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Original Article

Audiological profile of agricultural drivers exposed to noise and hydrocarbons

Perfil audiológico de motoristas agrícolas expostos: ruído e hidrocarbonetos

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ABSTRACT

Purpose: To establish the audiological profile of agricultural drivers simultaneously exposed to noise and hydrocarbons. **Methods:** The study comprised analysis of the medical records of agricultural drivers with hearing complaints, from an agricultural company of Lençóis Paulista (SP), Brazil, within the Environmental Risk Prevention Program. The information analyzed included age, period of simultaneous exposure to noise and hydrocarbons and testing of reference pure tone audiometry. Survival models for grouped data (proportional risk and logistic) were adjusted to analyze the influence of age and period of exposure of hearing thresholds. **Results:** It was observed that the effects of age and period of simultaneous exposure to noise and hydrocarbons were significant for hearing loss in proportional risk and logistic models. **Conclusion:** It is fundamental to develop actions for the prevention of hearing loss in agricultural drivers exposed to the agents noise and hydrocarbons.

Keywords: Noise; Hearing; Occupational exposure; Chemical compounds; Hidrocarbons

RESUMO

Objetivo: Estabelecer o perfil audiológico de motoristas agrícolas expostos, simultaneamente, a ruído e hidrocarbonetos. **Métodos:** Foram analisados os prontuários de motoristas com queixas auditivas de uma empresa do ramo agrícola do município de Lençóis Paulista (SP), dentro do Programa de Prevenção de Riscos Ambientais (PPRA). As informações analisadas foram: idade, tempo de exposição combinada a ruído e hidrocarbonetos e exames de audiometria tonal liminar de referência. Para a análise da influência da idade e do tempo de exposição sobre os limiares auditivos, ajustaram-se modelos de sobrevivência para dados grupados (riscos proporcionais e logísticos). **Resultados:** Verificou-se que os efeitos da idade e do tempo de exposição combinada a ruído e hidrocarbonetos foram significativos na perda de audição, nos modelos de riscos proporcionais e logísticos. **Conclusão:** É fundamental o desenvolvimento de ações voltadas para a prevenção de perdas auditivas em motoristas agrícolas expostos aos agentes ruído e hidrocarbonetos.

Descritores: Ruído; Audição; Exposição ocupacional; Compostos químicos; Hidrocarbonetos

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INTRODUCTION

Hearing loss is an occupational disease and, even though it may be prevented, it is considered an important health problem in our society. Despite the higher prevalence in industrialized countries, in Brazil, the noise-induced hearing loss (NIHL) is among the main health problems of workers[(1)].

Workers affected by hearing loss are subjected to social isolation, impairing the communication with family and friends, reducing the ability to monitor the working environment (caution signs), increasing the risk of accidents in the workplace and reducing the quality of life, due to the inflexible tinnitus[(2)].

Therefore, the Ministry of Work[(3)] and the Guideline SSST/MTb n. 5, published in February 25th 1997[(4)], established minimum guidelines and parameters for the evaluation and follow-up of hearing in workers exposed to high sound pressure levels. The NIHL has been defined as a sensorineural change in hearing thresholds caused by exposure to occupational noise, presenting as main characteristics the irreversibility and gradual progression, according to the period of exposure.

It is known that, besides noise, some chemicals used in several industrial fields may also lead to hearing loss, and when there is co-exposure – chemical combined with noise – the hearing loss may be greater[(5,6)]. The synergic interaction between noise and solvents has been described in some studies[(7,8)], while others demonstrated that noise is dominant with regard to occupational hearing loss[(9,10)]. According to the National Institute for Occupational Safety and Health (NIOSH)[(11)], three groups are considered high priority for research: solvents, asphyxiating agents and metals, and more recently the organophosphate pesticides[(12)].

This study highlighted the effects of combined exposure of hydrocarbons and noise. Investigations on the effects of hydrocarbon on the auditory system, as well as the harmful effects of simultaneous exposure to more than one agent, such as noise, are still scarce.

