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ORIGINAL ARTICLE

High levels of sound pressure: acoustic reflex thresholds and auditory complaints of workers with noise exposure☆,☆☆

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Abstract
Introduction: The clinical evaluation of subjects with occupational noise exposure has been difficult due to the discrepancy between auditory complaints and auditory test results. This study aimed to evaluate the contralateral acoustic reflex thresholds of workers exposed to high levels of noise, and to compare these results to the subjects' auditory complaints.
Methods: This clinical retrospective study evaluated 364 workers between 1998 and 2005; their contralateral acoustic reflexes were compared to auditory complaints, age, and noise exposure time by chi-squared, Fisher's, and Spearman's tests.
Results: The workers' age ranged from 18 to 50 years (mean = 39.6), and noise exposure time from one to 38 years (mean = 17.3). We found that 15.1% (55) of the workers had bilateral hearing loss, 38.5% (140) had bilateral tinnitus, 52.8% (192) had abnormal sensitivity to loud sounds, and 47.2% (172) had speech recognition impairment. The variables hearing loss, speech recognition impairment, tinnitus, age group, and noise exposure time did not show relationship with acoustic reflex thresholds; however, all complaints demonstrated a statistically significant relationship with Metz recruitment at 3000 and 4000 Hz bilaterally.
Conclusion: There was no significance relationship between auditory complaints and acoustic reflexes.

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PALAVRAS-CHAVE
Perda auditiva provocada por ruído;
Ruído ocupacional;
Reflexo acústico

Níveis elevados de pressão sonora: limiares dos reflexos estapedianos e queixas auditivas de trabalhadores expostos

Resumo

Introdução: A avaliação clínico-ocupacional de trabalhadores expostos a ruído é dificultada pela discrepância entre queixas auditivas e resultados dos exames audiológicos. Este estudo pretende avaliar limiares dos reflexos estapedianos contralaterais em sujeitos expostos a níveis elevados de pressão sonora, relacionando-os com queixas auditivas.

Método: Estudo clínico retrospectivo que analisou 364 trabalhadores e seus limiares de reflexos estapedianos contralaterais, relacionado-os com queixas auditivas, idades e tempos de exposição ao ruído.

Resultados: Dos trabalhadores avaliados, com idades de 18 a 50 anos (média 39,6) e tempos de exposição entre um e 38 anos (média 17,3); 15,1% (55) tinham queixa de perda auditiva bilateral, 38,5% (140) zumbidos bilaterais, 52,8% (192) irritação ao ouvir sons intensos e 47,2% (172) dificuldades para reconhecer a fala. As variáveis: perda auditiva, dificuldade para reconhecimento da fala, zumbidos, faixa etária e tempo de exposição ao ruído não se relacionaram significativamente com limiares dos reflexos estapedianos, mas todas as queixas apresentaram relação estatisticamente significante com o recrutamento de Metz nas frequências de 3000 e 4000 Hz, bilateralmente.

Conclusão: Não houve relações significativas entre limiares dos reflexos estapedianos e queixas auditivas.

Introduction

Noise-induced hearing loss (NIHL) is characterized by a gradual loss of hearing acuity, resulting from a continuous exposure to high sound pressure levels.

The principal characteristic of NIHL is an irreversible sensorineural hearing loss that is usually bilateral. Initially, the clinical picture involves auditory thresholds of one or more frequencies between 3000 and 6000 Hz, forming a characteristic notch. The highest and lowest frequencies may take longer to be affected. There is variability in pattern of evolution for the NIHL due to individual susceptibility, that is more pronounced in the first 10–15 years of exposure, decreasing and tending to stabilize thereafter.[1]

Histological studies in humans have shown that the more damaged cochlear sensory cells in patients with NIHL correspond to the frequency range of 3000–6000 Hz in the basal turn of the cochlea, about 8–14 mm from the oval window. The changes caused by noise exposure vary, from minor changes in hair cells to the complete absence of the spiral organ.[1,2]

Because this is a predominantly cochlear disorder, the individual affected by NIHL may exhibit reduced hearing, oversensitivity to loud sounds and tinnitus, as well as impairment of speech intelligibility, especially in situations with competing noise. It is important to remember that retrocochlear diseases most commonly affect speech intelligibility.[3]

However, exposure to noise also can cause important psychosocial changes in workers, affecting their quality of life, such as stress, anxiety, and impairment in social relations, as well as activities of daily living.[2]

The diagnosis of NIHL can only be established through a set of evaluations that include clinical history, occupational history, physical examination, audiological assessment and supplementary tests when necessary.[4]

The audiological evaluation is conducted primarily through pure tone audiometry, logoaudiometry, and immittance testing. The latter is a test of great clinical importance, which quickly and objectively evaluates the eardrum-ossicular system and the acoustic reflex.

Immittance testing can evaluate tympanic membrane mobility and middle ear conditions, tubal function, and the stapedial reflex.

