHz	5.21	9.12	5	0	65	71	4.26	5.42	5	-5	20	47	5.21	6.36	5	0	25	48	0.840
	10 kHz	5.85	8.66	5	0	60	71	4.47	5.13	5	0	15	47	5.63	6.81	5	-10	30	48	0.687
	11 kHz	5.49	9.90	5	0	70	71	4.26	5.00	5	0	15	47	6.15	6.78	5	0	25	48	0.372
	12 kHz	4.44	9.51	0	0	65	71	3.30	5.03	0	0	20	47	5.63	6.49	5	0	25	48	0.080
	14 kHz	2.68	8.19	0	0	45	71	1.70	3.50	0	0	15	47	3.13	6.07	0	0	25	48	0.412
	16 kHz	2.57	6.58	0	0	35	70	2.34	5.60	0	0	20	47	2.50	6.10	0	-10	25	48	0.839

Result of the Kruskal-Wallis test

Caption: SD = standard deviation; Min = minimum; Max = maximum

Table 3. Description and comparison of transient otoacoustic emissions and distortion product otoacoustic emissions in each frequency of each ear in the three groups

	Ear	Frequency	Group																		p-value
			No tinnitus						Sporadic tinnitus						Constant tinnitus						
			Mean	SD	Median	Min	Max	n	Mean	SD	Median	Min	Max	n	Mean	SD	Median	Min	Max	n	
TE	Right	TE 1500 Hz	1.13	5.75	1	-18	12	71	1.11	4.87	2	-13	10	38	1.22	5.27	1.5	-9	12	46	0.991
		TE 2000 Hz	-3.22	4.91	-3	-20	10	73	-3.28	5.03	-3	-14	7	39	-2.70	5.81	-4	-12	15	47	0.959
		TE 2500 Hz	-8.60	6.20	-9	-22	13	73	-8.51	5.45	-9	-20	3	39	-7.57	5.32	-8	-19	3	47	0.573
		TE 3000 Hz	-9.74	5.70	-10	-23	9	73	-10.28	6.07	-10	-22	1	39	-10.00	6.30	-11	-22	5	47	0.847
		TE 3500 Hz	-6.95	6.69	-7	-26	10	73	-8.03	6.07	-8	-22	3	39	-6.72	6.63	-6	-23	8	47	0.614
		TE 4000 Hz	-7.74	6.03	-9	-23	7	73	-8.95	6.11	-10	-18	5	39	-7.72	6.30	-7.5	-21	3	46	0.431
		SN 1500 Hz	9.11	5.60	9	-4	23	73	9.59	5.08	9	0	25	39	10.43	5.68	12	0	22	47	0.333
		SN 2000 Hz	8.53	4.72	9	-6	20	73	9.15	5.00	9	-2	23	39	10.13	6.15	9	-4	28	47	0.420
		SN 2500 Hz	8.30	5.00	8	-2	19	73	8.85	4.57	8	1	17	39	10.60	5.28	11	0	25	47	0.073
		SN 3000 Hz	9.86	5.33	9	0	28	73	9.38	4.97	8	2	19	39	10.36	6.46	9	-2	24	47	0.868
		SN 3500 Hz	10.78	6.05	10	-2	24	73	9.18	4.98	10	-2	18	39	10.60	6.44	11	-4	23	47	0.404
		SN 4000 Hz	6.77	5.09	6	-5	21	73	6.03	5.89	6	-5	22	39	7.09	6.22	5.5	-4	18	46	0.815
	Left	TE 1500 Hz	0.18	6.18	1	-18	12	73	-0.65	5.69	0	-13	12	40	0.10	5.60	0	-10	12	48	0.540
		TE 2000 Hz	-4.44	5.63	-4	-24	8	73	-5.55	5.35	-6	-18	5	40	-4.65	6.06	-3	-18	6	48	0.559
		TE 2500 Hz	-9.97	5.79	-9	-29	1	73	-9.50	5.49	-10	-22	4	40	-8.81	6.22	-10	-19	10	48	0.945
		TE 3000 Hz	-9.73	6.16	-9	-30	4	73	-10.58	5.80	-10.5	-21	0	40	-10.13	7.62	-11.5	-22	11	48	0.603
		TE 3500 Hz	-6.97	6.54	-7	-29	6	73	-7.93	7.13	-6	-23	5	40	-6.96	7.67	-8	-22	14	48	0.763
		TE 4000 Hz	-8.74	6.46	-9	-27	7	73	-8.75	7.20	-8	-24	10	40	-9.10	6.78	-8.5	-24	8	48	0.938
		SN 1500 Hz	8.59	5.85	9	-14	18	73	7.92	5.15	8	-5	22	40	10.75	6.23	11.5	1	29	48	0.102
