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Methods: Application of questionnaires to 278 workers potentially exposed to occupational noise in an industry in Brazil. After, we used multivariate analysis by Pearson correlation and multiple linear regressions applied on subconstructs identified.

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MULTIVARIATEANALYSISOFRISKFACTORSAPPLIEDTOTHESTUDYOFINDUCEDHEARINGLOSSDUETOOCCUPATIONALNOISEINTHEINDUSTRY

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Helder Cesar Tinoco DSc[α], Alan Tavares Miranda Esp[σ], André Luiz do Carmo Leal MSc[ρ] & Luiz Antônio de Oliveira Chaves MSc[ω]

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Methods: Application of questionnaires to 278 workers potentially exposed to occupational noise in an industry in Brazil. After, we used multivariate analysis by Pearson correlation and multiple linear regressions applied on subconstructs identified.

Results: The dominance of cases suggestive of NIHL and significant associations ($p<0.05$) were identified and suggests risk perception and age variables as a potential factor.

Conclusions: The results contribute to a better understanding of the possible risk factors related to the development of NIHL in the industrial segment.

Keywords: perception; noise; exposure; nihl; risk; hearing loss.

I. Introduction

Approximately 30 million workers are exposed daily to high levels of sound pressure in the United States only, with the potential for real damage to health.[1] Loss hearing induced by high levels of sound pressure is the second cause of occupational disease.[2]

In 2006, only in Norway, of 3392 cases of occupational diseases reported to the government, about 59% were related to noise-induced hearing loss.[3] Checking occupational diseases most incident in Mongolia was observed the predominance of noise-induced hearing loss, a phenomenon associated with the rapid industrialization that occurred in that country.[4]

The magnitude of hearing loss would be a direct result of excessive exposure to noise, thus being dependent on several factors, among them those associated with exposure and related to the characteristics of the individual: sound pressure level (SPL), duration of exposure, type and frequency of the noise, susceptibility to damage by noise, age, history of hearing loss.[5]

Models relating labor hearing loss to the behavioral of workers, named Health Promotion Model, analyze modifying factors (behavioral characteristics) and cognitive-perceptual factors (such as perceived benefits and self-efficacy).[6] The authors indicate that this and other developed models, allow them to infer that workers must be aware of the risk of noise-induced hearing loss (NIHL), and that they can do something to prevent of this disease.

In a survey that took as sample a group of researchers in this area of occupational health and safety, noted that the notion of risk perception is socially constructed variable, being influenced by the nature of labor relations; valuesin society and individual events.[7]

Although there are some publications on occupational noise exposure, the analysis of the individual perception of the worker and its implications on his behavior remains a poorly discussed subject. Moreover, the approaches verified relating the understanding of the behavioral phenomenon to the exposure to occupational noise, need more analysis and the support of quantitative approaches of main humans factors relacteds to NIHL. This paper aims to use the technique of factor analysis as a tool for examining the variable noise-induced hearing loss, to propose actions that may contribute to the prevention and anticipation of mitigating the risk of the exposed worker.

This research started the discussion of two specific contextual proposals: (1) identification of approaches to understanding the exposure to occupational noise; (2) application of statistical to analysis of risk factors such as: perception of effects, age, safety culture, risk index and sex.

II. Methods

Across-sectional study was carried out in an industry in Brazil looking for analyze the prevalence of cases suggestive of noise-induced hearing loss (NIHL) among 278 industrial workers potentially exposed to work noise (more than 80 dB (A)) between 11/2013 and 06/2014. The research procedures verified two perspectives: Theoretical and Applied.

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a) Theoretical Research

For development of the theoretical research, there was conducted a literature search of indexed journals, seeking to identify main studies conducted in the identification of variables related to the development of noise-induced hearing loss.

The research showed that the variables related to the development of NIHL would be influenced by a lot of factors related to the individual, as well as by the social and cultural organizational system, as shown in Table 1.

