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Music students: conventional hearing thresholds and at high frequencies☆

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Abstract
Introduction: Research has shown that hearing loss in musicians may cause difficulty in timbre recognition and tuning of instruments.
Aim: To analyze the hearing thresholds from 250 Hz to 16,000 Hz in a group of music students and compare them to a non-musician group in order to determine whether high-frequency audiometry is a useful tool in the early detection of hearing impairment.
Methods: Study design was a retrospective observational cohort. Conventional and high-frequency audiometry was performed in 42 music students (Madsen Itera II audiometer and TDH39P headphones for conventional audiometry, and HDA 200 headphones for high-frequency audiometry).
Results: Of the 42 students, 38.1% were female students and 61.9% were male students, with a mean age of 26 years. At conventional audiometry, 92.85% had hearing thresholds within normal limits; but even within the normal limits, the worst results were observed in the left ear for all frequencies, except for 4000 Hz; compared to the non-musician group, the worst results occurred at 500 Hz in the left ear, and at 250 Hz, 6000 Hz, 9000 Hz, 10,000 Hz, and 11,200 Hz in both the ears.
Conclusion: The periodic evaluation of high-frequency thresholds may be useful in the early detection of hearing loss in musicians.

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PALAVRAS-CHAVE
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Perda auditiva;
Audiometria

Estudantes de música: limiares auditivos convencionais e em altas frequências

Resumo
Introdução: Pesquisas comprovam que a perda auditiva em músicos pode gerar dificuldade no reconhecimento de timbres e na afinação dos instrumentos.
Objetivo: Analisar os limiares auditivos de 250 Hz a 16.000 Hz de um grupo de estudantes de música e compará-los a um grupo de não músicos para determinar se a audiometria de altas frequências é um recurso útil na detecção precoce da deficiência auditiva.
Método: Forma de estudo: observacional, de coorte, retrospectivo. Realizou-se audiometria convencional e de altas frequências em 42 estudantes de música (audiômetro Madsen Itera II, fones TDH39P para a audiometria convencional e HDA 200 para audiometria de altas frequências).
Resultados: Dos 42 estudantes, 38,10% eram do gênero feminino e 61,9% do gênero masculino, com média de 26 anos; na audiometria convencional 92,85% apresentaram limiares auditivos dentro dos padrões de normalidade; mesmo dentro da normalidade, piores resultados ocorreram na orelha esquerda para todas as frequências, excetuando-se 4000 Hz; quando comparado ao grupo de não músicos os piores resultados ocorreram em 500 Hz na orelha esquerda e 250 Hz, 6000 Hz, 9000 Hz, 10.000 Hz e 11.200 Hz em ambas as orelhas.
Conclusão: A avaliação dos limiares de altas frequências de forma periódica pode ser útil na detecção precoce da deficiência auditiva em músicos.

Introduction

Music has always been connected to people's life history, as a marker of both good times and bad times, and has increasingly become the focus of attention of professionals in several fields, mainly experts in hearing and acoustics. This interest is due to the fact that exposure to music is not only a social issue, but also a professional issue.

However, what is intended to be enjoyable and stimulating can damage the hearing, considering that music, as well as noise at high intensities, can cause irreversible damage to hearing.[1]

In a study[2] performed in music schools in Germany, the sound intensity during the rehearsal of a major orchestra with a romantic music repertoire exceeded 85 dB (A). If the musicians worked for eight hours a day, five days a week, noise exposure for most would exceed the upper tolerance threshold.

Another study,[3] performed by the music research institute of the University of North Carolina in the United States, found that 52% of the students who participated in a woodwind instrument band, and who attended one or more rehearsals per week, were exposed to sound levels higher than 100% of the allowed dose, according to the National Institute for Occupational Safety and Health (NIOSH). At above 100% of the noise levels as defined by NIOSH, these students are exposed to very dangerous levels of sound intensity during a single rehearsal. A total of 40 students (representing brasswind, woodwind, and voice) showed a mean level of 87–95 dB (A), with brasswind showing significantly higher levels.

