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Original Article

Progressive Asymmetry in Occupational Noise-Induced Hearing Loss: A Large Population-Based Cohort Study With a 15-Year Follow-Up

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BACKGROUND: To evaluate interaural differences between the right and left ears at frequencies from 0.25 to 8 kHz in 3 groups of workers from metallurgy companies.

METHODS: This study is a cross-sectional cohort study. Workers were divided into 3 groups: (1) workers without occupational noise exposure and normal audiometric testing; (2) workers with 10 years of occupational noise exposure; and (3) workers with 15 years of occupational noise exposure. The interaural difference from 0.25 to 8 kHz was measured in each group.

RESULTS: A total of 2103 workers were included. Of these, 483 workers had been exposed to noise in the workplace for 10 years and 216 workers for 15 years. Group 1, only at 4 and 6 kHz, the difference was statistically significant. Group 2, only at 3 , 4 , and 6 kHz, the difference was statistically significant. Group 3, the difference was statistically significant at the frequencies from 2 to 8 kHz.

CONCLUSION: Asymmetry between the right and left ears was observed in all groups, with higher air-conduction thresholds in the left ear. It is important for otolaryngologists be aware that NIHL can also cause or accentuate asymmetry between the right and left ears over time.

KEYWORDS: Auditory, hearing loss, hearing loss, hearing thresholds, noise, noise-induced hearing loss

INTRODUCTION

Sensorineural hearing loss is influenced by age, sex, comorbidities, noise exposure, and genetic predisposition.[1] Despite preventive interventions in the workplace, noise-induced hearing loss (NIHL) remains the second most common occupational disease.[2] NIHL is irreversible.[3] For each decibel (dB) of hearing loss, there is a statistically significant increase in the risk of work-related injuries leading to hospitalization.[4]

NIHL usually affects the ears symmetrically, unless the individual is exposed to unilateral noise sources, such as weapon firing and noise exposures experienced by truck drivers.[5] Asymmetric hearing loss is defined as loss of 10 dB or more for 3 consecutive frequencies or of 15 dB for any one of the frequency from 0.25 to 8 kHz.[6] The left ear has been shown to have a higher hearing threshold than the right ear even in individuals who have not been exposed to noise,[7] especially at high frequencies.[8]

Individuals with asymmetric hearing loss may have a reduction in their ability to localize sound and difficulty in understanding speech in the presence of competitive noise, which may lead to work termination in some groups of workers, such as firefighters

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and security workers.[9] Although asymmetric hearing loss may be associated with NIHL, it is important to rule out other diseases, such as retrocochlear lesions and inner or middle ear disease.

The aim of this study is to evaluate interaural differences between the right and left ears at frequencies from 0.25 to 8 kHz in 3 groups of workers from metallurgy companies with different durations of noise exposure.

METHODS

This study was approved by the Institutional Review Board (protocol no. 09053119.6.0000.5404).

Data from audiometric tests performed between January 1995 and July 2018 were obtained from 8 different metallurgy companies in Brazil. All companies had the same sound exposure level and had implemented hearing conservation programs according to the National Noise and Hearing Conservation Committee guidelines.

The audiometers used in this study are calibrated annually. All workers had a normal physical examination. Pure-tone audiometry was performed by 11 different experts audiologists. They performed air-conduction (AC) thresholds at frequencies of 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz and bone-conduction (BC) thresholds at frequencies of 0.5, 1, 2, 3, and 4 kHz if the AC thresholds were altered.

Eligible participants were all male metallurgy workers aged <50 years on the date of occupational audiometric testing. Exclusion criteria were women, incomplete audiometric data, conductive hearing loss, flat sensorineural hearing loss, hypertension, diabetes mellitus, autoimmune diseases, central nervous system diseases, infectious diseases, immunodeficiencies, smoking, tumors of the middle ear or inner ear, and cerebellopontine angle tumors. Workers with hearing thresholds > 25 dB HL at any frequency at the time of baseline testing were also excluded.