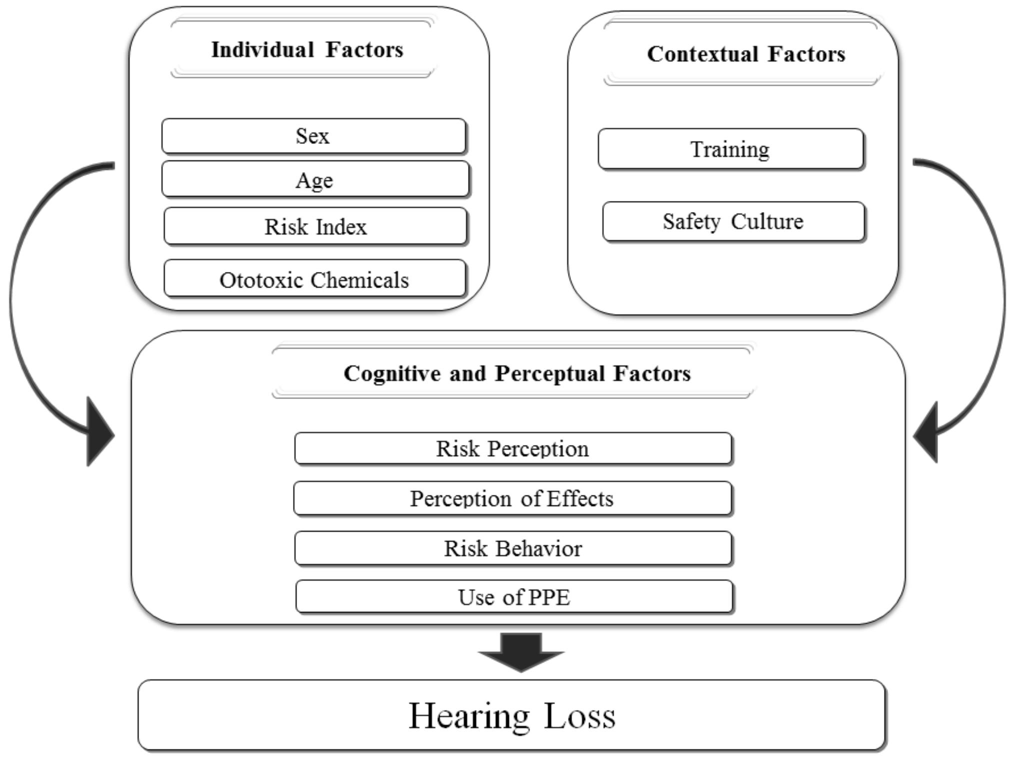
Table 1: Theoretical framework in research–NIHL

	Variables related to hearing loss due to noise exposure - NIHL																										
References	Sex	Age	Race/Ethnicity	RH ffactor	Exercise and nutrition	Fasting glucose / diabetes	Confort of PPE	Daily period in area	Risk of exposure to noise	Leq	Exposure period (years)	Training	Level of education	Safety culture	Risk perception	Perception of effects	Expect. and exploit. of results	Risk behavior	Use of PPE	Hearing loss	Training for use PPE	Discipline / Habit	Ototoxic chemicals	Alcohol use	Auditory symptoms	Extra-auditory symptoms	Occupational group
8		X						X	X	X	X					X		X		X						X	
9		X						X			X									X					X		
10		X						X	X	X		X		X	X	X		X		X							
11		X						X	X	X	X							X									X
12																				X			X				
13		X						X	X	X	X					X				X							
14		X						X	X	X	X					X	X			X			X				
15	X	X	X		X			X	X	X	X	X		X	X			X					X		X		
16		X						X	X	X					X	X		X	X	X					X		X
17	X	X						X	X	X	X	X	X	X		X		X	X	X	X				X		
18		X					X				X					X				X			X				
19	X	X						X	X	X	X				X	X		X	X	X		X			X		
20		X						X	X	X	X									X							
21		X							X	X										X			X				
22				X				X	X	X	X																
23		X							X	X				X					X	X					X		
24		X						X	X	X	X									X			X				X
25		X						X	X	X	X	X		X						X					X		
26							X		X	X		X		X	X	X		X	X	X	X						
27	X	X						X			X									X					X		
28		X						X	X	X	X	X				X				X							
29		X			X	X		X	X	X	X									X			X	X			
30		X			X			X	X	X	X												X		X		
31		X						X	X	X	X							X					X				
32		X						X	X	X	X			X						X							
33		X						X	X	X	X	X															X
34	X	X				X		X	X	X	X													X	X		
35	X	X						X	X																		
36		X																					X				
37	X	X						X	X		X												X				
38	X	X				X		X	X	X	X								X	X			X		X	X	
Total	**8**	**28**	**1**	**1**	**3**	**3**	**2**	**25**	**26**	**24**	**23**	**7**	**1**	**7**	**5**	**10**	**1**	**9**	**6**	**21**	**2**	**1**	**12**	**2**	**11**	**2**	**4**

Source: The author.