The stapedial reflex indicates that contraction of the stapedius muscle occurred, when the system is stimulated with a sudden and intense sound. The analysis of this reflex can document the presence of Metz recruitment in cochlear diseases, and of pathological adaptation in retrocochlear disorders.[5,6]

The acoustic reflex measurement is usually performed at 500, 1000, 2000, and 4000 Hz; according to several authors, the intensity necessary to trigger the reflex in individuals with normal hearing is in the range of 70–100 dB SL.[7]

In routine audiological testing, reflexes at 3000 Hz are not usually evaluated, although there is no explanation for this omission, given the importance of this frequency in speech perception and in audiometric tests in patients exposed to loud noises. An important application of acoustic reflex measurement is in the evaluation of the cochlear phenomenon of abnormal growth of loudness (recruitment).[5–8]

The contralateral stapedial reflex threshold at sensitivity levels below 60 dB SL can occur in ears with cochlear injury and is suggestive of recruitment. Analysis of objective Metz recruitment is conducted by measuring the sensitivity level (SL); that is, by comparing the level of the acoustic reflex threshold and the level of audiometric threshold at each frequency.[5-8]

The interpretation of the stapedial reflex is of great importance in clinical diagnosis. However, the literature has not yet established what its values represent in relation to hearing complaints such as hearing loss, oversensitivity to loud sounds, tinnitus, and speech perception difficulties.

This study aimed to assess contralateral stapedial reflex thresholds at 500, 1000, 2000, 3000, and 4000 Hz in subjects exposed to high sound pressure levels, relating these results with the hearing complaints cited by these patients. Comparisons were made with both the absolute values of reflex thresholds and with the occurrence of Metz recruitment, measured by their respective sensitivity levels (difference between reflex and audiometric thresholds) for each frequency.

Methods

Medical records of workers exposed to high sound pressure levels were examined, and their socio-demographic data, hearing complaints, and audiometric and immittance tests were collected. Next, the relationship between hearing complaints, age, duration of noise exposure, and the results of conventional immittance tests were analyzed.

Since the decrease in hearing thresholds caused by noise exposure tends to stabilize after 15 years of exposure, we categorized the participants into two groups: <16 years of exposure to noise and ≥16 years of exposure.[1]

In the comparative analyses, the stapedial reflex thresholds were categorized into three groups: ≤100 dB, 105–120 dB, and absent reflexes. The differences between reflex and pure tone thresholds were categorized into two ranges: ≤60 dB (suggestive of Metz recruitment) and >60 dB (no recruitment).

A search was also performed on PubMed/MEDLINE and Scopus databases, with the MeSH terms: ''Perda Auditiva Provocada por Ruído; Ruído Ocupacional; Testes Auditivos; Testes de Impedância Acústica; Detecção de Recrutamento Audiológico; Hearing Loss; Noise-Induced; Noise Occupational; Hearing Tests; Acoustic Impedance Tests; Recruitment Detection, Audiologic'', in the Portuguese and English languages, with no time limit.

Participants – inclusion and exclusion criteria

Medical records of 364 workers attended to at the Occupational Otorhinolaryngology Outpatient Clinic of a university hospital between 1998 and 2005, with ages ranging from 18 to 50 years, of both genders, pertaining to multiple professional categories and with different times of occupational noise exposure, with normal audiometric exams or with exams suggestive of hearing loss induced by noise, normal tympanograms (type A), and presence of contralateral stapedial reflexes were analyzed.

Medical records of workers with current or previous occupational exposure to chemicals, with a history of middle ear disorder, with current or previous use of ototoxic drugs, with previous acoustic, face, neck, and cervical spine trauma, and with traumatic brain injury, as well as those with diabetes, high blood pressure, kidney failure, and thyroid disorders, were excluded from the study.

Procedures

For this analysis, the following complaints were considered: bilateral hearing loss; speech perception difficulties in adverse listening situations; oversensitivity to loud sounds, and presence of bilateral tinnitus.

The results of contralateral stapedial reflexes with immittance testing were related to hearing complaints and workers' age and exposure times, both by their absolute values (hearing levels) and by the differences between their thresholds and pure tone audiometric thresholds (sensitivity levels). The occurrence of Metz recruitment was considered when the sensitivity level was lower than 60 dB.[5-8]

In the comparative analysis, the thresholds of stapedial reflexes were categorized into three groups: ≤100 dB, 105–120 dB, and absent reflexes. The differences between reflex thresholds and pure tone audiometric thresholds were categorized into two groups: ≤60 dB (suggestive of Metz recruitment) and >60 dB (no recruitment).

We chose to describe the full table of analyses only for situations in which there was a statistically significant relationship in the analyzed data.

Statistical analysis

The profile of the sample was described by frequency tables for categorical variables (professional category and hearing complaints) and by descriptive statistics of continuous variables (age, noise exposure time, and stapedial reflex thresholds).

To examine the relationship between categorical variables, the chi-squared test and Fisher's exact test were used (for expected values < 5). To examine the relationship between continuous variables, Spearman's correlation coefficient was used.

The significance level for statistical tests was 5% ($p < 0.05$).

In the statistical analysis, the SAS System for Windows 8.02 (SAS Institute Inc., 1999–2001, Cary, NC, United States) was used.

Ethical aspects

This research was approved by the Research Ethics Committee of the institution, under No. 794/2005.

Results

Medical records of 364 workers of both genders were analyzed. 316 belonged to the metallurgical category (86.8%) and the remaining participants (13.2%) came from several other professional categories (food, oil refinery, electronics, chemistry, laundry, cosmetics, and telephony).