Among the many factors that make group rehearsals a risk to hearing are the duration of exposure, the intensity of music, the acoustics of the rehearsal space, proximity to noise sources (when they are not the sound source itself, as in the case of singers), choice of repertoire, and the repetition of specific musical passages. Mostly, it is the group rehearsal that prepares students for their professional careers. Therefore, the conductors of these rehearsals are important models for the students. Methods of hearing conservation in this type of activity should be incorporated and shared between the conductors and students as a matter of professional longevity.[3]

The literature has many studies[4–10] that present hearing loss as a result of exposure to music at high intensities, also accompanied by symptoms such as tinnitus, sensation of ear fullness, headache, and dizziness. These symptoms, along with non-auditory manifestations such as irritability and fatigue, may be the first signs of hearing damage.[11]

The loss of the external ciliated cells, caused by constant and systematic exposure to high sound pressure levels, can produce a reduction in cochlear amplification (motility of the external ciliated cells), resulting in loss of sensitivity to low to moderate sounds (40–60 dB HL). This causes the musician to play and/or sing at increasingly higher volume, leading to higher physical effort and greater hearing loss. The loss of external ciliated cells also reduces frequency selectivity and spectral resolution of the cochlea, leading to diplacusis (abnormal perception of pitch). This condition can put the musician's career at risk for those who often make decisions about the vocal and/or instrumental tone performance. In addition, damage to the external ciliated cells leads to lack of cochlear compression or recruitment (abnormal loudness perception), which can shorten a musician's career.[12]

Hearing loss, regardless of the degree of auditory system involvement, can hinder the perception of tones and timbres, also hindering the tuning of the instruments, which, for musicians, can have serious consequences for their professional performance.[13]

Conventional pure tone audiometry (PTA) is considered the basis of audiological evaluation, representing the first test that composes the assessment. It aims to determine the individual's minimum threshold of audibility for frequencies from 250 Hz to 8000 Hz. This evaluation technique is the most widely used for the detection of hearing loss in individuals exposed to high sound pressure levels, either noise or music, especially at intensities >85 dB (A).[14,15]

Although hearing disorders can be detected by conventional PTA, currently, due to the emphasis on health promotion, professionals and researchers have increasingly sought to identify these alterations as early as possible. In relation to sensorineural hearing loss, high-frequency audiometry has been used as a way to detect these alterations at an early stage, so that prevention can be performed before more significant lesions occur, according to the concept of health promotion.[16]

In a literature review[17] on the contribution of high-frequency audiometry to the early identification of noise-induced hearing loss, the authors concluded that the hearing thresholds at high frequencies are often reduced earlier than conventional frequency thresholds, from 250 Hz to 8000 Hz, and therefore, they should be used in occupational hearing loss prevention programs.

The II International Congress of Medicine for Musicians, held in September 2005 in Spain, stressed that musicians are professionals with a high risk of occupational diseases, also emphasizing that there is a lack of awareness about this risk, and little demand for information that can preserve and manage the working conditions of this professional class. Although advances have occurred, preventive and health maintenance actions are still far from the ideal.[18]

In the field of music, music students and teachers, administrators of music schools, and conservatories have not made an effort to prevent several health risks involved in music learning and performance.[19]

Thus, it is imperative that preventive measures are taken, together with this professional class, to minimize the harmful effects of exposure to high sound pressure levels; this concern has led to this study, which aimed to analyze the hearing thresholds of 250–16,000 Hz in a group of music students and compare them to a control group, to determine whether high-frequency audiometry can be a useful tool for early identification of hearing impairment.

Materials and methods

This was an observational, retrospective cohort study with a quantitative approach that analyzed the auditory thresholds of 250–16,000 Hz in a group of undergraduate music students, compared to a group of non-musicians and non-music students.

This research had the approval of the research ethics committee, No. 190/2011, and all individuals assessed signed an informed consent, after receiving information about the objectives, rationale, and methodology of the proposed study.

The sample consisted of 84 subjects, divided into two groups: one group (G1) consisting of 42 undergraduate music students and one group (G2) comprising 42 individuals who were non-musicians and non-music students, and who were not exposed to noise at work. Students were from three public educational institutions distributed across several areas of study (music education, popular music, instruments, music composition and conducting, sound production, and singing) and all participated in academic practice activities together.