The audiological findings of hearing loss due to occupational exposure to chemicals are not very different from NIHL concerning the audiometric configuration. In general, this loss is characterized as being cochlear, bilateral, symmetric, progressive and irreversible, with onset in high frequencies, being nearly identical to NIHL[(13)]. The toxic action of chemicals on the auditory system may be peripheral or central, ranging from lesions to external ciliated cells to lesions of the 8th cranial nerve, changes in the vestibular system and central nervous system[(14)].

Petroleum is a complex mixture containing several compounds, mostly represented by hydrocarbons. According to its origin, chemical compositions and physical properties, there is variation from an oil field to another. The compounds of interest that require greater environmental concern are benzene, toluene, ethylbenzene and xylene. These compounds, also known as BTEX, are defined as monoaromatic hydrocarbons, whose molecular structures are primarily characterized by the presence of a benzene ring. They are mainly used in solvents and fuels, being the most soluble constituents of gasoline. These compounds are toxic for both the environment and mankind, depressing the central nervous system and presenting chronic toxicity[(15)].

Studies demonstrated that the site of the lesion, mechanisms and extension of the disorder caused by these toxins may vary according to the risk factors, which include the type of contaminant, interactions with other ototoxic agents, concentration and period of exposure[(16)].

Findings of ototoxicity caused by exposure to chemicals demonstrated the need to broaden the discussion on assessment of the auditory risk and adoption of preventive measures for application in workers simultaneously exposed to certain agents.

International laws do not consider as mandatory the monitoring of hearing of workers exposed to chemical products, unless exposure occurs at noise levels above the allowed limits. In Brazilian work laws there is no recommendation for the regular accomplishment of audiometry in workers exposed to chemical products, except for those exposed to noise according to annexes I and II of NR-15[(17)]. The Decree 3048 of Social Security[(18)] acknowledges benzene and its toxic homologues (toluene and xylene) and aliphatic or aromatic hydrocarbons (their toxic halogenated derivatives) as etiological agents or risk factors for hearing loss of occupational origin. This decree indicates that exposures to these agents should be considered when assessing a hearing loss and the workplace conditions. However, the decree only acknowledges the causal relationship, and does not establish conditions for prevention.

Therefore, this study analyzed the audiological profile of agricultural drivers simultaneously exposed to noise and hydrocarbons.

METHODS

This study was approved by the Institutional Review Board of Bauru School of Dentistry, *Universidade de São Paulo* (protocol n. 488.758) and was conducted upon acceptance of the participating company.

Study design

This was an analytical cohort prospective study, characterized by a non-probabilistic sample, based on collection of data from the records of workers in an agricultural company from the interior of São Paulo State, based on the Environmental Risk Prevention Program (PPRA).

Inclusion criteria and sample selection

The inclusion criteria adopted for sample selection were the simultaneous exposure to noise and hydrocarbons, besides the presence of hearing complaints.

The records of 25 drivers meeting the inclusion criteria were selected in November and December 2013. The age of workers ranged from 21 to 54 years, with mean age of 37.8 years (±9.81). The period of combined exposure to noise and hydrocarbon was 6 to 20 years, with mean exposure of 8.5 years (±7.04).

Data collection

The study collected data from workers related to age, period of combined exposure to noise and hydrocarbons and the results of reference pure tone audiometry.

Data analysis

Due to the large number of drawn hearing thresholds in multiples of five, the survival for grouped data was the most adequate statistical model for this study[19]. The investigation also analyzed hearing thresholds at frequencies of 500, 1000, 2000 and 4000 Hz, to score the degree of hearing loss. The importance to analyze thresholds at frequencies of 6000 Hz in studies involving exposure to ototoxic agents is well known, since they are often affected in this type of hearing loss (noise and/or chemicals), and 8000 Hz, which may be influenced by age (presbycusis). However, aiming to address the internationally standardized criterion to score the degree of hearing loss[20], these frequencies were not considered in the statistical analysis. The present results may also raise reflections on the scoring of degree of hearing loss in cases of exposure to ototoxic agents. Considering the ratio of expressive draws equal to 0.80, the discrete model was adequate to determine the hearing threshold. Also, due to the low frequency in some intervals, the hearing thresholds were grouped in intervals of (0,15], (15,20], (20,25] and (25,45], for both ears. The adjusted models were the classical discrete models of proportional risk and Colosimo's logistic[19], which model the conditional likelihood of not detecting the stimulus in a given time period, if the individual detected it in previous intervals. The models further considered the covariables age and period of exposure and the interaction between them. The proportional risk model was adjusted using linearization of conditional probability, according to the covariables. Estimate of the logistic model was performed by logit transformation, which is a logarithm of the ratio of conditional probabilities. Both adjustments may be done only numerically and with the aid of softwares.