Workers were included if they had no previous history of noise exposure and normal baseline testing and then were divided into 3 groups: (1) workers without occupational noise exposure; (2) workers with 10 years of occupational noise exposure; and (3) workers with 15 years of occupational noise exposure. Occupational audiometric testing was considered normal if the worker had AC thresholds ≤ 25 dB HL at all frequencies analyzed. Occupational noise exposure was defined as exposure to ≥ 85 dB sound pressure level for at least 8 h/day.

Workers were classified as having NIHL if they had a 3-, 4-, and 6-kHz arithmetic mean of AC thresholds > 25 dB, but thresholds within the normal range at other frequencies. In workers with 15-year exposure, NIHL was also considered to be present if there was an increase in the mean AC thresholds at 3, 4, and 6 kHz above 25 dB along with an increase in thresholds at other frequencies, provided the thresholds at other frequencies were lower than the mean of the 3, 4, and 6 kHz frequencies.

The interaural difference at each frequency from 0.25 to 8 kHz was measured in each group. Because the different frequencies were evaluated separately, asymmetry was considered to be present only if there was a difference of 15 dB or more at each frequency evaluated.

Statistical analysis was performed using the nonparametric Wilcoxon test. Data were analyzed using R software (version 3.6.3.), GNU General Public License (http://www.R-project.org), Auckland, Australia. Results were considered statistically significant at $P < .05$.

RESULTS

A total of 2103 workers were included, all of them were with normal hearing thresholds at the time of baseline testing and had no previous history of occupational noise exposure. Of these, 483 workers had been exposed to noise in the workplace for 10 years and 216 workers for 15 years.

Mean age was 26.1 (range, 18-31) years for non-noise-exposed workers, 32.3 (range, 28-37) years for workers with 10-year noise exposure, and 43.8 (range, 39-46) years for workers with 15-year noise exposure. A significant difference in the mean age among the groups was observed. There was a statistically significant difference between the non-noise exposed group and 10-year exposition ($P = .032$); between the non-noise exposed and 15-year exposition ($P = .001$); and between the 10-year and 15-year exposition ($P = .018$).

Table 1 shows the mean (SD) AC thresholds at each frequency from 0.25 to 8 kHz for each ear in workers without occupational noise exposure.

As shown in Table 1, mean AC thresholds were higher in the left ear than in the right ear at all frequencies, with the difference between the mean thresholds ranging from 0.2 to 2.5 dB. Only at 4 and 6 kHz, the difference was statistically significant.

Figure 1 shows the AC threshold difference between the right and left ears at each frequency, considering the mean levels. The 4 kHz and 6 kHz frequencies are highlighted, as they showed a statistically significant difference.

When evaluating the baseline tests, 32 (1.52%) workers had an interaural difference of 15 dB or more at a specific frequency, with the

Table 1. Mean (SD) Air-Conduction Thresholds at Each Frequency in the Right and Left Ears in Workers Without Occupational Noise Exposure

	0.25 kHz	0.50 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
RE	9.7 (5.55)	9 (6.80)	8.1 (6.44)	7.6 (6.25)	9.7 (7.29)	12.7 (7.43)	14.2 (7.31)	12.3 (6.78)
LE	10.3 (6.23)	9.5 (6.95)	8.3 (6.13)	8.4 (7.78)	11 (9.12)	14.2 (8.73)	15.7 (8.77)	13.7 (5.86)
LE−RE	0.6	0.2	0.2	0.8	1.3	2.5	1.5	1.4
P	.089	.102	.158	.079	.059	.028	.046	.053

RE, right ear; LE, left ear; LE−RE, interaural difference between mean air-conduction thresholds in the right and left ears.