The inclusion criterion for group G1 comprised being a music student, and the exclusion criteria included having conductive and/or sensorineural hearing disorders not associated with noise exposure, evaluated by audiometric and imitanciometry assessment.

Initially, visual inspection of the external auditory meatus was performed with a Kole otoscope to verify possible obstructions of the external auditory canal that could impair the audiological assessment. Only two students had excess wax, which was removed by an otorhinolaryngologist at the clinic where audiological evaluations were performed before the start of the examination.

The audiological evaluations were performed with a Madsen audiometer; model ITERA II with TDH 39P headphones for the conventional audiometry, and HDA 200 headphones for high-frequency audiometry and audiometric booth. All individuals were assessed according to the current standards (CFFa, 2010). The auditory rest before the audiological evaluation was 14 h.

The conventional PTA assessed air-conduction hearing thresholds at frequencies from 250 Hz to 8000 Hz and bone conduction hearing thresholds, when the air conduction thresholds showed values >25 dB HL for frequencies from 500 Hz to 4000 Hz.

The high-frequency tone audiometry assessed air-conduction hearing thresholds at frequencies of 9000 Hz, 10,000 Hz, 11,200 Hz, 12,500 Hz, 14,000 Hz, and 16,000 Hz.

Student's *t*-test with a significance level of 0.05 (5%) was used for the statistical analysis.

Results

In G1, age ranged from 18 to 58 years, with a mean of 26 years, median of 25.7 years, and standard deviation of 7.7 years. Regarding gender, 38% were female students and 62% were male students. The time of musical practice varied between one and 41 years, with a mean of 11.17 years, median of 10 years, and standard deviation of 8.42 years.

Among the 42 students, 69% played string instruments (mainly the guitar), 16.66% played woodwind and brasswind instruments, 16.66% played the piano, 14.28% played percussion, and 4.76% sang. Several students played more than one musical instrument or sang and also played an instrument. A total of 80% have played and/or sung for more than four years, and 56% have been a member of a musical group for more than four years. All students (100%) participated in academic practice activities together.

In G2, age ranged from 18 to 56 years, with a mean 25.8 years, median of 24.5 years, and standard deviation of 7.5 years. Regarding gender, 38% were female students and 62% were male students.

Of the 42 students in G1, only three had pure tone air-conduction thresholds >25 dB HL in the conventional

Table 1 Mean conventional and high frequency pure-tone air-conduction hearing thresholds in G1 and G2 ($n = 84$).

Ear	Frequency (Hz)	G1 ($n = 42$)		G2 ($n = 42$)		p
		Mean dB HL	Standard deviation	Mean dB HL	Standard deviation	
Right	250	10.1	4.6	8.0	4.0	0.0255[a]
	500	8.5	3.2	6.8	5.0	0.0745
	1000	5.5	4.9	5.2	4.4	0.8158
	2000	3.9	4.6	5.4	5.0	0.1772
	3000	3.2	5.8	6.0	5.7	0.0317[a]
	4000	6.2	7.1	8.0	6.8	0.2414
	6000	9.6	8.8	9.0	7.0	0.7324
	8000	7.4	7.8	8.2	6.7	0.6016
	9000	12.6	10.9	7.9	8.5	0.0286[a]
	10,000	13.3	11.2	11.8	9.8	0.5021
	11,200	13.1	11.0	9.9	9.3	0.1535
	12,500	8.3	11.2	14.9	10.3	0.0066[a]
	14,000	3.5	14.2	15.5	12.8	0.0001[a]
	16,000	7.0	17.5	17.0	16.5	0.0085[a]
Left	250	10.7	5.1	7.6	4.5	0.0041[a]
	500	9.9	3.6	7.0	5.1	0.0037[a]
	1000	5.4	5.7	6.2	5.7	0.5044
	2000	6.4	7.4	6.2	5.2	0.8650
	3000	4.6	8.9	6.0	5.7	0.4219
	4000	5.7	9.5	7.7	6.6	0.2624
	6000	10.2	13.3	8.8	7.9	0.5527
	8000	7.5	12.6	8.0	6.4	0.8280
	9000	12.7	13.6	8.9	8.6	0.1292
	10,000	13.8	14.7	10.7	8.2	0.2369
	11,200	13.5	15.0	10.8	9.9	0.3473
	12,500	9.2	15.3	16.5	12.0	0.0162[a]
	14,000	5.7	16.9	15.4	13.9	0.0055[a]
	16,000	7.6	20.6	15.9	13.7	0.0353[a]