According to Table 1, the following subconstructs that may influence strongly in the development of NIHL was found in the literature: risk behavior, safety culture, training, sex, age, risk index, risk perception, perception of effects, hearing loss, chemicals ototoxic drugs, use of PPE.

For this research, a sustained quantitative methodology for factor analysis technique was developed, and a statistical model was adjusted to support the conceptual model.The proposed conceptual model, as shown in Figure1, is structured on the adaptation of similar models of other authors who also researched on this topic. [10,39,40]



Source: The author.

Figure 1: Conceptual model proposed

b) Applied Research

In a second stage, for the research development, data collection was performed using questionnaires, in a sample of 278 workers exposed to noise beyond the action level - defined in Brazilian law as 80 dB (A).

The self-administered questionnaires comprise the most frequently indicated version.[41]During filling, someone was available to assist in understanding the instrument, ensuring that no questions were left blank.

In research on the influence of the perception of employees on the effects of occupational health hazards was also used as an instrument of data collection a questionnaire then generating similar analysis, with the objective of further reducing the dimensionality of the data. The analysis was useful for the planning of health promotion campaigns and prioritization of other interventions.[42]

The initial questionnaire aimed to characterize the individual risk perception, consisting of questions divided into the following sections: worker´s identification (name, workplace, age, sex, marital status and education), individual risk perception and perception of noise effects, expectation and appreciation of the results of use of PPE, barriers, safety culture and risk behavior.

The second questionnaire intended to characterize the noise exposure and the use of PPE, having questions grouped into the following sections: risk exposure, exposure to ototoxic chemicals, family history of hearing loss, training in occupational health and safety/hearing loss/use of PPE, comfort, and use of PPE and audiometry.

The evaluation instrument used the Likert five-level scale, from "strongly agree" to "strongly disagree." After filling in all the 278 questionnaires, responses were converted into numbers, according to the scale, and tabulated in a spreadsheet. The answers were coded on scales from 1 (strongly disagree) to 5 (strongly agree). In some cases, the use of inverted scale was necessary, for example, for questions about barriers, physical load, and risk behavior.

In a second stage, through the environmental noise assessment of each work micro-area of all evaluated employees, was possible the characterization of daily personal exposure level. The evaluated employees were still undergoing tonal audiometric examination by ISO 8253.1 standard.

In a third stage, the model was tested and validated through multivariate statistical analysis which took into account, in addition to the construct (the development of NIHL), dependent subconstructs: risk perception; perception of effects; risk behavior and use of PPE.

Because of this study include more than two dependents subconstructs, will be used the technique of multiple regression analysis (MRA), which, using dependent subconstructs whose values are known, allows predicting a single subconstruct independently selected.[43] Equation 1 presents the MRA adopted in this article, which aimed to:

1) maximize the overall power prediction of a group of independent subconstructs as representatives of a composition;
2) to compare two or more groups of independent subconstructs regarding the predictive power of each factor.

$$Y_1 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m + \in \qquad \text{Equation 1}$$

where
Y1: Dependent subconstruct or criterion;
Xi: Independent subconstructs or predictor;
β_i: Regression coefficients;
$\in$: Associated error;

The path analysis is an essential resource of multivariate statistics, allowing correlations between characters are split into direct and indirect effects, measuring the influence of a variable, independent of the other, on the other.

Path analysis was used to proof the conceptual model. Following the results of this analysis, the corresponding path diagram was established, as the summary presented in Figure 3. Statistical analysis was performed using IBM SPSS.

III. Results

Using the alpha (α) of Cronbach, it was possible to test the internal reliability, allowing a decrease up to 37,5% of the items. Thus, from the starting 74 questions, the technique applied in this questionnaire allowed to shorten it down to only 61 questions.