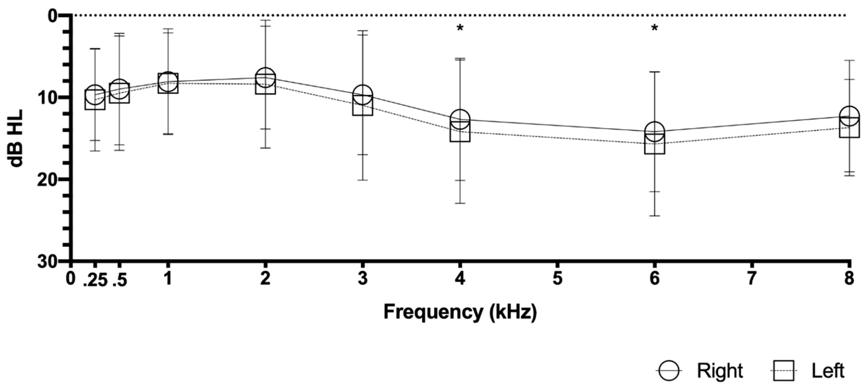

Figure 1. Air-conduction threshold difference between the right and left ears at each frequency, considering the mean levels. The 4 kHz and 6 kHz frequencies are highlighted, as they showed a statistically significant difference.

left ear often showing a higher threshold than the right ear, with a mean difference of 17.22 (range, 15-20) dB between the ears. Only 5 workers had a higher threshold in the right ear. The mean age of these workers was 29.2 years. The largest number of workers with interaural asymmetry was observed at 4 kHz (4 workers). The same asymmetry was observed at 3 kHz (2 workers) and at 6 kHz (3 workers).

Table 2 shows the mean (SD) AC thresholds at each frequency from 0.25 to 8 kHz for each ear in workers with 10-year occupational noise exposure.

As shown in Table 2, mean AC thresholds were higher in the left ear than in the right ear at all frequencies, with the difference between the mean thresholds ranging from 0.3 to 4.2 dB. Only at 3, 4, and 6 kHz, the difference was statistically significant.

Figure 2 shows the AC threshold difference between the right and left ears at each frequency, considering the mean levels. The 3, 4, and 6 kHz frequencies are highlighted, as they showed a statistically significant difference.

After 10 years of noise exposure, the mean AC threshold at 3, 4, and 6 kHz was 24.2 dB for the right ear and 30.5 dB for the left ear. Of 483 workers with 10-year exposure, 196 (40.57%) had mean thresholds >25 dB HL at 3, 4, and 6 kHz and within the normal range at other frequencies. Also, 39 (8.07%) had an interaural difference of 15 dB or more at a specific frequency (mean, 19.08 dB; range, 15-20 dB); of these, 33 had AC thresholds compatible with NIHL. The mean age of these workers was 35.4 years. The largest number of workers with interaural asymmetry was observed at 4 kHz (18 workers). The same asymmetry was observed at 2 kHz (4 workers), at 3 kHz (8 workers), at 6 kHz (6 workers), and at 8 kHz (3 workers). The left ear was most commonly affected (31 workers).

Table 3 shows the mean (SD) AC thresholds at each frequency from 0.25 to 8 kHz for each ear in workers with 15-year occupational noise exposure.

As shown in Table 3, mean AC thresholds remained higher in the left ear than in the right ear at all frequencies, with the difference between the mean thresholds ranging from 1.2 to 6.9 dB. The difference was statistically significant at the frequencies from 2 to 8 kHz.

Figure 3 shows the AC threshold difference between the right and left ears at each frequency, considering the mean levels. The 2 and 8 kHz frequencies are highlighted, as they showed a statistically significant difference.

After 15 years of noise exposure, the mean AC threshold at 3, 4, and 6 kHz was 32.43 dB for the right ear and 38.06 dB for the left ear. Of 216 workers with 15-year exposure, 168 (77.77%) had mean thresholds > 25 dB HL at 3, 4, and 6 kHz and within the normal range at other frequencies or with increased thresholds at 2 kHz and/or 8 kHz. Also, 76 (35.18%) had an interaural difference of 15 dB or more at a specific frequency, with a mean difference of 23.07 dB. The mean age of these workers was 44.2 years. The largest number of workers with interaural asymmetry was observed at 4 kHz (22 workers). The same asymmetry was observed at 1 kHz (7 workers), at 2 kHz (11 workers), at 3 kHz (15 workers), at 6 kHz (12 workers), and at 8 kHz (9 workers). An interaural difference of 15 dB or more was not observed only at 0.25 and 0.50 kHz. Sixty-two workers had left-ear asymmetry, and 14 had right-ear asymmetry.