[a] Student's *t*-test with significance level of 0.05.

Table 2 Mean conventional and high frequency pure-tone air-conduction hearing thresholds of right and left ears, per frequency, in G1 ($n = 42$).

Frequency (Hz)	Right ear		Left ear		p
	Mean dB HL	Standard deviation	Mean dB HL	Standard deviation	
250	10.1	4.6	10.7	5.1	0.3420
500	8.5	3.2	9.9	3.6	0.0125[a]
1000	5.5	4.9	5.4	5.7	0.8642
2000	3.9	6.4	4.6	7.4	0.0109[a]
3000	3.2	5.8	4.6	8.9	0.1477
4000	6.2	7.1	5.7	9.5	0.6818
6000	9.6	8.8	10.2.	13.3	0.7289
8000	7.4	7.8	7.5	12.6	0.9336
9000	12.6	11.9	12.7	13.6	0.9371
10,000	13.3	11.2	13.8	14.7	0.7789
11,200	13.1	11	13.4	15	0.8303
12,500	8.3	11.2	9.2	15.3	0.6238
14,000	3.4	14.2	5.7	16.9	0.0814
16,000	7	17.5	7.6	20.6	0.7249

[a] Student's *t*-test with significance level of 0.05.

Table 3 Mean pure-tone air-conduction hearing thresholds of right and left ears, per frequency, between male and female genders ($n = 42$).

Frequency (Hz)	Male ($n = 26$)				Female ($n = 16$)				p	
	Mean dB HL		Standard deviation		Mean dB HL		Standard deviation			
	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
250	9.4	12.2	4.5	5.8	11.3	9.8	4.7	4.6	0.2172	0.1463
500	8.5	10.0	3.1	3.7	8.4	9.8	3.5	3.6	0.9816	0.8680
1000	5.6	4.7	3.8	6.7	5.3	5.8	6.4	5.0	0.8680	0.5550
2000	4.2	6.3	4.4	9.6	3.4	6.5	5.1	6.0	0.5955	0.9045
3000	2.7	5.0	5.9	11.1	4.1	4.4	5.8	7.4	0.4659	0.8406
4000	5.6	8.7	7.5	12.2	7.2	3.8	6.3	7.1	0.4793	0.1063
6000	10.4	12.8	9.6	19.9	8.4	8.7	7.5	6.9	0.4926	0.3327
8000	7.5	9.7	7.4	17.6	7.2	6.2	8.8	8.4	0.9018	0.3841
9000	12.5	14.1	12.0	15.3	12.8	11.9	9.3	12.7	0.9297	0.6271
10,000	13.1	13.8	12.2	18.6	13.8	13.8	9.7	12.1	0.8526	0.9839
11,200	14.6	15.3	12.3	18.7	10.6	12.3	8.3	12.4	0.2604	0.5350
12,500	8.3	11.3	11.7	20.8	8.4	7.9	10.6	11.1	0.9629	0.4966
14,000	2.7	8.4	12.3	22.2	4.7	4.0	17.2	12.8	0.6631	0.4188
16,000	2.1	13.1	11.8	25.2	15.0	4.2	22.2	16.8	0.0183[a]	0.1768

RE, right ear; LE, left ear.
[a] Student's t-test with significance level of 0.05.

audiometry: a 20-year-old student (hearing loss at 6000 Hz in the right ear), who had played the guitar for three years; a 34-year-old student (hearing loss at 8000 Hz in the left ear), who had played the trombone for 20 years, and a 36-year-old student with bilateral alteration (6000 Hz in the right ear and 2000–8000 Hz in the left ear), who had played the guitar for one year. In all three cases, there are no reports of the use of hearing protection devices.