The Bayesian Information Criterion of Schwarz (BIC) was applied for selection between the two models (proportional risk and logistic). This criterion assumes a true model, which describes the relationship between hearing threshold and the independent variables (age and period of exposure), between the two models proposed. Therefore, the criterion is based on the statistics that maximizes the likelihood to identify this true model, more specifically, $BIC=-2L + 2\ k\ \ln(n)$, in which L is the natural logarithm of the maximum likelihood function, k is the number of parameters and n is the number of observations. The model with lower BIC value presents the best adjustment[21].

The degree of hearing loss was determined by the scoring proposed by the World Health Organization[20], which considers the mean frequencies of 500, 1000, 2000 and 4000 Hz (Chart 1).

Chart 1. Classification of the degree of hearing loss according to the WHO[23]

Degree of hearing loss	Mean ISO value
Normal	0 to 25 dBNA
Mild	26 to 40 dBNA
Moderate	41 to 60 dBNA
Severe	61 to 80 dBNA
Deep	≥ 81 dBNA

Data were processed and analyzed on the software Microsoft Office Professional Plus 2013 and the software R, version 2.12.2.

RESULTS

Characterization of the sample regarding the hearing thresholds for frequencies of 500 to 4000 Hz, for the right and left ears, respectively, is presented in Tables 1 and 2.

Table 1. Sample characterization according to the hearing thresholds for frequencies of 500 to 4000 Hz, on the right ear

Hearing threshold (dB)	500 Hz	1000 Hz	2000 Hz	4000 Hz
0 to 15	10	16	15	9
15 to 20	4	4	5	4
20 to 25	4	3	2	5
25 to 45	3	2	3	7
Total number of individuals	25	25	25	25

Table 2. Sample characterization according to the hearing thresholds for frequencies of 500 to 4000 Hz, on the left ear

Hearing threshold (dB)	500 Hz	1000 Hz	2000 Hz	4000 Hz
0 to 15	11	18	16	8
15 to 20	7	6	7	6
20 to 25	5	1	1	4
25 to 45	2	0	1	7
Total number of individuals	25	25	25	25

Table 3. Proportional risk and logistic models for the hearing thresholds on the right ear

CV	DF	Proportional risk		Logistic	
		LRT	p-value	LRT	p-value
0 to 15	1	7.59	0.536	0.72	0.810
15 to 20	1	1.64	0.328	12.20	0.119
20 to 25	1	17.07	0.062	41.78	0.016*
25 to 45	1	24.43	0.046*	54.09	0.011*
Age	1	0.12	0.576	0.33	0.576
Exposure	1	0.02	0.642	0.07	0.948
Age exposure	1	0.28	0.609	0.02	0.882

*Significant values (p<0.05) – Likelihood Ratio Test
Note: CV = causes of variation; DF = degrees of freedom; LRT = Likelihood Ratio Test

Analysis of the logistic and proportional risks models for the hearing thresholds on the right ear did not reveal significant interaction between period of combined exposure to noise and hydrocarbons and age (p=0.882) (Table 3), and on the left ear there was significant interaction between the period of combined exposure to noise and hydrocarbons and worker's age (p=0.043) (Table 4).

The estimates of coefficients of logistic and proportional risk models were performed for each ear. There was small variation in the standard errors of estimates, indicating that convergence was achieved and the adjustment of models was adequate for the analysis. Also, calculation of the BIC selection criterion (used in this case due to the large sample size) revealed little variation in the values achieved, thus both models could be applied to determine the hearing threshold (Table 5).