DISCUSSION

Asymmetry in NIHL has some exogenous, endogenous, and anatomical explanations. The lateralization of sound sources and the head-shadow effect may explain some causes of asymmetry, such as in drivers who travel with the car window open and rifle

Table 2. Mean (SD) air-conduction thresholds at each frequency in the right and left ears in workers with 10-year occupational noise exposure.

	0.25 kHz	0.50 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
RE	11.4 (6.52)	12.0 (6.01)	12.6 (6.78)	15.2 (6.03)	20.3 (8.79)	26.9 (9.02)	24.8 (8.49)	22.3 (6.05)
LE	11.9 (7.01)	12.1 (6.88)	12.9 (6.91)	16.5 (6.16)	23.5 (9.06)	33.1 (10.1)	29.9 (10.56)	25.8 (5.73)
LE−RE	0.5	0.5	0.3	1.3	3.2	6.2	5.1	3.5
P	.058	.062	.199	.083	**.002**	**.004**	**.009**	.078

RE, right ear; LE, left ear; LE−RE, interaural difference between mean air-conduction thresholds in the right and left ears. Bold values are statistically significant.

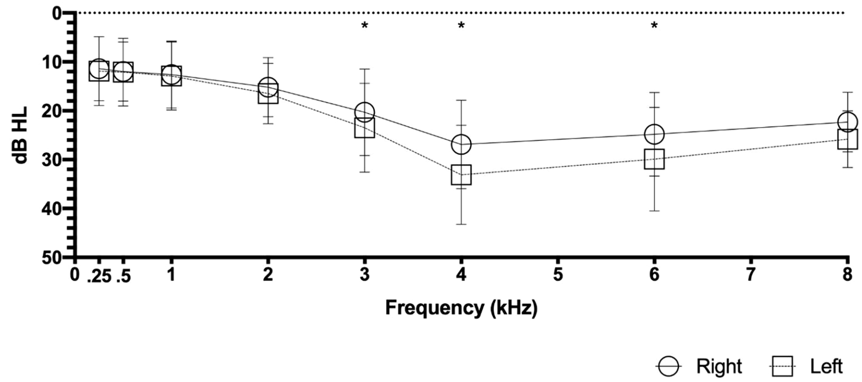

Figure 2. Air-conduction threshold difference between the right and left ears at each frequency, considering the mean levels. The 3, 4, and 6 kHz frequencies are highlighted, as they showed a statistically significant difference.

Table 3. Mean (SD) Air-Conduction Thresholds at Each Frequency in the Right and Left ears in Workers With 15-Year Occupational Noise Exposure

	0.25 kHz	0.50 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
RE	14.4 (6.45)	17.8 (6.15)	19.2 (6.41)	22.5 (7.43)	31.2 (9.26)	35.2 (10.49)	30.9 (10.32)	27.2 (8.29)
LE	15.6 (7.02)	19.6 (5.23)	21.5 (6.88)	25.3 (7.99)	35.5 (9.09)	42.1 (10.56)	36.6 (11.11)	32.1 (9.04)
LE−RE	1.2	1.8	2.3	2.8	4.3	6.9	5.7	4.9
P	.161	.095	.061	**.047**	**.0022**	.002	.006	**.012**

RE, right ear; LE, left ear; LE−RE, interaural difference between mean air-conduction thresholds in the right and left ears. Bold values are statistically significant.

shooters who place one of the ears closer to the trigger.[10] One possible explanation for the variation in noise susceptibility is a variation in the functional activity of the medial olivocochlear efferent system. It has been shown that the medial olivocochlear efferent system is stronger in the right ear than in the left in humans.[11] Neuropsychological studies have demonstrated that speech perception is lateralized in the central nervous system, with involvement of the left upper and middle temporal gyri. Temporary changes in hearing thresholds after binaural exposure are greater in the left ear than in the right ear.[12]

Men and women differ in the progression and increase of hearing thresholds over time. An increase in thresholds is observed after 20-30 years of age in men and after 50 years of age in women, especially in the high frequencies.[13] Men have more evidence of NIHL in the left ear than women.[11] In the metallurgy industry, women are mostly employed in the administrative and human resources departments, where there is no exposure to noise. These factors led us not to include women in this study.