The ages of the workers ranged from 18 to 50 years (median 40 years, mean 39.6 ± 7.25 years). For this analysis,

Table 1 Distribution of workers by age and length of exposure ($n = 364$).

	Age	Frequency	Rate
Age	<40	163	44.8%
	≥40	201	55.2%
Length of exposure	<16	136	37.4%
	≥16	228	62.6%

Table 2 Distribution of workers by hearing complaints ($n = 364$).

Hearing complaints		
Hearing loss		
Bilateral	55	15.1%
Right	44	12.1%
Left	40	10.9%
Absent	225	61.9%
Tinnitus		
Bilateral	140	38.5%
Right	11	3%
Left	18	4.9%
Absent	195	53.6%
Oversensitivity to loud sounds		
Present	192	52.8%
Absent	172	47.2%
Speech recognition difficulties		
Present	172	47.2%
Absent	192	52.8%

the participants were categorized into two groups: <40 years and ≥40 years (Table 1).

All workers were exposed to occupational noise during at least one year, up to a maximum of 38 years (median 18 years, mean 17.3 ± 8.1 years) (Table 1).

We found that only 15.1% of workers (55) had bilateral hearing loss complaints. For this analysis, complaints of unilateral hearing loss were not considered. It was also found that 38.5% of workers (140) complained of bilateral tinnitus. For this analysis, unilateral tinnitus was not considered. More than half of the workers experienced oversensitivity when hearing loud sounds (52.8%) and almost half reported speech recognition difficulties in day-to-day situations (47.2% [AG1]) (Table 2).

Contralateral stapedial reflex thresholds ranged from 75 dB to 120 dB in the right afferent and from 65 dB to 120 dB in the left afferent pathways. The means for contralateral stapedial reflex thresholds ranged from 91.3 dB at 500 Hz to 97.0 dB at 4000 Hz in the right afferent, and from 91.2 dB at 500 Hz to 97.5 dB at 4000 Hz in the left afferent. A tendency of increase in absolute values and variability with an increase of the frequencies' value was observed (Table 3).

The differences between reflex thresholds and pure tone thresholds ranged from 30 to 120 dB on the right side and from 30 to 115 dB on the left side. The means of differences between reflex thresholds and pure tone thresholds decreased, from 81.2 dB at 500 Hz to 69.5 dB at 4000 Hz in the right afferent; and from 81.4 dB at 500 Hz to 67.4 dB at 4000 Hz in the left afferent. A trend of a decrease in differences and of an increase in variability was observed, with an increase of frequency value (Table 3).

There was a significant relationship between hearing loss complaints and reflex thresholds only for the frequencies of 4000 Hz in the right ear and of 2000 Hz in the left ear (Table 4).

The relationship between hearing loss complaints and the presence of Metz recruitment was significant at all frequencies, except at 500 Hz in the left afferent (Table 5).

A relationship was noted between speech recognition difficulties in unfavorable listening places and the presence of Metz recruitment (Table 6).

The comparison between irritation with loud sounds and the absolute values of contralateral stapedial reflex thresholds showed no significance in all presentations, except at 1000 Hz in the right afferent ($p = 0.048$) (Table 7).

The comparison between oversensitivity to loud sounds and the occurrence of Metz recruitment showed significance, with reflexes at 3000 and 4000 Hz bilaterally (Table 8).

The comparison between bilateral tinnitus complaints and the absolute values of contralateral stapedial reflex thresholds showed no significant relationship for all frequencies bilaterally.

The comparison between tinnitus complaints and the presence of Metz recruitment showed a significant relationship at the frequencies of 3000 and 4000 Hz bilaterally (Table 9).

No significant relationship was observed between age and contralateral stapedial reflex thresholds, or between age and absence of stapedial reflex.

The relationship between age and the presence of Metz recruitment showed significance with reflexes at 3000 and 4000 Hz bilaterally (Table 10).

There was a significant relationship between stapedial reflexes at 4000 Hz and the duration of noise exposure, bilaterally (Table 11).

There was a significant relationship between Metz recruitment and over 15 years of exposure, as well as between absence of recruitment and 15 or fewer years of exposure at 3000 and 4000 Hz, bilaterally (Table 12).

An analysis of correlations between age groups and exposure times was performed; the results were significant at all frequencies and means (Spearman's correlation coefficient, $p < 0.05$; $n = 188$).

Discussion

The World Health Organization (WHO) estimates that 10% of the world population is exposed to sound pressure levels that can potentially lead to hearing loss induced by noise. The WHO considers this situation as a public health problem, and in the United States, there is evidence that NIHL is the most prevalent occupational disease.[9]

The review of the pertinent literature, both in searches of PubMed and Scopus, shows no similar studies comparing hearing complaints with stapedial reflex and Metz recruitment in workers with noise-induced hearing loss.[10–12]

Table 3 Distribution of means of contralateral stapedial reflex thresholds.