		SN 2000 Hz	7.60	5.83	8	-17	19	73	7.13	4.92	6.5	-4	19	40	9.29	5.20	9		20	48	0.128
		SN 2500 Hz	7.26	6.13	7	-22	21	73	8.15	5.20	7	-2	23	40	9.46	5.49	8.5	1	27	48	0.310
		SN 3000 Hz	9.52	6.57	10	-26	21	73	9.20	5.39	7	1	21	40	10.65	7.16	8.5	-4	29	48	0.534
		SN 3500 Hz	9.78	6.74	10	-22	22	73	9.93	6.70	11	-6	22	40	11.25	7.06	10.5	0	30	48	0.844
		SN 4000 Hz	5.85	6.77	6	-23	23	73	6.68	5.81	6.5	-5	22	40	6.46	6.68	6	-8	22	48	0.885
DP	Right	DP 1500 Hz	6.80	7.30	8	-14	20	71	5.61	4.91	5	-5	16	41	7.60	6.12	8	-15	20	47	0.098
		DP 2000 Hz	2.07	6.20	3	-20	12	70	0.63	6.14	2	-19	13	41	2.10	5.56	3	-14	14	48	0.290
		DP 2500 Hz	2.44	9.38	5	-20	15	71	2.56	8.13	3	-20	16	41	3.12	7.08	4.5	-20	13	48	0.881
		DP 3000 Hz	-4.37	9.42	-5	-20	19	71	-4.51	8.29	-4	-20	9	41	-5.63	9.77	-6	-20	16	48	0.760
		DP 3500 Hz	0.83	9.38	1.5	-20	19	70	1.30	9.95	3	-20	17	40	0.79	10.17	0	-19	23	47	0.865
		DP 4000 Hz	-5.44	7.38	-6	-20	11	70	-3.38	9.63	-4	-20	12	40	-5.56	8.56	-4.5	-20	12	48	0.491
		SN 1500 Hz	17.41	9.27	19	-15	35	71	17.34	6.12	17	1	30	41	19.32	6.80	20	-2	31	47	0.355
		SN 2000 Hz	20.50	8.58	23	-20	32	70	19.80	6.87	22	0	33	41	21.60	5.45	22	6	31	48	0.506
		SN 2500 Hz	21.30	11.19	25	-20	35	71	21.80	9.11	23	-2	36	41	22.81	7.15	24	0	32	48	0.872
		SN 3000 Hz	12.77	10.46	13	-15	37	71	12.80	8.21	12		26	41	11.90	9.81	11.5	-4	33	48	0.810
		SN 3500 Hz	14.91	11.01	17	-20	33	70	15.80	10.24	16.5	-11	32	40	15.02	9.61	14	-5	36	47	0.784
		SN 4000 Hz	8.73	8.74	7.5	-13	27	70	10.33	9.69	9.5	-8	29	40	7.79	7.89	7	-7	26	48	0.402
	Left	DP 1500 Hz	5.97	7.91	7	-15	18	71	3.85	5.89	4	-7	15	40	5.90	7.53	7	-12	20	48	0.077
		DP 2000 Hz	0.44	6.96	2.5	-20	11	70	0.52	6.06	0	-15	11	40	1.29	5.59	2	-15	10	48	0.830
		DP 2500 Hz	2.41	8.08	3	-20	14	71	1.40	7.66	3	-20	14	40	1.38	7.20	2	-16	13	48	0.546
		DP 3000 Hz	-6.11	9.99	-8	-20	19	71	-4.15	9.07	-4	-21	15	40	-7.71	9.02	-8.5	-20	17	48	0.135
		DP 3500 Hz	0.11	10.11	0.5	-20	25	70	2.59	8.49	2	-17	20	39	-0.79	9.49	-1.5	-20	19	48	0.163
		DP 4000 Hz	-3.24	7.71	-3	-20	13	70	-4.41	9.18	-5	-20	14	39	-5.31	7.81	-3.5	-20	13	48	0.370
		SN 1500 Hz	18.23	8.67	20	-2	33	71	15.92	7.22	17.5	1	29	40	18.67	8.05	21		33	48	0.095
		SN 2000 Hz	20.11	6.88	22	0	31	70	20.20	6.15	20	5	31	40	20.92	5.66	22	5	30	48	0.868
		SN 2500 Hz	22.30	8.08	23	0	34	71	21.33	7.50	23	0	34	40	20.90	7.44	22	3	33	48	0.442
		SN 3000 Hz	11.44	10.50	10	-11	37	71	13.33	8.93	13		34	40	9.33	9.70	8	-6	37	48	0.113
		SN 3500 Hz	14.10	10.14	15	-7	40	70	17.46	8.27	20	1	38	39	13.46	10.34	13	-6	38	48	0.080
		SN 4000 Hz	10.84	7.81	11	-6	27	70	10.05	9.71	10	-10	27	39	8.94	7.91	10	-7	24	48	0.474