Table 1 compares the thresholds of conventional and high-frequency audiometry between G1 and G2.

It was observed that there was a significant difference between G1 and G2 at certain frequencies; in G1 the mean thresholds were worse than G2 at the frequency of 250 Hz in both ears, and at 500 Hz in the left ear. The study group had better mean thresholds only at 3000 Hz in the right ear, when compared to the control group.

In relation to higher frequencies, there was a significant difference between G1 and G2 at 12,500 Hz, 14,000 Hz, and 16,000 Hz in both ears, and the mean thresholds were better in the study group than the control group. Only the mean threshold of the 9000 Hz frequency in the right ear was worse in the study group when compared to the control group.

Table 2 compares the thresholds of conventional pure tone and high-frequency audiometry of G1 in the right and left ears.

Table 4 Mean right ear hearing thresholds, per frequency, for age up to 25 years ($n = 50$).

Frequency (Hz)	Up to 25 years – right ear				p
	G1 ($n = 25$)		G2 ($n = 25$)		
	Mean dB HL	Standard deviation	Mean dB HL	Standard deviation	
250	10.0	5.2	7.6	3.6	0.0951
500	9.0	3.5	8.2	5.0	0.0037[a]
1000	5.6	5.6	5.9	4.0	0.5743
2000	4.2	5.3	4.4	3.5	0.2142
3000	1.2	5.0	6.8	5.3	0.0096[a]
4000	4.2	5.9	9.4	7.0	0.0997
6000	9.4	8.7	11.2	7.6	0.4320
8000	6.2	7.0	9.4	7.7	0.4715
9000	10.2	8.1	11.2	10.5	0.0319[a]
10,000	9.6	8.0	16.5	11.7	0.6614
11,200	10.6	8.0	14.8	11.8	0.0740
12,500	5.0	7.6	19.1	12.5	0.0032[a]
14,000	−0.8	8.0	21.8	17.1	0.0000[a]
16,000	1.4	14.6	22.0	19.4	0.0019[a]

[a] Student's t-test with significance level of 0.05.

Table 5 Mean pure-tone air-conduction right ear thresholds, by frequency, for age range 26 and older, in groups G1 and G2 ($n = 34$).

Frequency (Hz)	Age 26 and older – right ear				p
	G1 ($n = 17$)		G2 ($n = 17$)		
	Mean dB HL	Standard deviation	Mean dB HL	Standard deviation	
250	10.3	3.7	7.7	3.6	0.0239[a]
500	7.7	2.6	8.2	5.0	0.6082
1000	5.3	3.7	5.9	4.0	0.6959
2000	3.5	3.4	4.4	3.5	0.4836
3000	6.2	5.7	6.8	5.3	0.7825
4000	9.1	7.8	9.4	7.1	0.8975
6000	10.0	9.2	11.2	7.6	0.6989
8000	9.1	8.9	9.4	7.7	0.9290
9000	16.2	13.6	11.2	10.5	0.2489
10,000	18.8	13.1	16.5	11.7	0.6248
11,200	16.8	13.8	14.7	11.8	0.6793
12,500	13.2	13.8	19.1	12.5	0.2485
14,000	9.7	18.7	21.2	17.1	0.0773
16,000	15.3	18.4	22.1	19.5	0.2273

[a] Student's *t*-test with level of significance of 0.05.

There was a significant difference between the mean thresholds in the right and left ears at frequencies of 500 Hz and 2000 Hz for the study group, with the left ear showing worse mean thresholds than the right ear.

Table 3 compares the mean conventional and high frequency hearing thresholds of G1, taking into account the frequency, gender, and ear.

There was a significant difference between the mean thresholds of male and female genders only for the right ear at 16,000 Hz, with female students showing worse means than the male students.

Table 4 compares the mean conventional pure tone air-conduction and high-frequency hearing thresholds in the right ear between G1 and G2 for the age range up to 25 years.