Type and duration of noise exposure are essential for the diagnosis of NIHL.[14] Noise frequency range, impulse noise, and peak sound pressure levels are also important, in addition to individual susceptibility. Exposure to organic solvents, for example, can have a synergistic effect.[2,3,15] Each occupational activity has a specific risk for the development of NIHL.[14,16] For this reason, we investigated only metallurgy workers, rather than workers from other economic sectors, due to the particularities of each type of work and noise exposure. Some occupations, such as drivers and security workers, may expose one side more than the other, thus increasing the likelihood of asymmetry.

Masterson et al[1] published a literature review of asymmetry in noise-exposed workers. The definition of asymmetry used was a difference of >15 dB in at least 1 frequency. They detected the presence of several biases that were not considered for statistical evaluation, such as comorbidities, age, and sex. This study attempted to avoid these biases and showed that noise played an important role in worsening asymmetry in workers with 10 and 15 years of noise exposure.

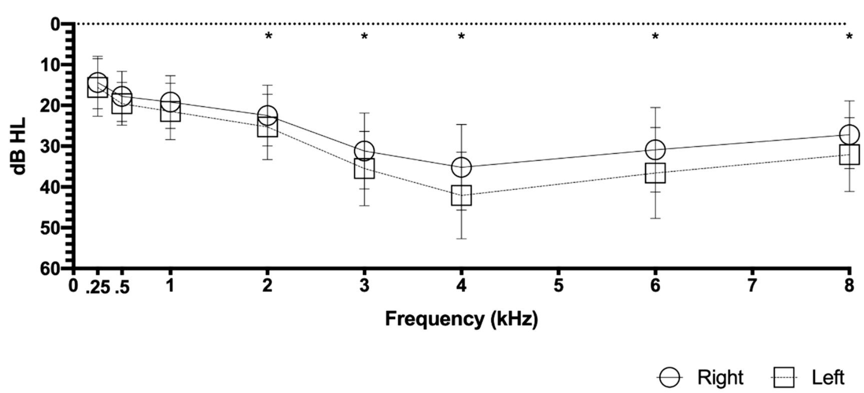

Figure 3. Air-conduction threshold difference between the right and left ears at each frequency, considering the mean levels. The 2 and 8 kHz frequencies are highlighted, as they showed a statistically significant difference.

There was a marked difference in the number of workers in each of the 3 groups evaluated. Factors that could contribute to a possible increase in hearing thresholds in workers in all groups were controlled, such as older age, female sex, chronic diseases, and smoking. Another important factor is that workers rarely stay for 10 or 15 years in the same company.

All companies under study are within the same economic sector and have similar noise exposure levels. It was not statistically significant, accounting for 8 hours of work per day and 85 dB HL exposure. Ear discomfort, occlusion effects, and aesthetic issues are known to hinder the use of hearing protection devices (HPDs) by workers throughout the workday.[14,15,17,18] The companies had their own policy to control sound exposure level, all of them in accordance with the government regulations. These factors are difficult to control in a study with a large number of workers.

Occupational audiometric tests followed the rules stated in current legislation. At least 14 hours of hearing rest were required prior to the test to prevent occasional exposures to noise from causing a temporary increase in hearing thresholds. However, given the widespread use of cell phones and headphones, it is not possible to assure that all workers included in the study followed the instructions concerning hearing rest.

