Ciência & Saúde Coletiva
cienciaesaudecoletiva.com.br
ISSN 1413-8123. v.30, n.9
DOI: 10.1590/1413-81232025309.16982023

Association between noise exposure and diabetes in hearing loss: a retrospective cohort study with workers from the sugarcane industry in the State of São Paulo, Brazil

Associação entre exposição ao ruído e diabetes na perda auditiva em trabalhadores de indústrias de açúcar e álcool no estado de São Paulo, Brasil

Asociación entre la exposicion al ruído y la diabetes na la perda auditiva en trabajadores de la industrias de la caña de azúcar en el estado de São Paulo, Brasil

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Resumo *O objetivo é avaliar a associação entre a exposição ao ruído e o diabetes mellitus no desencadeamento precoce de perdas auditivas ocupacionais de diferentes ambientes laborais e de diferentes intensidades. Estudo de coorte retrospectivo em trabalhadores de usina sucroalcooleira na região de Dracena/SP, Brasil. Foram comparados exames audiológicos referencial e sequencial. A variável dependente de desfecho foi a presença de perda auditiva, e as variáveis independentes foram idade, nível de pressão sonora ambiental, tipo de local de trabalho e presença de diabetes mellitus. Foram avaliados 547 trabalhadores. A avaliação univariada mostrou chance de encontrar indivíduos com idade superior a 39 anos com desencadeamento de perda auditiva 4,25 vezes maior em comparação com indivíduos com idade entre 19 e 28 anos. A presença de diabetes aumenta a chance de perda auditiva em comparação a indivíduos sem a doença. No modelo multivariado, ao ajustar pelos preditores, houve redução na chance de ter diabetes, pois parte do efeito observado estaria ligado à idade. Existe associação entre diabetes mellitus e o desencadeamento de perda auditiva em trabalhadores expostos a ruído ocupacional menores que 85 dB, e a proteção auditiva parece ser efetiva para a preservação da perda auditiva.*
Palavras-chave *Diabetes Mellitus, Perda auditiva, Ruído ocupacional, Estudo de coorte, Audiograma*

Abstract *The aim is to evaluate the association between noise exposure and diabetes mellitus in the early onset of occupational hearing loss in individuals exposed to occupational noise from different work environments and different intensities. Retrospective cohort study with workers at a sugar-ethanol plant in the region of Dracena, SP, Brazil. The reference and sequential audiological exams were compared. The outcome dependent variable was the presence of hearing loss and the independent variables were age, environmental sound pressure level, type of workplace and presence of diabetes mellitus. 547 workers were evaluated. The univariate assessment showed a chance of finding individuals older than 39 years old with hearing loss triggering was 4.25 times greater compared to individuals aged between 19 and 28 years. The presence of diabetes increases the chance of hearing loss when compared to individuals without the disease. In the multivariate model, when adjusting for the predictors, there was a reduction in the chance of having diabetes, since part of the observed effect would be linked to the age. There is an association between diabetes mellitus and onset of hearing loss in individuals exposed to occupational noise below 85 dB.*
Key words *Diabetes melittus, Hearing loss, Occupational noise, Cohort study, Audiogram*

Resumen *El objetivo es evaluar la asociación entre la exposición al ruido y la diabetes mellitus en la aparición temprana de la pérdida auditiva ocupacional en diferentes entornos laborales y a diferentes intensidades. Este estudio de cohorte retrospectivo fue realizado con trabajadores en una planta de azúcar y etanol en la región de Dracena de São Paulo, Brasil. Se compararon exámenes audiológicos de referencia y secuenciales. La variable de resultado dependiente fue la presencia de pérdida auditiva, y las variables independientes fueron la edad, el nivel de presión sonora ambiental, el tipo de lugar de trabajo y la presencia de diabetes mellitus. Se evaluó a un total de 547 trabajadores. El análisis univariado mostró que los individuos mayores de 39 años tenían 4,25 veces más probabilidades de experimentar pérdida auditiva que los individuos entre 19 y 28 años. La presencia de diabetes aumenta la probabilidad de pérdida auditiva en comparación con los individuos sin la enfermedad. En el modelo multivariable, al ajustar por predictores, se observó una reducción en la probabilidad de desarrollar diabetes, ya que parte del efecto observado se relacionó con la edad. Existe una asociación entre la diabetes mellitus y la aparición de pérdida auditiva en personas expuestas a niveles de ruido ocupacional inferiores a 85 dB, y la protección auditiva parece ser eficaz para prevenir la pérdida auditiva.*
Palabras clave *Diabetes mellitus, Pérdida auditiva, Ruido ocupacional, Estudio de cohorte, Audiograma*

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Introduction

Occupational noise is the most common and preventable cause of disabling hearing loss in adults. Noise-induced hearing loss (NIHL) is the second most common occupational disease[1] and is related to mechanical, metabolic and cellular changes[1,2].