Result of the Kruskal-Wallis test

Caption: TE = transient-evoked; SN = signal-to-noise; DP = distortion product; SD = standard deviation; Min = minimum; Max = maximum did not perceive it at the time of examination. Therefore, even with the addition of this accuracy criterion that differentiates our study from that of others in the literature, the prevalence of tinnitus in this age group was surprisingly high, exceeding the extrapolation estimates for the world population that have been made in other studies[22,23].

2. Evident minimal hearing damage in the individuals with tinnitus, in the tone levels at high frequencies and/or OAEs. These tests are traditionally considered for the early detection of cochlear damage. Nevertheless, this item was not confirmed, showing that both exams were not sensitive enough to detect minimal cochlear alterations in the presence of tinnitus in our sample of adolescents, regardless of whether it occurs in sporadic or constant frequency.

The literature shows some articles whose results differ from ours. One study[16] evaluated adults with unilateral tinnitus and normal hearing (the contralateral ears were used as control group), noting that the ears with tinnitus had significant alterations in the frequency bands above 2,000 Hz. Another study[24] evaluated the potential of DPOAE to distinguish four groups of adults with normal hearing: (G1) control, without tinnitus or hyperacusis; (G2) with tinnitus; (G3) with hyperacusis; and (G4) with tinnitus and hyperacusis. There was a consistent trend for the three symptoms groups to present lower levels of DPOAE response in the frequency of 4,000 and 6,000 Hz compared to members of the control group. In addition to that, the same authors also found that the average inclination of the growth curves (CC-DPOAE)

Table 4. Description and comparison of Loudness Discomfort Levels in each frequency of each ear in the three groups