The estimated survival curves were close to the thresholds obtained for the right ear. Conversely, for the left ear, there was great difference in the hearing threshold for individuals with different periods of exposure.

Since the hearing threshold is defined as the lowest sound intensity in which the individual detects the presence of stimulus in 50% of presentations, high survival likelihood indicates worse performance in the audiometric tests, evidenced in this study for workers with longer periods of combined exposure to noise and hydrocarbons (Figure 1).

DISCUSSION

Several physical and chemical agents present in the workplace, combined with social and organizational stressors, pose health risks and compromise the wellbeing of exposed individuals. Intense noise, vibrations and chemical substances represent risk factors for hearing[22]. Even in companies where noise is the main risk factor for hearing loss, there may be other factors that, individually or mainly by interaction with high levels of sound pressure, may cause changes in the hearing thresholds[23].

This confirms the relevance and need to develop studies and investigations on conditions of workplaces that may pose risks to the health and wellbeing of agricultural employees.

This study revealed clear relationship between the period of combined exposure to noise and hydrocarbons, hearing loss and worker's age for the left ear. There was statistically

Table 4. Proportional risk and logistic models for the hearing thresholds on the left ear

CV	GL	Proportional risk		Logistic	
		LRT	p-value	LRT	p-value
0 to 15	1	9.33	0.046*	1.24	0.004*
15 to 20	1	0.41	<0.001*	8.83	<0.001*
20 to 25	1	26.98	<0.001*	56.80	<0.001*
25 to 45	1	36.84	<0.001*	72.44	<0.001*
Age	1	5.78	<0.001*	6.36	<0.001*
Exposure	1	0.58	0.085	3.44	0.135
Age exposure	1	4.76	0.028*	4.26	0.043*

*Significant values (p<0.05) – Likelihood Ratio Test
Note: CV = causes of variation; DF = degrees of freedom; LRT = Likelihood Ratio Test

Table 5. Estimates and standard error of the parameters of intervals and ages and period of exposure for each ear

Parameters	Right ear				Left ear			
	Proportional risk		Logistic		Proportional risk		Logistic	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE
0 to 15	-0.297	0.481	0.204	0.852	0.995	0.498	2.620	0.903
15 to 20	0.442	0.451	1.311	0.840	1.752	0.491	3.780	0.938
20 to 25	0.894	0.449	2.07	0.857	2.470	0.513	5.186	1.014
25 to 45	0.894	0.448	2.180	0.856	2.530	0.515	5.427	1.023
Age	-0.007	0.013	-0.013	0.023	-0.050	0.014	-0.094	0.026
Exposure	-0.002	0.004	-0.005	0.007	-0.007	0.004	-0.013	0.008
Age exposure	<0.001	<0.001	<0.001	0.0001	0.0002	0.0001	0.0004	0.0002