Over time, exposure to noise increased the number of workers with hearing loss and asymmetry. The frequencies of 3, 4, and 6 kHz are most commonly affected by noise,[19-21] which was confirmed in the present study. This range of frequencies was more affected over time than the range of low frequencies. One of the theories attempting to explain the higher susceptibility of high frequencies to noise is that the protective effect of the stapedial reflex is more efficient in the range of low frequencies than high frequencies.[18] The increase in hearing thresholds over time also shows that measures adopted by the companies to control workers' exposure to noise may have not been entirely appropriate. After 15 years of noise exposure, the vast majority of workers had mean AC thresholds at 3, 4, and 6 kHz above 25 dB HL.

In the general population, the incidence of interaural threshold difference of 15 dB HL or more is only 1%.[22] In this study, 1.52% of workers with normal baseline testing showed a difference of 15 dB or more at 4 and 6 kHz, more pronounced at 4 kHz, which is the frequency most commonly affected by noise.[6,17,23] Although recreational noise exposure is common and perceived as not harmful by the population, the use of headphones to listen to music by children and adolescents has caused tinnitus and hearing loss at high frequencies in these age groups.[24]

Studies conducted over the past 2 decades investigating industrial or continuous exposure to noise have found that the left ear is more affected by noise than the right ear.[6,15,20] The incidence of asymmetric hearing loss in individuals exposed to noise ranges from 4.7% to 36%.[2,15] Chung et al[25] showed that 82.6% of people with NIHL, with a well-defined pattern of hearing loss on audiograms, had higher hearing thresholds in the left ear at 2 kHz. Dobie et al[21] evaluated the pure-tone audiograms at frequencies from 0.5 to 6 kHz of 2044 workers aged > 40 years, divided into 2 groups of exposed and non-exposed to noise. They found a statistically significant difference between the left and right ears, particularly at 3, 4, and 6 kHz, but no significant differences in asymmetry between the exposed and non-exposed groups.

Our study showed that the frequency range most affected by asymmetry was also the most affected by noise (3, 4, and 6 kHz). In non-noise-exposed workers, a baseline significant interaural difference was already observed at 4 kHz and 6 kHz. In workers with 10-year noise exposure, only the frequency range of 3, 4, and 6 kHz showed a statistically significant difference. In workers with 15-year noise exposure, a marked asymmetry was observed at 3, 4, and 6 kHz, where 35.18% of workers had an interaural asymmetry of 15 dB HL or more. Most cases of asymmetry occurred at 4 kHz, with the statistically significant mean difference extending to the frequencies of 2 kHz and 8 kHz.

Asymmetry between the right and left ears in noise-exposed workers has been demonstrated in several studies, but with smaller sample sizes than that of the present study.[6,10,18] Nageris et al[20] and Fernandes et al[6] showed asymmetry between the ears and, although in some workers the right ear had higher hearing thresholds than the left ear, in most cases, the cause of asymmetry was the increased thresholds in the left ear. This study showed, in a large number of workers, that asymmetry more frequently affecting the left ear, especially at high frequencies, which was accentuated by noise exposure and hearing loss.

Asymmetry of hearing thresholds between the left and right ears is typically small (<5 dB).[26] This small difference could only be detected in our study by calculating the mean threshold levels per group. Asymmetry would probably go unnoticed if the workers were evaluated individually, being noticeable only in those with a threshold difference of 15 dB HL or more. There is a trend toward increasing asymmetry at high frequencies with increasing levels of hearing loss.[27] At all frequencies analyzed, in all 3 groups, the left-ear threshold was always higher than the right-ear threshold. When evaluating the mean thresholds of the frequencies, we observed a really small interaural difference, especially in individuals not exposed to noise, with a maximum difference of 2.5 dB between the right and left ears at 4 kHz. The interaural difference increased with increasing duration of noise exposure, being always greater at 4 kHz in this study. The largest difference between the mean thresholds was 6.2 dB at 10 years of noise exposure and 6.9 dB at 15 years of exposure. In both time points, the difference was statistically significant.