	Frequencies	Right afferent			Left afferent		
		n	Means (dB)	SD	*n*	Means (dB)	SD
Reflex thresholds	500	364	91.3	7.6	364	91.2	7.3
	1000	364	91.7	6.5	364	91.9	7.0
	2000	363	92.0	7.0	364	92.2	7.4
	3000	355	94.0	8.9	352	93.9	8.6
	4000	312	97.0	9.9	319	97.5	10.1
Reflex differences	500	364	81.2	8.9	364	81.4	9.1
	1000	364	82.5	8.9	364	83.0	9.5
	2000	363	80.4	11.7	364	80.0	11.3
	3000	355	74.5	14.7	352	72.2	14.3
	4000	312	69.5	15.9	319	67.4	15.3

Table 4 Comparison between hearing loss complaints and contralateral stapedial reflex thresholds ($n = 364$).

Reflex thresholds	<100 dB		>100 dB		Absence of reflex		*p*-value
Hearing loss	Without complaint	With complaint	Without complaint	With complaint	Without complaint	With complaint	
Right							
500 Hz	285 (92.2%)	53 (96.4%)	24 (7.8%)	2 (3.6%)	–	–	0.397[a]
1000 Hz	294 (95.1%)	53 (96.4%)	15 (4.9%)	2 (3.6%)	–	–	1.000[a]
2000 Hz	286 (92.6%)	51 (92.7%)	22 (7.1%)	4 (7.3%)	1 (0.3%)	–	1.000[a]
3000 Hz	254 (82.2%)	41 (74.6%)	48 (15.5%)	12 (21.8%)	7 (2.3%)	2 (3.6%)	0.404[b]
4000 Hz	209 (**67.6%**)	30 (54.5%)	62 (20.1%)	11 (20.0%)	38 (12.3%)	14 (**25.5%**)	**0.032**[b]
Left							
500 Hz	289 (93.5%)	53 (96.3%)	20 (6.5%)	2 (3.7%)	–	–	0.551[a]
1000 Hz	292 (94.5%)	52 (94.5%)	17 (5.5%)	3 (5.5%)	–	–	1.000[a]
2000 Hz	290 (**93.8%**)	47 (85.4%)	19 (6.2%)	8 (**14.6%**)	–	–	**0.045**[a]
3000 Hz	255 (82.5%)	42 (76.3%)	46 (14.9%)	9 (16.4%)	8 (2.6%)	4 (7.3%)	0.184[b]
4000 Hz	199 (64.4%)	27 (49.1%)	75 (24.3%)	18 (32.7%)	35 (11.3%)	10 (18.2%)	0.089[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

Table 5 Comparison between hearing loss complaints and occurrence of Metz recruitment.

Threshold differences	*n*	<60 dB		>60 dB		*p*-value
Hearing loss		Without complaint	With complaint	Without complaint	With complaint	
Right						
500 Hz	364	5 (1.6%)	6 (**10.9%**)	304 (**98.4%**)	49 (89.1%)	**0.002**[a]
1000 Hz	364	0 (0.0%)	3 (**5.5%**)	309 (**100.0%**)	52 (94.5%)	**0.003**[a]
2000 Hz	363	13 (4.2%)	11 (**20.0%**)	295 (**95.8%**)	44 (80.0%)	**0.001**[a]
3000 Hz	355	50 (16.6%)	25 (**47.2%**)	252 (**83.4%**)	28 (52.8%)	**<0.001**[b]
4000 Hz	313	89 (32.7%)	23 (**56.1%**)	183 (**67.3%**)	18 (43.9%)	**0.004**[b]
Left						
500 Hz	364	7 (2.3%)	4 (7.3%)	302 (97.7%)	51 (92.7%)	0.068[a]
1000 Hz	364	1 (0.3%)	5 (**9.1%**)	308 (**99.7%**)	50 (90.9%)	**<0.001**[a]
2000 Hz	364	14 (4.5%)	13 (**23.6%**)	295 (**95.5%**)	42 (76.4%)	**<0.001**[a]
3000 Hz	352	60 (19.9%)	25 (**49.0%**)	241 (**80.1%**)	26 (51.0%)	**<0.001**[b]
4000 Hz	319	103 (37.6%)	26 (**57.8%**)	171 (**62.4%**)	19 (42.2%)	**0.011**[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

Table 6 Comparison between speech recognition and occurrence of Metz recruitment.

Reflex differences	n	<60 dB		>60 dB		p-value
Speech recognition		Without complaint	With complaint	Without complaint	With complaint	
Right						
500 Hz	364	2 (1.0%)	9 (5.2%)	190 (99.0%)	163 (94.8%)	**0.020**[b]
1000 Hz	364	0 (0.0%)	3 (1.7%)	192 (100.0%)	169 (98.3%)	0.105[a]
2000 Hz	363	2 (1.1%)	**22 (12.8%)**	189 **(98.9%)**	150 (87.2%)	**<0.001**[b]
3000 Hz	355	23 (12.1%)	52 **(31.5%)**	167 **(87.9%)**	113 (68.5%)	**<0.001**[b]
4000 Hz	313	44 (25.3%)	68 **(48.9%)**	130 **(74.7%)**	71 (51.1%)	**<0.001**[b]
Left						
500 Hz	364	4 (2.1%)	7 (4.1%)	188 (97.9%)	165 (95.9%)	0.269[b]
1000 Hz	364	1 (0.5%)	5 (2.9%)	191 (99.5%)	167 (97.1%)	0.105[a]
2000 Hz	364	4 (2.1%)	23 **(13.4%)**	188 **(97.9%)**	149 (86.6%)	**<0.001**[b]
3000 Hz	352	25 (13.2%)	60 **(36.8%)**	164 **(86.8%)**	103 (63.2%)	**<0.001**[b]
4000 Hz	319	60 (34.3%)	69 **(47.9%)**	115 **(65.7%)**	75 (52.1%)	**0.014**[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

Table 7 Comparison between oversensitivity to loud sounds and contralateral stapedial reflex thresholds ($n = 364$).