Note: Est = estimate; SE = standard error

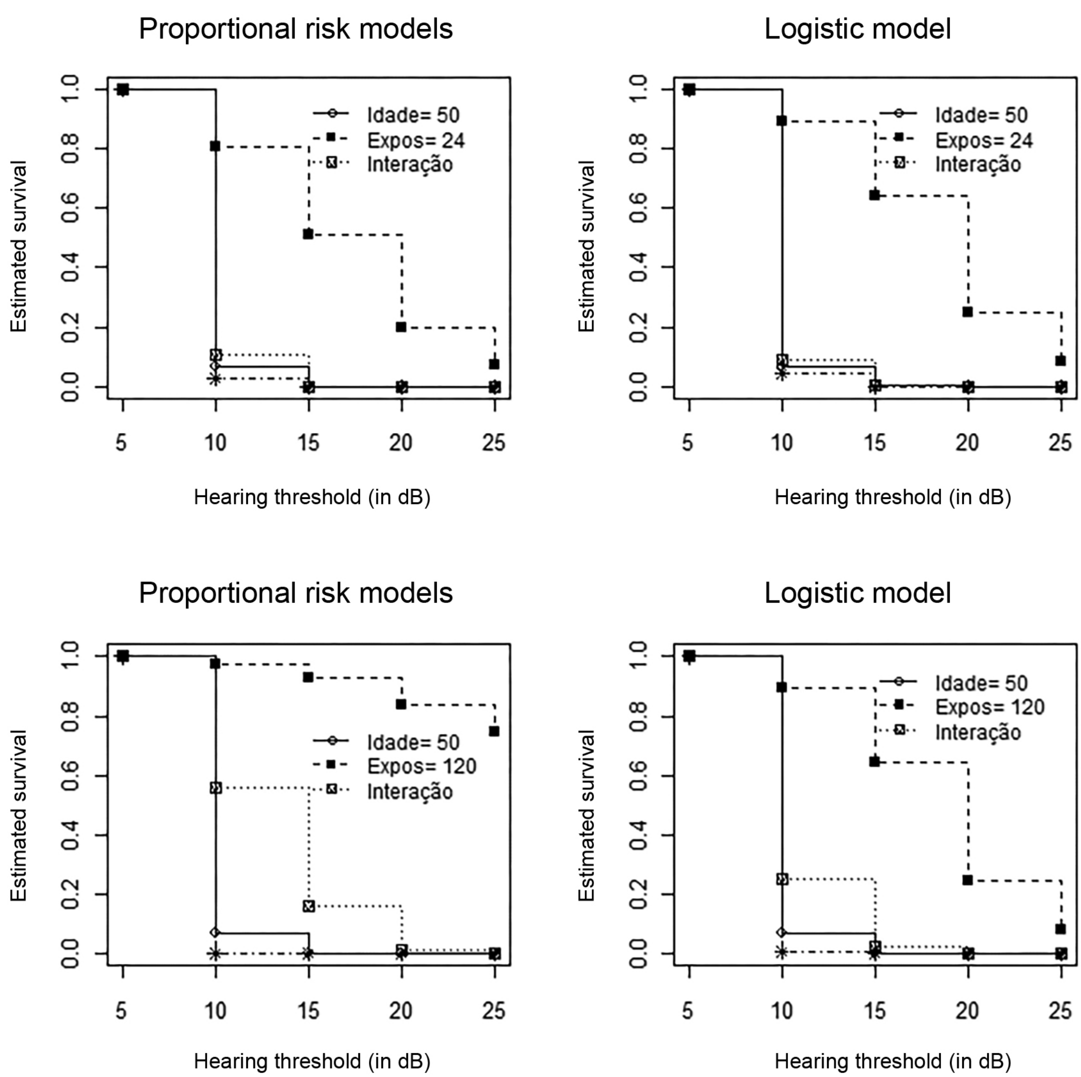

Figure 1. Proportional risk and logistic models and estimated survival curves for the hearing thresholds obtained on the left

significant association between the period of combined exposure to noise and hydrocarbons and the worker's age (Table 4), making the relationship between hearing threshold and age distinct and dependent on the period of exposure of the individual.

Few epidemiological studies in the literature demonstrate the triggering of hearing loss, in relation to the period of exposure to chemicals. A study conducted on agricultural workers exposed to chemicals at the state of Rio Grande do Sul revealed hearing loss in 60% of individuals exposed to pesticides and noise. Conversely, only 7% in the control group (not exposed to such agents) presented altered thresholds [24].

A study[25] observed significant difference only for age and period of exposure, demonstrating that sensorineural hearing losses in individuals simultaneously exposed to noise and solvents occurred earlier compared to the group exposed only to occupational noise, which confirms the present results.

Analysis of the hearing thresholds and the relationship between period or exposure, age and hearing loss revealed statistically significant association only for the left ear. An investigation conducted in a petrochemical industry[26] analyzed the audiological profile of 63 workers of both genders, aged 18 to 60 years, all of whom were exposed to noise and oil--derived hydrocarbons. The thresholds were lowered for both ears, especially in high frequencies after 4000 Hz, associating the evolution of loss with the increase in age. This study demonstrated the same characteristic of lowered thresholds related with the increase in age.