Ear	Frequency	No tinnitus						Sporadic tinnitus						Constant tinnitus						p-value
		Mean	SD	Median	Min	Max	n	Mean	SD	Median	Min	Max	n	Mean	SD	Median	Min	Max	n	
Right	500 Hz	109.8	10.7	115	75	115	73	110.7	9.7	115	80	115	47	98.3	21.4	110	40	115	48	<0.001
	1 kHz	110.7	9.7	115	80	115	73	111.4	7.9	115	80	115	47	100.2	20.8	110	30	115	48	<0.001
	2 kHz	110.1	10.1	115	75	115	73	110.1	9.1	115	75	115	47	100.0	21.4	110	20	115	48	0.001
	4 kHz	102.3	8.3	105	65	105	73	102.7	7.2	105	75	105	47	93.7	19.4	105	20	105	48	<0.001
Left	500 Hz	109.9	11.8	115	65	115	73	110.7	10.3	115	80	115	47	100.4	20.4	110	45	115	48	<0.001
	1 kHz	111.3	9.8	115	75	115	73	111.6	8.5	115	75	115	47	100.4	20.4	110	45	115	48	<0.001
	2 kHz	110.6	10.6	115	70	115	73	110.2	9.6	115	70	115	47	100.5	19.6	110	55	115	48	<0.001
	4 kHz	102.4	9.1	105	65	110	73	103.2	6.3	105	75	105	47	92.2	21.9	105	0	105	48	<0.001

Result of the Kruskal-Wallis test

Caption: SD = standard deviation; Min = minimum; Max = maximum

Table 5. Result of the multiple comparisons of Loudness Discomfort Levels on each side and each frequency between the groups, in pairs

Ear	Frequency	Comparison	z-value	p-value
Right	500 Hz	No tinnitus x Sporadic tinnitus	-0.13	0.896
		No tinnitus x Constant tinnitus	3.68	<0.001
		Sporadic tinnitus x Constant tinnitus	3.46	0.001
	1 kHz	No tinnitus x Sporadic tinnitus	0.20	0.840
		No tinnitus x Constant tinnitus	3.70	<0.001
		Sporadic tinnitus x Constant tinnitus	3.16	0.002
	2 kHz	No tinnitus x Sporadic tinnitus	0.53	0.596
		No tinnitus x Constant tinnitus	3.31	0.001
		Sporadic tinnitus x Constant tinnitus	2.52	0.012
	4 kHz	No tinnitus x Sporadic tinnitus	0.11	0.912
		No tinnitus x Constant tinnitus	2.57	0.010
		Sporadic tinnitus x Constant tinnitus	2.22	0.026
Left	500 Hz	No tinnitus x Sporadic tinnitus	-0.82	0.411
		No tinnitus x Constant tinnitus	2.75	0.006
		Sporadic tinnitus x Constant tinnitus	3.24	0.001
	1 kHz	No tinnitus x Sporadic tinnitus	0.02	0.982
		No tinnitus x Constant tinnitus	3.60	<0.001
		Sporadic tinnitus x Constant tinnitus	3.24	0.001
	2 kHz	No tinnitus x Sporadic tinnitus	0.57	0.568
		No tinnitus x Constant tinnitus	3.39	0.001
		Sporadic tinnitus x Constant tinnitus	2.55	0.011
	4 kHz	No tinnitus x Sporadic tinnitus	0.01	0.992
		No tinnitus x Constant tinnitus	2.85	0.004
		Sporadic tinnitus x Constant tinnitus	2.57	0.010

Result of nonparametric multiple comparisons of Dumm for each of the symptoms groups was consistently steeper than in the control group. Sanchez et al.[15] also found alterations in the registration of CC-DPOAE in normal-hearing adults with tinnitus compared to a control group. These data reinforce that the presence of tinnitus and hyperacusis is consistent with alterations in the cochlear level, even when the pure-tone thresholds are normal.

However, these studies were conducted with adults and did not mention the tinnitus existing period. Therefore, it is possible that the age of the cochlea and the period of tinnitus in adults may have influenced the results of decrease or absence of emissions.