Reflex thresholds	<100 dB		>100 dB		Absence of reflex		p-value
Oversensitivity to loud sounds	Without complaint	With complaint	Without complaint	With complaint	Without complaint	With complaint	
Right							
500 Hz	156 (90.7%)	182 (94.8%)	16 (9.3%)	10 (5.2%)	–	–	0.130[b]
1000 Hz	160 (93.0%)	187 **(97.4%)**	12 (7.0%)	5 (2.6%)	–	–	**0.048**[b]
2000 Hz	158 (91.8%)	179 (93.2%)	13 (7.6%)	13 (6.8%)	1 (0.6%)	0 (0.0%)	0.684[a]
3000 Hz	137 (79.7%)	158 (82.3%)	31 (18.0%)	29 (15.1%)	4 (2.3%)	5 (2.6%)	0.766[a]
4000 Hz	117 (68.0%)	122 (63.5%)	34 (19.8%)	39 (20.3%)	21 (12.2%)	31 (16.2%)	0.529[b]
Left							
500 Hz	159 (92.4%)	183 (95.3%)	13 (7.6%)	9 (4.7%)	–	–	0.251[b]
1000 Hz	161 (93.6%)	183 (95.3%)	11 (6.4%)	9 (4.7%)	–	–	0.475[b]
2000 Hz	162 (94.2%)	175 (91.2%)	10 (5.8%)	17 (8.8%)	–	–	0.269[b]
3000 Hz	145 (84.3%)	152 (79.1%)	22 (12.8%)	33 (17.2%)	5 (2.9%)	7 (3.7%)	0.448[b]
4000 Hz	112 (65.1%)	114 (59.4%)	41 (23.8%)	52 (27.1%)	19 (11.1%)	26 (13.5%)	0.519[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

Although the importance of our data is evident, it is difficult to establish a comparison of this information with the medical literature.

The comparative analysis between complaints of speech recognition difficulties and the differences between stapedial reflex and audiometric tonal thresholds showed that the presence of Metz recruitment (difference < 65 dB) was significant among the complainants at 2000 Hz, 3000 Hz, and 4000 Hz bilaterally, and in the right afferent at 500 Hz (Table 6). According to Costa et al., speech recognition difficulties in patients with noise-induced hearing loss are more consistent and pronounced when speech audiometry for monosyllable words is tested with masking by competitive speech.[10]

The relationship between hearing loss complaints and stapedial reflex thresholds was only significant for the absence of complaints and reflexes ≤100 dB at 4000 Hz on the right side and at 2000 Hz on the left side.

A significant relationship between absence of hearing loss complaints and reflex thresholds ≤100 dB only was noted at 4000 Hz on the right side ($p = 0.032$) and at 2000 Hz on the left side ($p = 0.045$).

A significant relationship between the presence of hearing loss complaints and reflex thresholds >100 dB only was observed at 2000 Hz on the left side, and between the presence of complaints and absence of stapedial reflex at 4000 Hz on the right side ($p = 0.032$).

In both situations, there was a slightly significant trend ($p = 0.045$ and 0.032, respectively). In all other situations, there was no significant relationship between hearing loss complaints and contralateral stapedial reflex thresholds (Table 4).

Table 8 Comparison between irritation with loud sounds and occurrence of Metz recruitment.

Reflex differences	*n*	<60 dB		>60 dB		*p*-value
Oversensitivity to loud sounds		Without complaint	With complaint	Without complaint	With complaint	
Right						
500 Hz	364	3 (1.7%)	8 (4.2%)	169 (98.3%)	184 (95.8%)	0.178[b]
1000 Hz	364	0 (0.0%)	3 (1.6%)	172 (100.0%)	189 (98.4%)	0.250[a]
2000 Hz	363	7 (4.1%)	17 (8.8%)	164 (95.9%)	175 (91.2%)	0.068[b]
3000 Hz	355	27 (16.1%)	48 (**25.7%**)	141 (**83.9%**)	139 (74.3%)	**0.027**[b]
4000 Hz	313	39 (25.8%)	73 (**45.1%**)	112 (**74.2%**)	89 (54.9%)	**<0.001**[b]
Left						
500 Hz	364	4 (2.3%)	7 (3.7%)	168 (97.7%)	185 (96.3%)	0.463[b]
1000 Hz	364	2 (1.2%)	4 (2.1%)	170 (98.8%)	188 (97.9%)	0.688[a]
2000 Hz	364	11 (6.4%)	16 (8.3%)	161 (93.6%)	176 (91.7%)	0.481[b]
3000 Hz	352	29 (17.4%)	56 (**30.3%**)	138 (**82.6%**)	129 (69.7%)	**0.005**[b]
4000 Hz	319	51 (33.3%)	78 (**47.0%**)	102 (**66.7%**)	88 (53.0%)	**0.013**[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

Table 9 Comparison between lateral tinnitus and occurrence of Metz recruitment ($n = 364$).