It was possible to observe the relationship between period of combined exposure to noise and hydrocarbons and the hearing loss. Some studies did not reveal association with worsening of hearing loss when there is combined exposure to noise and chemicals, while others strongly demonstrate the effect of this coexposure.

A study conducted on employees from a fiberglass industry in Sweden[27] demonstrated higher prevalence of hearing loss in high frequencies in the group simultaneously exposed to noise and styrene (48%), followed by the group exposed only to styrene (47%) and the group exposed to noise (42%). However, the difference between prevalences was not significant. Age, exposure to noise and biological marker of styrene exposure were the only variables considered as significant.

A research conducted on employees exposed to noise and chemicals[14] in a sugar/alcohol plant in the interior of São Paulo analyzed the audiological profile of these workers. The participants were divided in three groups: (1) exposure to noise; (2) exposure to chemicals; and (3) combined exposure (noise and chemicals). The audiological findings were scored and revealed that 40% of workers in group 2 presented loss grade 1 (lowered hearing in frequencies of 4 kHz and 6 kHz), with higher percentage of losses. In group 3, 10% of workers presented hearing loss grade 1 and 20% exhibited loss grade 2 (lowered hearing at frequencies of 3, 4 and 6 kHz). These results evidenced lower number of losses, yet with worsening concerning the grade, indicating the greatest noxiousness of combined agents. In the sector with exposure to noise, 20% of workers presented loss grade 1. Therefore, it was concluded that there is risk of hearing loss not only with exposure to noise, but also with exposure to chemicals, indicating worse outcomes for the combined exposure (noise and chemicals).

Other investigations agree with the aforementioned results. One example is a cross-sectional study conducted on 99 workers from a petrochemical industry, exposed to a mixture of organic solvents and noise[28]. The study evidenced that individuals with mean duration of work of 3.7 years, exposed to a mixture of aromatic solvents at higher than allowed levels, without exposure to noise, did not present an altered hearing threshold. Other studies[29] revealed that the association between exposure in short term (≤4 years) and a mixture of low concentration of chemicals (<10 ppm) did not increase the risk of hearing loss. However, the concentrations of intermediate chemicals increased the risk of hearing loss. A study[30] conducted on 190 Brazilian workers of a graphic industry revealed that the simultaneous exposure to noise and excessive toluene levels increases the likelihood of triggering hearing loss in 11 times. When compared to workers exposed only to noise, this likelihood reached four times, and the risk was five times higher for workers exposed only to toluene. Therefore, it was concluded that the mixture of solvents (toluene, xylene, methyl-ethyl-ketone) associated with noise increases the risk of hearing loss, with a relatively higher risk than observed for the group exposed only to noise.

This close relationship has been previously discussed in a study[7] that analyzed the interaction between solvents, occupational noise and disorders of the auditory system by a thorough literature review. It was demonstrated that the incidence of sensorineural hearing loss was greater than expected in workers exposed to both noise and solvents.

The solvents are known for their neurotoxic effects, both for the central and peripheral nervous system, being able to cause lesions at the cochlear level, i.e. harming the external ciliated cells, or the auditory nerve and auditory pathways[8]. Most scenarios of exposure to chemicals present this combined exposure to noise. The hearing losses observed in these situations are often assigned to exposure to noise, yet isolated analysis of the audiogram does not allow determination of their etiology. The audiometric configuration in cases of hearing loss induced by noise and ototoxicity may be identical. Therefore, complementary audiological examinations are necessary for a diagnostic conclusion.

This study analyzed the audiological profile of agricultural drivers simultaneously exposed to noise and hydrocarbons. Even though the results demonstrated important associations between hearing loss, period of combined exposure to noise and hydrocarbons and worker's age, the possible extrapolation of these findings to other situations should be analyzed, considering the sample size and study design.

CONCLUSION

The combined exposure to noise and hydrocarbons, considering the variables period of exposure and worker's age, may be a factor worsening the occupational hearing losses. Thus, strategies targeted to the prevention and promotion of hearing health should establish a more critical standpoint, looking beyond the environmental factors, such as noise.

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