There is a significant difference for G1 between the mean pure tone air-conduction hearing thresholds in students aged up to 25 years and G2 at 500, 3000, 9000, 12,500, 14,000 and 16,000 Hz, with the best results reported by G1, except at

Table 6 Mean pure-tone air-conduction thresholds in the left ear, by frequency, for age up to 25 years in groups G1 and G2 ($n = 50$).

Frequency (Hz)	Up to 25 years – left ear				p
	G1 ($n = 25$)		G2 ($n = 25$)		
	Mean dB HL	Standard deviation	Mean dB HL	Standard deviation	
250	10.0	4.8	8.2	4.3	0.0504[a]
500	9.4	3.6	5.8	4.9	0.0104[a]
1000	4.8	5.9	4.8	4.7	0.5025
2000	6.2	7.3	6.0	5.8	1.0000
3000	2.4	6.8	5.4	5.9	0.1081
4000	3.0	5.2	7.0	6.6	0.2228
6000	7.8	7.5	7.6	6.3	0.6252
8000	4.2	5.5	7.4	6.0	0.4570
9000	9.0	7.4	5.6	6.0	0.0875
10,000	10.8	8.0	8.6	6.8	0.3147
11,200	9.8	8.1	6.6	5.3	0.2563
12,500	6.0	9.0	12.0	7.5	0.0310[a]
14,000	2.2	10.7	11.6	6.9	0.0117[a]
16,000	3.6	17.8	13.6	13.5	0.3410

[a] Student's *t*-test with level of significance of 0.05.

Table 7 Mean pure-tone air-conduction thresholds in the left ear, by frequency, for age range 26 and older, in groups G1 and G2 ($n = 34$).

Frequency (Hz)	Age 26 and older − left ear				p
	G1 ($n = 17$)		G2 ($n = 17$)		
	Mean dB HL	Standard deviation	Mean dB HL	Standard deviation	
250	11.8	5.6	7.9	3.6	0.0143[a]
500	10.6	3.5	8.2	4.7	0.0564[a]
1000	6.2	5.5	6.5	5.2	0.8679
2000	6.8	7.9	6.2	5.2	0.7983
3000	7.9	10.6	7.4	6.6	0.8579
4000	9.7	12.8	9.1	6.4	0.8708
6000	13.8	18.7	11.8	9.2	0.6934
8000	12.4	17.9	12.1	6.6	0.9527
9000	18.2	18.5	13.8	9.6	0.4084
10,000	18.2	20.5	13.8	8.6	0.4440
11,200	18.8	20.7	15.9	11.9	0.6342
12,500	13.8	21.0	21.8	13.6	0.2267
14,000	10.9	22.6	10.9	14.8	0.1109
16,000	13.5	23.4	21.8	15.2	0.1748

[a] Student's t-test with level of significance of 0.05.

the frequency of 500 Hz, where better results were observed in G2.

Table 5 compares conventional pure-tone and high frequency air-conduction hearing thresholds in the left ear between G1 and G2 in those aged 26 years and older.

There was a significant difference for G1 between mean pure tone air-conduction hearing thresholds in students aged 26 years and older and G2 only at the frequency of 250 Hz, with the best results reported by G2.

Table 6 compares the mean conventional pure-tone and high frequency air-conduction hearing thresholds in the left ear between G1 and G2 in students aged up to 25 years.

There was a significant difference for G1 between the mean pure tone air-conduction hearing thresholds in students aged up to 25 years and G2 at frequencies of 250 and 500 Hz, where G1 has worse results when compared to G2. As for the frequencies of 12,500 and 14,000 Hz, the best results were shown by G1.

Finally, Table 7 compares the mean conventional pure-tone air-conduction and high frequency hearing thresholds in the left ear between the two groups in students aged 26 years and older.

There was a significant difference for G1 between the mean pure-tone air-conduction hearing thresholds in students aged 26 years and older and G2 only at frequencies of 250 and 500 Hz, with the best results reported by G2.