Reflex differences	*n*	<60 dB		>60 dB		*p*-value
Tinnitus		Without complaint	With complaint	Without complaint	With complaint	
Right						
500 Hz	364	4 (1.8%)	7 (5.0%)	220 (98.2%)	133 (95.0%)	0.114[a]
1000 Hz	364	0 (0.0%)	3 (2.1%)	224 (100.0%)	137 (97.9%)	0.056[a]
2000 Hz	363	5 (2.2%)	19 (**13.6%**)	218 (**97.8%**)	121 (86.4%)	<0.001[b]
3000 Hz	355	31 (14.2%)	44 (**32.1%**)	187 (**85.8%**)	193 (67.9%)	<0.001[b]
4000 Hz	313	51 (26.8%)	61 (**49.6%**)	139 (**73.2%**)	62 (50.4%)	<0.001[b]
Left						
500 Hz	364	5 (2.2%)	6 (4.3%)	219 (97.8%)	134 (95.7%)	0.347[a]
1000 Hz	364	2 (0.9%)	4 (2.9%)	222 (99.1%)	136 (97.1%)	0.210[a]
2000 Hz	364	13 (5.8%)	14 (10.0%)	211 (94.2%)	126 (90.0%)	0.137[b]
3000 Hz	352	41 (19.0%)	44 (**32.4%**)	175 (**81.0%**)	92 (67.6%)	**0.004**[b]
4000 Hz	319	64 (32.7%)	65 (**52.9%**)	132 (**67.3%**)	58 (47.2%)	**<0.001**[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

The relationship between hearing loss complaints and the presence of Metz recruitment was significant in all presentations, except at 500 Hz on the left afferent, yet with a slight trend ($p = 0.068$) (Table 5). Metz recruitment was related also with age over 40 years and with exposure time over 16 years.

Examining the results, it can be noted that there was a significant relationship between hearing loss complaints, speech recognition difficulties, oversensitivity to loud sounds, tinnitus, age group, duration of exposure, and the occurrence of Metz recruitment at 3000 and 4000 Hz bilaterally. Despite the significant relationship, no conclusions can be drawn regarding the relationship of cause and effect between these variables.

The comparison between oversensitivity to loud sounds and the absolute values for contralateral stapedial reflex thresholds showed no significance in all presentations, except at 1000 Hz in the right afferent ($p = 0.048$) (Table 7).

The comparison between sensitivity to loud sounds and the occurrence of Metz recruitment showed significance with reflexes at 3000 and 4000 Hz bilaterally (Table 8).

The comparison between bilateral tinnitus complaints and the absolute values for contralateral stapedial reflex thresholds showed no significant relationship at all frequencies applied, on both sides. Also, there was no significant relationship between tinnitus complaints and absence of stapedial reflexes.

The comparison between tinnitus complaints and presence of Metz recruitment showed a significant association at frequencies of 3000 and 4000 Hz bilaterally, and at 2000 Hz in the right afferent (Table 9).

There was no significant relationship between the fact that the participants were under or over 40 years of age and had contralateral stapedial reflex thresholds at all frequencies and on both sides. Additionally, there was no significant

Table 10 Comparison between age group of workers and occurrence of Metz recruitment.

Reflex differences	*n*	<60 dB		>60 dB		*p*-value
Age group		<40 years	≥40 years	<40 years	≥40 years	
Right						
500 Hz	364	4 (2.5%)	7 (3.5%)	159 (97.6%)	194 (96.5%)	0.761[a]
1000 Hz	364	2 (1.2%)	1 (0.5%)	161 (98.8%)	200 (99.5%)	0.589[a]
2000 Hz	363	6 (3.7%)	18 (**9.0%**)	156 (**96.3%**)	183 (91.0%)	**0.043**[a]
3000 Hz	355	24 (15.0%)	51 (**26.1%**)	136 (**85.0%**)	144 (73.9%)	**0.010**[b]
4000 Hz	313	32 (21.9%)	80 (**47.9%**)	114 (**78.1%**)	871 (52.1%)	**<0.001**[b]
Left						
500 Hz	364	5 (3.1%)	6 (3.0%)	158 (96.9%)	195 (97.0%)	1.000[a]
1000 Hz	364	3 (1.8%)	3 (1.5%)	160 (98.2%)	198 (98.5%)	1.000[a]
2000 Hz	364	9 (5.5%)	18 (9.0%)	154 (94.5%)	183 (91.0%)	0.214[b]
3000 Hz	352	23 (14.6%)	62 (**32.0%**)	135 (**85.4%**)	132 (68.0%)	**<0.001**[b]
4000 Hz	319	44 (29.7%)	85 (**49.7%**)	104 (**70.3%**)	86 (50.3%)	**<0.001**[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

Table 11 Comparison between noise exposure time and contralateral stapedial reflex thresholds ($n = 364$).