Asymmetry for a specific frequency is considered to occur only when the interaural difference is ≥15 dB HL. Most of our participants did not show such difference at a specific frequency. Asymmetry was observed only in 1.8% of non-noise-exposed workers, in 8.07% of workers exposed to noise for 10 years, and in 35.18% of those exposed to noise for 15 years. These data are supported by the worsening of AC thresholds over time, particularly at the frequencies most affected by noise — 3, 4, and 6 kHz. Pure tone asymmetry may increase with age.[28] The three groups included in the present study showed a significant difference in the mean age. In average, the difference between ages in the non-noise-exposed group and 15-year noise-exposed group was 17.7 years. Therefore, a part of the worsening of hearing thresholds may also be assigned to aging.

For medicolegal reasons, it is important for otolaryngologists be aware that NIHL can also cause or accentuate asymmetry between the right and left ears over time if there is no other evidence of otologic disease.[6] The left ear was more susceptible to NIHL and had higher AC thresholds than the right ear, regardless of other factors.

The workers' audiograms were obtained exactly at the time points reported in the study. Because they were occupational audiometric tests, complaints such as tinnitus or hyperacusis were not evaluated in workers with increased thresholds at high frequencies. Considering that these are common complaints of patients with hearing loss, it is possible that some of them had these symptoms.

This study evaluated workers who had a normal baseline occupational audiometric test, and many of those who continued to be exposed to noise had worsening hearing thresholds. It is possible that a still unknown genetic component is related to the worsening of workers' hearing thresholds.

CONCLUSION

Asymmetry between the right and left ears was observed in all groups, with higher AC thresholds in the left ear. In workers without occupational noise exposure, there was a significant interaural difference at 4 and 6 kHz. Noise accentuated asymmetry over time. In workers with 10-year noise exposure, the frequencies of 3, 4, and 6 kHz showed a significant difference. In workers with 15-year noise exposure, a significant difference was observed at 2, 3, 4, 6, and 8 kHz.

Ethics Committee Approval: The authors have no ethical conflicts to disclose.

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer Review: Externally peer-reviewed.

Author Contributions: Concept – V.A.R.S., M.M.K.; Design - V.A.R.S., A.C.G, M.M.K .; Supervision - A.M.C. J.L., A.N.C.; Resource - A.M.S.D, H.F.P; Materials - V..A.R.S.; Data Collection and/or Processing -A.M.C. J.L., M.M.K. .; Analysis and/or Interpretation - V.A.R.S., M.M.K..; Literature Search - J.L., H.F.P.; Writing - V.A.R.S., A.C.G.; Critical Reviews -A.M.C., A.N.C.

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Conflict of Interest: The authors have no conflict of interest to declare.