The etiopathogenesis is multifactorial, with a genetic component, exposure to noise, chemicals, among others[3].

The role of diabetes mellitus (DM) in hearing loss has been investigated since the 50's, being the subject of debates and controversies until today[4]. According to the Diabetes Federation (2019-2020), there are about 425 million adults with DM in the world, and the projection indicates that in 2045, there will be a 48% increase in this number in the adult population. The prevalence of the disease is related to a fast urbanization, with the consequent adoption of a sedentary lifestyle and a diet rich in carbohydrates, and to the aging of the population[5].

Among the complications of DM, peripheral polyneuropathy stands out, which is the result of changes in nerve cells triggered by glycemic decompensation. Hyperglycemia, if sustained over a long period, can induce cranial nerve damage, progressing from malnutrition to membrane necrosis and nerve cell demyelination. This degeneration can lead to a reduction in the conductivity of the electrical impulse, and consequently, in hearing sensitivity[6-10].

Once installed, most cases of hearing loss can be irreversible, especially if it has a sensorineural origin[11].

NIHL appears initially and predominantly at higher frequencies (3kHz, 4kHz and 6kHz). Although the frequency of audiometric tests established by Brazilian legislation be semiannual, few has been studied about the contributing factors for the development of hearing loss among workers occupationally exposed to noise[12]. The high prevalence of DM in the economically active population points to the relevance of investigating its influence on the development and worsening of NIHL.

The objective of this study was to evaluate the association between noise exposure and diabetes mellitus in the early onset of occupational hearing loss in individuals exposed to occupational noise from different work environments and different intensities.

Methods

Retrospective cohort study, conducted among active workers, of both genders, aged between 19 and 59 years old, exposed to occupational noise, employed in sugar-ethanol plant in the region known as Nova Alta Paulista, countryside of São Paulo, from 2010 to 2020. All workers with a record of admission audiometric examination and recent periodic examination were included.

This study was approved by the Instituto de Assistência ao Servidor Público Estadual de São Paulo – IAMSPE Research Ethics Committee, with assent procedure number 3,631,114. All workers exposed to noise above 70 dB (A) who underwent audiometry at the company's Occupational Health Clinic were invited to participate in the study by the main researcher. They were informed that occupational records data would be collected from their medical records, without the possibility of identifying the subjects, according to the research project described in the Free and Informed Consent Form. After acceptance, these workers signed the Form and received a copy.

Data collection

The data used followed a 12-month interval between the reference and sequential. For data collection, a structured and pre-coded form was used, containing personal background and medical history, medication use, occupational data, and work history with emphasis on exposure to noisy environments, non-occupational noise exposure, use of safety equipment, impression of one's own hearing, and significant audiological backgrounds.

The audiometric examination was performed to determine the hearing thresholds of workers exposed to high levels of sound pressure and to elucidate the diagnosis of hearing loss. However, this is an exam that directly depends on the patient's response. Several precautions were taken regarding the examination to guarantee its quality and trustworthiness. The audiometric examination was preceded by a prior meatoscopy carried out by the professional responsible for conducting the examination, to check for earwax plugs or any foreign body, and individuals were asked for a minimum acoustic rest of 14 hours prior to the examination, so that effects such as Temporary Threshold Shift (TTS) did not occur in order to obtain a more reliable result.