Discussion

Hearing loss induced by high levels of sound pressure occurs by systemic and prolonged exposure to loud sounds (>85 dB (A)/8 h/day). With an insidious onset, its main features are chronicity and irreversibility, as it affects the ciliated cells of the organ of Corti.[20–23] In addition, according to the National Committee on Noise and Hearing Conservation, not only the time of exposure and sound intensity, but also individual susceptibility is considered as a factor for hearing loss onset.

According to NR7, Annex I (1998), hearing loss induced by high levels of sound pressure is considered as changes in hearing thresholds resulting from systematic occupational exposure to intense sound. Its main features, irreversibility and gradual progression with time of exposure to risk, initially affect the frequencies of 3000 Hz, 4000 Hz or 6000 Hz, followed by 8000 Hz and 500 Hz, and finally 250 Hz.

In comparison with conventional audiometry, a significant difference was observed between G1 and G2 at frequencies of 250 Hz in both ears and 500 Hz in the left ear. Although there was no significant difference for the frequency of 6000 Hz, the mean pure tone air-conduction thresholds found in G1, at that frequency in both ears, were worse than the thresholds shown by G2.

These findings are in agreement with a study[24] conducted with 329 music students, in which there was an audiogram notch at the frequency of 6000 Hz in 78% of the audiometries performed.

Another study[25] observed that 20% of the music students had music-induced hearing loss (MIHL), and in Brazil, one study[16] demonstrated that 38.46% of the music students had an audiogram suggestive of MIHL, followed by 46.15% showing a normal audiogram with notch at 3000, 4000, or 6000 Hz.

A study[4] performed with young musicians, aged 18–37 years, found 7% with normal audiogram and presence of notch, and 24% of the audiograms suggested MIHL.

A study[26] conducted with 23 rock musicians, aged 21–38 years, with the majority (57%) in the age range between 21 and 26 years, demonstrated that, although 100% of the ears had auditory thresholds within normal limits, the distribution of hearing thresholds showed a large concentration of worse thresholds at 3000, 4000 and 6000 Hz, exactly those that are first affected in the process that triggers MIHL.

Regarding professional musicians, the literature is vast regarding the results that are characterized as MIHL. For instance, there are three studies performed with orchestra musicians: the first study[27] shows 52.5% of musicians with MIHL; the second study,[28] shows 21.7%; and the third study[29] shows 19%. Concerning hearing loss in rock and jazz bands, one study[30] reported 52.39% of musicians with MIHL, and regarding instrumental bands, one study[31] observed 13% of musicians with MIHL; another study[8] demonstrated 52.4% with MIHL, and a third study[6] showed 24% with hearing disorders suggestive of MIHL.

Regarding the lower frequencies, the literature showed no findings that either corroborated or contested those found in this study. As all participating groups (G1 and G2) underwent audiometric evaluation under the same test conditions, it is suggested that further studies be performed to increase the knowledge of the effects of high-intensity music on the lower frequencies.

Regarding the thresholds at frequencies of 3000, 4000 and 6000 Hz, which, when lowered, can disclose hearing loss due to exposure to high sound pressure levels; it should be emphasized that this study observed a difference, although not significant, between the mean conventional pure-tone air-conduction thresholds for the frequency of 6000 Hz between G1 and G2, with a worse mean in G1 (Table 1). The presence of the audiometric notch, even if at only one frequency, should be seen as a warning sign, as it could suggest a trend of the onset of hearing loss.[32]

Still in relation to conventional audiometry, when comparing the right and left ears of G1, the results of this study showed worse results in the left ear for all frequencies (except for 4000 Hz), disclosing asymmetry between the ears (Table 2).

Corroborating the present results, a study[33] on the audiological profile of 40 symphonic orchestra musicians resulted in a profile that follows the pattern of MIHL evolution, but with asymmetric alteration between the ears, with the left ear as the most affected. Two studies[27,34] reported greater hearing loss in the left ear, both carried out with violinists. However, the present study included the participation of only two violin students.