Reflex thresholds	<100 dB		>100 dB		Absence of reflex		*p*-value
Exposure time	<15 years	>15 years	<15 years	>15 years	<15 years	>15 years	
Right							
500 Hz	123 (90.4%)	215 (94.3%)	13 (9.6%)	13 (5.7%)	–	–	0.167[b]
1000 Hz	126 (92.7%)	221 (96.9%)	10 (7.3%)	7 (3.1%)	–	–	0.061[b]
2000 Hz	127 (93.4%)	210 (92.1%)	8 (5.9%)	18 (7.9%)	1 (0.7%)	0 (0.0%)	0.330[a]
3000 Hz	117 (86.0%)	178 (78.1%)	16 (11.8%)	44 (19.3%)	3 (2.2%)	6 (2.6%)	0.160[b]
4000 Hz	99 (72.8%)	140 (61.4%)	27 (19.9%)	46 (20.2%)	10 (7.3%)	42 (**18.4%**)	**0.011**[b]
Left							
500 Hz	125 (91.9%)	217 (95.2%)	11 (8.1%)	11 (4.8%)	–	–	0.206[b]
1000 Hz	126 (92.7%)	218 (95.6%)	10 (7.3%)	10 (4.4%)	–	–	0.230[b]
2000 Hz	129 (94.9%)	208 (91.2%)	7 (5.1%)	20 (8.8%)	–	–	0.202[b]
3000 Hz	118 (86.8%)	179 (78.5%)	17 (12.5%)	38 (**16.7%**)	1 (0.7%)	11 (**4.8%**)	**0.049**[b]
4000 Hz	93 (**68.4%**)	133 (58.3%)	35 (25.7%)	58 (25.5%)	8 (5.9%)	37 (**16.2%**)	**0.013**[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

relationship between the subjects' age group and absence of stapedial reflex.

The relationship between age group and presence of Metz recruitment was significant with reflexes at 2000, 3000, and 4000 Hz in the right afferent, and at 3000 and 4000 Hz in the left afferent (Table 10).

There was a significant relationship between reflexes ≤100 dB and subjects with 15 or fewer years of exposure at 4000 Hz bilaterally. Also, there was a significant relationship between the absence of stapedial reflex and over 15 years of exposure at 4000 Hz bilaterally (Table 11).

There was a significant relationship between Metz recruitment and over 15 years of exposure, as well as between absence of recruitment and 15 or fewer years of exposure at 3000 and 4000 Hz bilaterally (Table 12).

Evolution has programmed humans to be aware of sounds as possible sources of danger.[13] Noise can be considered as an undesirable sound that, if at high levels and after prolonged exposure, can lead to auditory and non-auditory health problems.

Hearing loss induced by noise continues to be highly prevalent in the workplace, but this condition is increasingly caused by exposure to social noises present in everyday life, e.g., the use of digital sound players.[9,14]

The exposure to noise, whether or not occupational, is increasingly related to auditory health problems (hearing loss, tinnitus, speech perception difficulties, and hyperacusis) and non-auditory health problems (irritation, sleep disorders, cardiovascular disease, and cognitive impairment in children).[15–19]

Over the past five years, several studies and advances have improved the understanding of the causes and factors of susceptibility to noise-induced hearing loss. A widely accepted hypothesis is that NIHL results from the interaction of genetic and environmental factors.[20,21]

Table 12 Comparison of noise exposure time of workers and occurrence of Metz recruitment.

Reflex differences	*n*	<60 dB		>60 dB		*p*-value
Exposure time		<15 years	>15 years	<15 years	>15 years	
Right						
500 Hz	364	4 (2.9%)	7 (3.1%)	132 (97.1%)	221 (96.9%)	1.000[a]
1000 Hz	364	2 (1.5%)	1 (0.4%)	134 (98.5%)	227 (99.6%)	0.559[a]
2000 Hz	363	7 (5.2%)	17 (7.5%)	128 (94.8%)	211 (92.5%)	0.400[b]
3000 Hz	355	20 (15.0%)	55 (**24.8%**)	113 (**85.0%**)	167 (75.2%)	**0.030**[b]
4000 Hz	313	26 (20.6%)	86 (**46.0%**)	100 (**79.4%**)	101 (54.0%)	**<0.001**[b]
Left						
500 Hz	364	5 (3.7%)	6 (2.6%)	131 (96.3%)	222 (97.4%)	0.753[a]
1000 Hz	364	2 (1.5%)	4 (1.7%)	134 (98.5%)	224 (98.3%)	1.000[a]
2000 Hz	364	9 (6.6%)	18 (7.9%)	127 (93.4%)	210 (92.1%)	0.653[b]
3000 Hz	352	22 (16.3%)	63 (**29.0%**)	113 (**83.7%**)	154 (71.0%)	**0.009**[b]
4000 Hz	319	42 (32.8%)	87 (**45.6%**)	86 (**67.2%**)	104 (54.4%)	**0.023**[b]

[a] Fisher's exact test.
[b] Chi-squared test. Significant values are highlighted in **bold**.

The understanding of the pathophysiological mechanisms involving hair cells and auditory nerve damage has increased substantially, and several therapeutic guidelines have recently been explored. Oral medications to protect against noise-induced hearing loss are expected to become available in the coming years.[9,22–24]

Conclusions

There was no significant relationship between absolute values of stapedial reflex thresholds and hearing loss complaints, oversensitivity to loud sounds, tinnitus, and age group.