Air conduction frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz were tested and, when altered, bone conduction testing was included at 500, 1000, 2000, 3000, and 4000 Hz. Audiometric examinations were conducted in an acoustic environment where sound pressure levels did not exceed international recommendations (ANSI 3.1 (1991) or OSHA 81 Appendix D parameter). Audiograms were classified according to the audiometric tracing defined by Ordinance 19 (04/09/98), Annex I of Regulatory Norm 7 of the Ministry of Labor, and described as normal tracing for individuals with hearing thresholds up to 25 dBHL, suggestive tracing of Noise Induced Hearing Loss (SPAINPSE) for individuals with auditory alterations at frequencies of 3000 and/or 4000 and/or 6000 Hz, of the sensorineural type; or in cases where auditory alteration was verified at other frequencies, the thresholds of 3000, 4000, and 6000 Hz will necessarily be more depressed, and non-suggestive tracing of Noise Induced Hearing Loss (NSPAINPSE) for examinations with auditory alterations whose results do not fit into any of the previous definitions.

In the natural history of diabetes mellitus, pathophysiological changes are present before glycemic values are above reference values, but still below the diagnostic values for Diabetes Mellitus, called pre-diabetes. Insulin resistance is already present and, in the absence of measures to combat modifiable risk factors, it often evolves into clinically manifested disease. The diagnosis of diabetes can be made through laboratory tests as: fasting blood glucose, oral glucose tolerance test (OGTT) and glycated hemoglobin (HbA1c). Confirming the diagnosis of the disease requires repeating the altered tests. The results were considered in percentage (%) and the individual was considered normoglycemic, pre-diabetic or diabetic.

Occupational records were reviewed to obtain demographic, clinical, and noise exposure information.

The dependent or outcome variable was the presence of sensorineural hearing loss, defined by the decrease recorded in the last exam in relation to the admission exam. The independent or predictive variables were: age (grouped according to the expected physiological change in hearing), environmental sound pressure level (categorized into risk classes for hearing loss), type of workplace (agricultural or industrial) and the presence of DM (referred or diagnosed during periodic examinations).

Statistical analysis

The estimated sample size was 365 patients, considering two standard deviations for confidence level, 70% of the phenomenon percentage, 5% maximum error, and infinite population. The statistical analysis was performed in stages:

1. Comparison of the relative frequencies of NIHL for each of the studied variables categories. In the comparison, the probability function adopted for the hypothesis test was Pearson's chi-square.

2. In this stage, factors with greater significance were identified. Subsequently, univariate Cox proportional hazards regression was applied. The Cox proportional hazards model provides predictors of death with their probability of occurrence (risk) compared to the reference group, which presents the lowest risk for death. The adequacy of the model is verified by the likelihood ratio test (log likelihood).

3. Variables that were identified in the univariate analysis as significant ($p < 0.05$) or that have an influence on NIHL (age, occupational sound pressure level and work environment) were included in the multivariate logistic regression model. For this, the "stepwise forward" method was used, in which each variable was inserted until the best fit for the maximum likelihood value was obtained. The statistical program Stata 15.1 (StataCorp LLC) was used for the analyses.

Results

In the period from 2010 to 2020, 547 individuals were evaluated. The age ranged from 19 to 59 years old (mean 35 ± 8 years), with the majority of workers engaged in an agricultural environment (64.2%). The prevalence of diabetes among the workers in the sample was 5.9% (CI 4.15%-8.17%)

Analyzing Table 1, it is observed that statistically significant differences were found for the presence of DM ($p < 0.001$) and for the age group to which the worker belongs ($p < 0.001$).

The univariate evaluation of the NIHL predictors obtained from the logistic regression model, showed that the chance of finding individuals aged over 39 years old among workers with hearing loss was 4.25 times greater than the chance of finding workers aged between 19 and 28 years old with the same condition. Regarding

the presence of DM, the chance of having individuals with DM among workers with hearing loss was 4.63 times greater than the chance of finding individuals without the disease (Table 2).

In the multivariate model, when adjusting for the other predictor variables, there is a reduction in the Odss Ratio (OR) for the presence of DM, since part of the observed effect would be associated with the worker's age (Table 3).

Table 1. Sample characteristics of workers at a sugar-ethanol plant in the region of Dracena, from 2010 to 2020 (n = 547).

Variable	Noise-induced hearing loss (NIHL)		
	without NIHL	with NIHL	p[1]
Age			< 0.001
19 to 28 years old	132	8	
29 to 38 years old	227	14	
39 years old or more	132	34	
Occupational sound pressure level			0.055
80dBA to 82.9dBA	301	30	
83dBA to 84.9dBA	45	11	
85dBA to 88.9dBA	74	5	
89dBA or more	71	10	
Diabetes mellitus			< 0.001
no	469	46	
yes	22	10	
Work environment			0.783
Industrial	175	21	
Agricultural	316	35	

[1] p value estimated from the Pearson's chi-square test.