On the other hand, in a research conducted by Sztuka et al.[11], no difference was observed in the curves of growth of DPOAE when evaluating patients with tinnitus and normal audiometric thresholds, divided into three groups: with hyperacusis, with misophonia, and without both. Notwithstanding, the DPOAE amplitude was significantly higher in patients with tinnitus and hyperacusis, suggesting that tinnitus can be caused even in the early stages of impairment in the auditory pathway, before there is direct cellular damage to the outer hair cells (OHCs). Although she did not study tinnitus, Ferreira[25] had also suggested the existence of this initial stage of injury. The author found that male bikers exposed to noise recently had a higher amplitude of DPOAE than those exposed long ago or not exposed.

Thus, at this early stage of aggression, the cochlea would react only with increased motility of the OHCs, which could explain the increase described in the OAEs. This earlier stage of cochlear damage may have a direct connection with our results, because the tinnitus would already be clinically present, even before there was a decrease of pure-tone thresholds or OAEs.

Our study showed no significant difference between the pure-tone thresholds in the three groups of adolescents, even in the frequencies traditionally most affected by exposure to noise (3,000, 4,000, and 6,000 Hz). The only exception was the frequency of 2,000 Hz, in which adolescents with constant tinnitus had better results ($p=0.02$). At first, we did not see clinical relevance for this finding. However, two other studies had suggested that this frequency seems to be different from the others, though they were performed in adults. Figueiredo et al.[26] studied individuals aged between 15 and 30 years to compare the incidence of tinnitus among users and nonusers of personal stereos. The personal stereo users had lower amplitude at 2,000 Hz in the DPOAE. Sanches et al.[15] analyzed the CC-DPOAE in normal-hearing adults with and without tinnitus, verifying that the tinnitus group presented higher thresholds at 2,000 Hz in the growth curves. In light of this, it is possible that the frequency of 2,000 Hz is more vulnerable, presenting better thresholds in adolescents, which could evolve to worse thresholds in adults. However, only longitudinal studies could confirm this hypothesis.

While the OAEs already have greater acceptance regarding the ability to detect minor hearing losses, the high-frequency audiometry still has limited use, perhaps for lack of consensus standardization. Nevertheless, in our clinical practice oriented to patients with tinnitus, we often see descendant configurations of these thresholds on the ears with tinnitus, which becomes even more apparent in the cases of unilateral tinnitus, that has a frequency in tinnitus pitch/loudness matching higher than 8,000 Hz. Furthermore, some of these cases still show normal OAEs, as they investigate cochlear regions similar to the conventional audiometry. Therefore, patients with tinnitus in a frequency higher than 8,000 Hz and normal hearing until 8,000 Hz can be mistakenly interpreted as having no apparent cochlear damage if they are not submitted to the investigation of thresholds at the frequencies higher than 8,000 Hz.

The analysis of the LDL results has shown that adolescents with constant tinnitus presented greater hypersensitivity / intolerance to sounds than others. This means that young people with tinnitus start to have discomfort with sounds in weaker intensity than the adolescents without tinnitus. Although not recognized as a detection test of minimal hearing loss, it is consistent to assume that the ears that present earlier discomfort are really the most vulnerable to sounds. Therefore, a long-term monitoring could show the evolution of this finding in the adolescents. As part of the “mother study” currently in progress, we will do the follow-up of 2 years with the participants and we can possibly elucidate some more pertinent questions.

CONCLUSION

In this sample of adolescents with and without tinnitus, the high-frequency audiometry, and examinations of TOAE (up to 4,000 Hz) and DPOAE (up to 12,000 Hz) were not sensitive enough to show differences in cochlear responses in this age group. Unlike what happens with the adults, these findings suggest that the OHCs of adolescents with tinnitus may not be sufficiently compromised to cause alterations in these exams.

However, the research of LDL showed that adolescents with tinnitus have discomfort to sounds in weaker intensities than those with no tinnitus. This shows that the LDL research may indicate that there is already an alteration of the auditory system in young individuals with normal audiometry and tinnitus, whether sporadic or constant.

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