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REFERENCES

1. Masterson L, Howard J, Liu ZW, Phillips J. Asymmetrical hearing loss in cases of industrial noise exposure: a systematic review of the literature. *Otol Neurotol*. 2016;37(8):998-1005.
2. Lie A, Skogstad M, Johannessen HA, et al. Occupational noise exposure and hearing: a systematic review. *Int Arch Occup Environ Health*. 2016;89(3):351-372.
3. Silva VARD, Mitre EI, Crespo AN. Is noise-induced hearing loss still a public health problem after decades of legislation? *Braz J Otorhinolaryngol*. 2020;86(6):665-666.
4. Girard SA, Leroux T, Courteau M, Picard M, Turcotte F, Richer O. Occupational noise exposure and noise-induced hearing loss are associated with work-related injuries leading to admission to hospital. *Inj Prev*. 2015;21(e1):e88-e92.
5. ACOEM Task Force on Occupational Hearing Loss, Kirchner DB, Evenson E, et al. Occupational noise-induced hearing loss: ACOEM Task Force on Occupational Hearing Loss. *J Occup Environ Med*. 2012;54(1): 106-108.
6. Fernandes SV, Fernandes CM. Medicolegal significance of asymmetrical hearing loss in cases of industrial noise exposure. *J Laryngol Otol*. 2010;124(10):1051-1055.
7. Pirilä T, Jounio-Ervasti K, Sorri M. Hearing asymmetry among left-handed and right-handed persons in a random population. *Scand Audiol*. 1991;20(4):223-226. .
8. Axelsson A, Jerson T, Lindberg U, Lindgren F. Early noise-induced hearing loss in teenage boys. *Scand Audiol*. 1981;10(2):91-96.
9. Hong O, Samo D, Hulea R, Eakin B. Perception and attitudes of firefighters on noise exposure and hearing loss. *J Occup Environ Hyg*. 2008;5(3):210-215.
10. Wang J, Puel JL. Presbycusis: an update on cochlear mechanisms and therapies. *J Clin Med*. 2020;9(1).
11. McFadden D. A speculation about the parallel ear asymmetries and sex differences in hearing sensitivity and otoacoustic emissions. *Hear Res*. 1993;68(2):143-151.
12. Daniell WE, Swan SS, McDaniel MM, Camp JE, Cohen MA, Stebbins JG. Noise exposure and hearing loss prevention programmes after 20 years of regulations in the United States. *Occup Environ Med*. 2006;63(5):343-351.
13. McBride DI, Williams S. Audiometric notch as a sign of noise induced hearing loss. *Occup Environ Med*. 2001;58(1):46-51.
14. Coles RR, Lutman ME, Buffin JT. Guidelines on the diagnosis of noise-induced hearing loss for medicolegal purposes. *Clin Otolaryngol Allied Sci*. 2000;25(4):264-273.
15. Le TN, Straatman LV, Lea J, Westerberg B. Current insights in noise-induced hearing loss: a literature review of the underlying mechanism, pathophysiology, asymmetry, and management options. *J Otolaryngol Head Neck Surg*. 2017;46(1):41.
16. Duarte AS, Guimarães AC, de Carvalho GM, et al. Audiogram comparison of workers from five professional categories. *BioMed Res Int*. 2015;2015:201494.
17. Lutman ME, Coles RR. Asymmetric sensorineural hearing thresholds in the non-noise-exposed UK population: a retrospective analysis. *Clin Otolaryngol*. 2009;34(4):316-321.
18. Rabinowitz PM, Slade M, Dixon-Ernst C, Sircar K, Cullen M. Impact of OSHA final rule–recording hearing loss: an analysis of an industrial audiometric dataset. *J Occup Environ Med*. 2003;45(12):1274-1280.
19. Gilles A, Van Hal G, De Ridder D, Wouters K, Van de Heyning P. Epidemiology of noise-induced tinnitus and the attitudes and beliefs towards noise and hearing protection in adolescents. *PLoS One*. 2013;8(7):e70297.
20. Nageris BI, Raveh E, Zilberberg M, Attias J. Asymmetry in noise-induced hearing loss: relevance of acoustic reflex and left or right handedness. *Otol Neurotol*. 2007;28(4):434-437.
21. Dobie RA. Does occupational noise cause asymmetric hearing loss? *Ear Hear*. 2014;35(5):577-579.
22. Cox HJ, Ford GR. Hearing loss associated with weapons noise exposure: when to investigate an asymmetrical loss. *J Laryngol Otol*. 1995;109(4):291-295.
23. Sataloff J, Hawkshaw MJ, Sataloff RT. "Gun-shooting hearing loss": a pilot study. *Ear Nose Throat J*. 2010;89(1):E15-E19.
24. Job A, Grateau P, Picard J. Intrinsic differences in hearing performances between ears revealed by the asymmetrical shooting posture in the army. *Hear Res*. 1998;122(1-2):119-124.
25. Chung DY, Willson GN, Gannon RP. Lateral differences in susceptibility to noise damage. *Audiology*. 1983;22(2):199-205.
26. May JJ, Marvel M, Regan M, Marvel LH, Pratt DS. Noise-induced hearing loss in randomly selected New York dairy farmers. *Am J Ind Med*. 1990;18(3):333-337.
27. Thurston FE. The worker's ear: a history of noise-induced hearing loss. *Am J Ind Med*. 2013;56(3):367-377.
28. Sharma RK, Lalwani AK, Golub JS. Modeling hearing loss progression and asymmetry in the older old: a national population-based study. *Laryngoscope*. 2021;131(4):879-884.