Source: Authors.

Discussion

The World Health Organization (WHO) estimates that 10% of the world population would be exposed to sound pressure levels that can potentially lead to NIHL, which makes occupational noise exposure a priority public health problem[8].

Hearing losses are caused by multiple factors and may be related to age, occupation, years of noise exposure, lack of use of individual hearing protection equipment, exposure to chemicals, infectious and degenerative diseases.

NIHL can even be confused with presbycusis, and studies are highly divergent, with references that can vary its onset between 45 and 65 years of age. The differential diagnosis between these two types of loss can be made with certainty by analyzing the audiogram, which shows a lesser hearing decline in NIHL.

The present study indicates an association between NIHL and DM among workers at a sugar and ethanol plant. Individuals exposed

Table 2. Noise-induced hearing loss (NIHL) predictors, obtained from the logistic regression model (univariate regression analysis), for workers at sugar-ethanol plant in Dracena region, from 2010 to 2020.

Variable	OR	95%CI	p
Age			
19 to 28 years old	1.00 (reference)		
29 to 38 years old	1.018	0.416 - 2.490	0.969
39 years old or more	4.250	1.896 - 9.526	< 0.001
Occupational sound pressure level			
80dBA to 82.9dBA	1.00 (reference)		
83dBA to 84.9dBA	2.452	1.149 - 5.237	0.020
85dBA to 88.9dBA	0.678	0.254 - 1.807	0.437
89dBA or more	1.413	0.660 - 3.025	0.373
Diabetes mellitus			
no	1.00 (reference)		
yes	4.634	2.069 - 10.381	< 0.001
Work environment			
Industrial	1.00 (reference)		
Agricultural	0.923	0.521 - 1.635	0.784

OR: *odds ratio*; CI: confidence interval.

Source: Authors.

in their workplaces are susceptible to the development of hearing loss, with its early onset and accelerated evolution due to the presence of this comorbidity that leads to a hearing structure degeneration. This loss can be avoided by actions for the control of noise exposure in the work environment, as well as health care for the prevention, early diagnosis and control of DM.

It would be advisable to review the legislation regulating labor laws regarding noise exposure and the mandatory use of ear protection for only individuals exposed to noises above 85 dB, and to include examinations for investigating diabetes diagnosis in pre-employment medical examinations.

The increased risk for individuals over 39 years old can be partly explained by the correlation between the development of DM and the individual's aging, since it is a chronic-degenerative disease. Furthermore, the difference found in the comparison with younger individuals may reflect an occupational past in environments with low noise control.

Another relevant finding in this study was the decreased risk for workers exposed to sound pressure levels above 85 dBA when compared to those exposed to lower levels. This result can be explained by the mandatory use of personal protective equipment by workers who are exposed to noise above 85 dBA[12]. The association found could be investigated through etiological studies, to analyze the safety of the threshold currently adopted in the prevention of NIHL.

The cross-sectional nature of this study does not make possible to study the occupational noise-DM interaction in the etiopathogenesis of hearing loss, since the reverse association could also be an interpretation for the model obtained. Workers exposed to sound pressure levels above 85dBA would be continuously subjected to a stressor that would induce the maintenance of higher glycemic levels. Consequently, the risk for the development of DM or decompensation of pre-existing disease would be higher for this population.

Table 3. Noise-induced hearing loss (NIHL) predictors, obtained from the logistic regression model (multivariate regression analysis), for workers at sugar-ethanol plant in Dracena region, from 2010 to 2020.