Few studies have been reported in the literature on the use of high-frequency audiometry for evaluation of musicians and music students. In the present study, a significant difference between G1 and G2 was found, with worse results for G1 only at the frequency of 9000 Hz in the right ear. However, the mean thresholds at 9000 Hz in the left ear and at 10,000 Hz and 11,200 Hz in both ears were worse in G1 when compared to G2, although not statistically significant (Table 1).

These findings differ from those of another study,[4] as although the author found mean thresholds of 11 dB HL at most, there was the presence of a notch at the frequency of 12,500 Hz bilaterally, and at the frequency of 14,000 Hz in the right ear.

In another study,[16] a notch was observed at the frequency of 11,200 Hz in the left ear, 12,500 Hz in the right ear, and 16,000 Hz in both ears; these results also differ from those of the present study.

Conversely, one study[35] evaluated the temporary change in threshold at 500–14,000 Hz in 16 non-professional musicians before and after 90 min of practice. All had experienced repeated exposures to intense sound levels for at least five years during their musical careers. The evaluation performed after the practice showed the lowest thresholds for frequencies from 500 Hz to 8000 Hz ($p < 0.004$), with worse results for the frequency of 6000 Hz, but there were no differences in the frequencies of 9000–14,000 Hz. The authors concluded, based on these results, that high-frequency audiometry does not appear to be advantageous as a means of early detection of hearing loss induced by high-intensity levels of music.

When analyzed according to age, for G1 up to 25 years (Table 4), although there was a significant difference only at frequencies of 250 Hz in the left ear and 500 Hz in both ears, the left ear in group G1 also showed the worst mean thresholds at frequencies 2000 Hz, 6000 Hz, 9000 Hz, 10,000 Hz and 11,200 Hz, when compared to G2.

For G1 of 26 years and older, there was a significant difference only at the frequency of 250 Hz in both ears and 500 Hz in the left ear. However, the mean thresholds of G1 were also worse than G2 at the frequencies of 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, 8000 Hz, 9000 Hz, 10,000 Hz and 11,200 Hz in the left ear; and at 9000 Hz, 10,000 Hz and 11,200 Hz in the right ear (Table 5).

Considering that the hearing loss induced by music or noise occurs after years of exposure and slowly progresses over time, the present study disclosed worse thresholds, although still within the normal range, for G1 at several frequencies, especially in the left ear for those older than 26 years, when compared to G2 (Tables 4 and 5).

The three institutions participating in this study offer music courses with a broad diversity of qualifications, which puts students in very diverse learning situations. Although common to all students, musical practice during training differs from course to course, depending on the institution and the qualification of choice and, in most cases, the student is not limited to just one musical instrument.

In this phase, the implementation of a hearing conservation program for this population could bring great benefits by providing students with all the necessary information on the risks of exposure to high-intensity music and how to prevent hearing loss.

In the present study, the audiometric findings, although mostly within the normal range, did not rule out possible early cochlear damage, which were perceived when appropriate comparisons were made, showing that the group of students (G1) exposed to music almost daily had worse pure-tone air conduction thresholds in the conventional audiometry and at high frequencies, especially in the left ear (Table 1).

High-frequency audiometry is a useful tool to detect early cochlear alterations. Despite the lack of standardized normality parameters and the fact that they are rarely performed in musicians, the differences in auditory thresholds at high frequencies, if followed for a longer period of time and also associated with conventional hearing thresholds, can provide information on the hearing status of musicians over the years.

The appearance of audiometric notches in both conventional and high-frequency audiometry could better clarify the effects of high-intensity music.

If this monitoring could be performed during the academic period, or even before graduation during the study of music in conservatories or music schools, the future musician would be much more prepared to face risk situations, and could collaborate to ensure that the sound intensities are neither strong enough nor of sufficient duration to result in hearing damage.

Conclusion

Both conventional and high-frequency audiometry disclosed statistically significant differences when comparing the audiometric thresholds of the music student group and the group consisting of non-musicians, non-music students, and those not exposed to noise at work, with the worst thresholds found in the group of music students. The most significant differences were found in the evaluation of high frequencies, which allows for the inference that sporadic high-frequency threshold assessment can be useful in early detection of hearing loss in musicians.

Conflicts of interest

The authors declare no conflicts of interest.

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