The significant relationship among hearing loss complaints, speech recognition difficulties, oversensitivity to loud sounds, tinnitus, age group (over 40 years), exposure time (greater than 15 years), and the occurrence of Metz recruitment at 3000 and 4000 Hz bilaterally are noteworthy. However, a cause-and-effect relationship among these variables cannot be determined.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Perda Auditiva Induzida por Ruído relacionado ao Trabalho. In: Boletim n° 1. Comitê Nacional de Ruído e Conservação Auditiva. 1999. Available from: http://bvsms.saude.gov.br/bvs/publicacoes/protocolo_perda_auditiva.pdf
2. Costa EA, Ibáñez RN, Nudelmann AA, Seligman J. A perda auditiva induzida pelo ruído (PAIR) relacionada ao trabalho. In: Costa SS, Cruz OLM, Oliveira JAA, editors. Otorrinolaringologia: princípios e prática. 2ª ed. Porto Alegre: Artmed; 2006. p. 410–2.
3. Hong O, Kerr MJ, Poling GL, Dhar S. Understanding and preventing noise-induced hearing loss. Dis Mon. 2013;59:110–8.
4. Diretrizes e Parâmetros Mínimos para Avaliação e Acompanhamento da Audição em Trabalhadores Expostos a Níveis de Pressão Sonora Elevados, da NR-7 – Programa de Controle Médico de Saúde Ocupacional – Portaria n°. 19; 09 de abril de 1998; Ministério do Trabalho – (DOU 22/04/98). Brasil, Brasília; 1998. Available from: http://portal.mte.gov.br/data/files/FF8080812BE914E6012BEEB7F30751E6/p_19980409_19.pdf
5. Thomsen KA. The origin of impedance audiometry. Acta Otolaryngol. 1999;119:163–5.
6. Thomsen KA. The Metz recruitment test and a comparison with the fowler method. Acta Otolaryngol. 1955;45:544–52.
7. Block MG, Wiley TL. Visão Geral e Princípios Básicos da Imitância Acústica. In: Katz J, editor. Tratado de audiologia clínica. 3rd ed. São Paulo: Manole; 1989. p. 512–9.
8. Guimarães AC, de Carvalho GM, Voltolini MM, Zappelini CE, Mezzalira R, Stoler G, et al. Study of the relationship between the degree of tinnitus annoyance and the presence of hyperacusis. Braz J Otorhinolaryngol. 2014;80:24–8.
9. Oishi N, Hacht JSC. Emerging treatments for noise-induced hearing loss. Expert Opin Emerg Drugs. 2011;16:235–45.
10. Costa EA [Dissertação, Mestrado] Estudo da Correlação entre a audiometria tonal e o reconhecimento de monossílabos mascarados pro fala competitiva nas perdas auditivas induzidas pelo ruído. São Paulo: Pontifícia Universidade Católica de São Paulo (PUCSP); 1992.
11. Mordini CA, Almeida K. Limiar do reflexo acústico e limiar de desconforto: estudo comparativo. Rev Cefac. 2000;2:32–9.
12. Northern JL, Gabbard SA. Reflexo acústico. In: Katz J, editor. Tratado de Audiologia Clínica. 3rd ed. São Paulo: Manole; 1989. p. 221–34.
13. Hughes RW, Jones DM. Indispensable benefits and unavoidable costs of unattended sound for cognitive functioning. Noise Health. 2003;6:63–76.
14. Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, et al. Auditory and non-auditory effects of noise on health. Lancet. 2014;383:1325–32.
15. Mied HME, Oudshoorn CGM. Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Environ Health Perspect. 2001;109:409–16.
16. Muze TA. Environmental noise, sleep and health. Sleep Med Rev. 2007;11:135–42.
17. van Kempen E, Babisch W. The quantitative relationship between road traffic noise and hypertension: a meta-analysis. J Hypertens. 2012;30:1075–86.

18. Sorensen M, Andersen ZJ, Nordsborg RB, Jensen SS, Lilelund KG, Belen R, et al. Road traffic noise and incident myocardial infarction: a prospective cohort study. PLoS ONE. 2012;7:e39283.
19. Stansfeld SA, Matheson MP. Noise pollution: non-auditory effects on health. Br Med Bull. 2003;68:243–57.
20. Fechter L, Chen G, Rao D. Chemical asphyxiants and noise. Noise Health. 2002;14:49–61.
21. Sliwinska-Kowalska M. Contribution of genetic factors to noise-induced hearing loss. In: Griefahn B, editor. 10th international congress on noise as a public health problem of the international commission on biological effects of noise. 2011. Available from: http://www.icben.org/proceedings.html
22. Chen W, Jongkamonwiwat N, Abbas L, Eshtan AJ, Johnson SL, Kuhn S, et al. Restoration of auditory evoked responses by human ES-cell-derived otic progenitors. Nature. 2012;490:278–82.
23. Campo P, Maguin K, Gabriel S, Moller A, Gomez MDS, Topilla E, et al. Combined exposure to noise and ototoxic substances: European Agency for Safety and Health at Work (EU-OSHA); 2009. Available from: https://osha.europa.eu/en/publications/literature_reviews/combined-exposure-to-noise-and-ototoxic-substances
24. Johnson A-C, Morata TC. The Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals: occupational exposure to chemicals and hearing impairment, Gothenburg, Sweden; 2010. Available from: https://gupea.ub.gu.se/bitstream/2077/23240/1/gupea_2077_23240_1.pdf