Variable	[1]$OR_{adjusted}$	95%CI	p
Age			
19 to 28 years old	1.00 (reference)		
29 to 38 years old	1.000	0.396 - 2.525	0.999
39 years old or more	4.133	1.742 - 9.807	0.001
Occupational sound pressure level			
80dBA to 82.9dBA	1.00 (reference)		
83dBA to 84.9dBA	2.276	1.007 - 5.146	0.048
85dBA to 88.9dBA	0.930	0.336 - 2.573	0.889
89dBA or more	1.758	0.783 - 3.949	0.171
Diabetes mellitus			
no	1.00 (reference)		
yes	4.400	1.786 - 10.842	0.001
Work environment			
Industrial	1.00 (reference)		
Agricultural	0.562	0.291 - 1.083	0.085

[1] Adjusted for age, work environment and occupational sound pressure level; OR: odds ratio; CI: confidence interval; the variables identified as significant ($p < 0.05$) in the univariate analysis, or those that have an influence on NIHL (age, occupational noise level and work environment), were included in the multivariate logistic regression model. For this, the "stepwise forward" method was used, in which each variable was inserted until the best fit for the maximum likelihood value was obtained. The statistical analysis was conducted using the Stata 15.1 software (StataCorp LLC).

Source: Authors.

Conclusion

In conclusion, the findings of this study suggest an association between DM and the onset of hearing loss in individuals exposed to occupational noise below 85 dB in a sugarcane mill. In individuals exposed to noise levels above 85 dB, auditory protection appears to be effective in preventing hearing loss.

Collaborations

All authors of this study participated in the conception, planning, analysis, interpretation, and writing of the work and agree to the submission.

Declaração de disponibilidade de dados

O conjunto de dados deste artigo está disponível no repositório SciELO Data, no Dataverse da Ciência & Saúde Coletiva, no link: https://doi.org/10.48331/SCIELODATA.2XY5ML.

References

1. Nemati S, Hassanzadeh R, Mehrdad M, Sajedi KS. Hearing status in patients with type 2 diabetes mellitus according to blood-sugar control: a comparative study. *Iran J Otorhinolaryngol* 2018; 30(99):209-218.
2. Bernardi APA, organizador. *Conhecimentos essenciais para atuar bem em empresas: Audiologia Ocupacional*. São José dos Campos: Editora Parma; 2003.
3. Lie A, Skogstad M, Johannessen HA, Tynes T, Mehlum IS, Nordby KC, Engdahl B, Tambs K. Occupational noise exposure ande hearing: a systematic review. *Int Arch Occupm Environ Health* 2016; 89(3):351-372.
4. Amaral MAS, Assencio FVA. Perda auditiva em pacientes diabéticos. *Rev Cefac* 2002; 4(7):71-76.
5. Sociedade Brasileira de Diabetes. *Diretrizes da Sociedade Brasileira de Diabetes 2019-2020*. São Paulo: Editora Clannad; 2019.
6. Jorge LG, Sandra PS, Joíza LC, Angela JR, Mirela JDA. Diabetes melito: diagnóstico, classificação e avaliação do controle glicêmico. *Arq Bras Endocrinol Metab* 2001; 46(1):16-26.
7. Meneses-Barriviera CL, Bazoni JA, Doi MY, Marchiori LLM. Probable association of hearing loss, hypertension and diabetes mellitus in the elderly. *Int Arch Otorhinolaryngol* 2018; 22(4):337-341.
8. Wang TC, Chang TY, Tyler R, Lin YJ, Liang WM, Shau YW, Lin WY, Chen YW, Lin CD, Tsai MH. Noise induced hearing loss and tinnitus – new research developments and remaining gaps in disease assessment, treatment, and prevention. *Brain Sci* 2020; 10(10):732.
9. Przewoźny T, Gójska-Grymajło A, Kwarciany M, Gąsecki D, Narkiewicz K. Hypertension and cochlear hearing loss. *Blood Press* 2015; 24(4):199-205.
10. Wattamwar K, Qian ZJ, Otter J, Leskowitz MJ, Caruana FF, Siedlecki B, Spitzer JB, Lalwani AK. Association of cardiovascular comorbidities with hearing loss in the older old. *JAMA Otolaryngol Head Neck Surg* 2018; 144(7):623-629.
11. Tikka C, Verbeek JH, Kateman E, Morata TC, Dreschler WA, Ferrite S. Interventions to prevent occupational noise-induced hearing loss. *Cochrane Database Syst Rev* 2017; 7(7):CD006396.
12. Oishi N, Schacht J. Emerging treatments for noise-induced hearing loss. *Expert Opin Emerg Drugs* 2011; 16(2):235-245.

Article submitted 08/11/2023
Approved 03/09/2024
Final version submitted 05/09/2024

Chief editors: Maria Cecília de Souza Minayo, Romeu Gomes, Antônio Augusto Moura da Silva, Vânia de Matos Fonseca