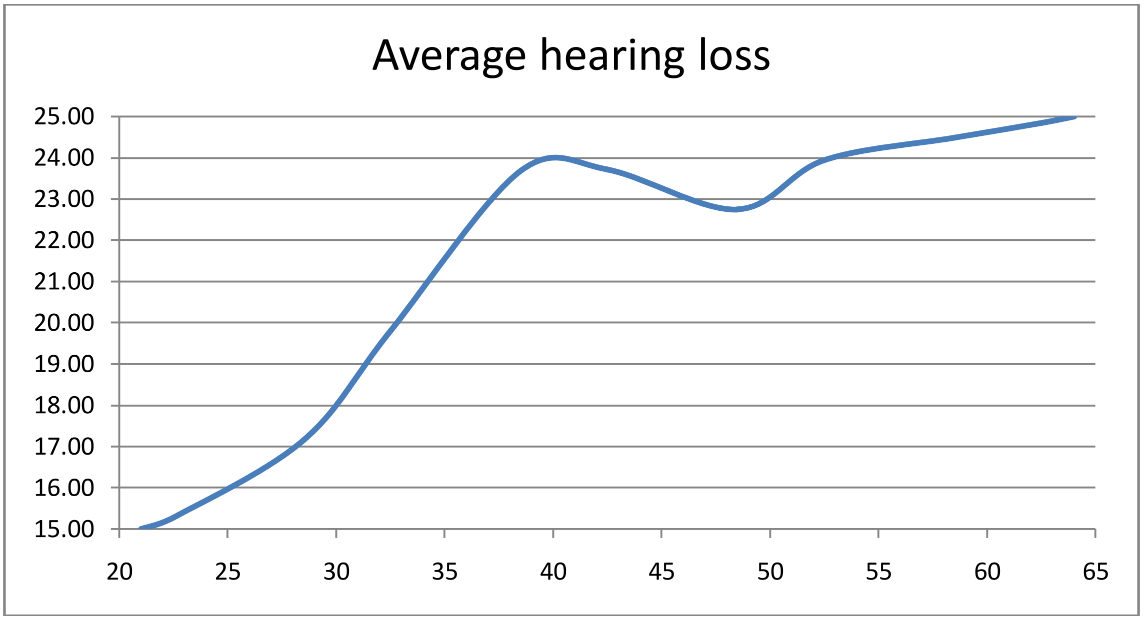
223 of the 278 employees evaluated in the sample were male and 55 were female, 147 had completed high school, 73 had incomplete graduation, and 44 had completed graduation. Table 2 shows the sample distribution between factories.

Table2: Sample distribution between factories

Factory	Total number of workers	Number of workers in the sample (N)	Number of workers in the sample (%)	Age (years)			Period of service (years)	
				Average	Standard Deviation		Average	Standard Deviation
A	689	152	22%	36,2	10,1		15,7	8,6
B	516	63	12%	42,9	9,2		3,3	4,8
C	153	20	13%	48,2	11,1		8,2	11,6
D	225	43	19%	42,6	8,9		7,9	9,5
Total	*1583*	*278*	*18%*	*39,6*	*9,2*		*11,1*	*1,5*

Source: The author.

The estimated average hearing losses versus age, in the sample, may be observed in Figure 2, where the increase of hearing loss due to the aging of the population, by presbycusis, can be evidenced.



source: The author.

Figure 2: Average hearing loss in the sample (age [years] versus loss [dB])

The questionnaire also asked about the period of use and comfort of hearing protection equipment, aiming to quantify the subconstruct *Use of PPE*, in this case particularly the hearing protector was considered - due to the focus of the study on NIHL. As provided in table 5, of 278 evaluated employees, the vast majority - 261 - reported using such equipment, and on average used their hearing protectors around 90% of the journey. The standard deviation was close to 18 points, featuring a small oscillation of the answers.

From 261 people who reported using hearing protection, there was a divergence of habits between the sexes of 4% of usage time and 6% in the proportion. Chi-square test for equality has the value of 0,0976. Threshold for rejecting the hypothesis of equality at the 5% value is 3,84, one cannot drop the hypothesis of no difference between men and women in the PPE use.

a) Statistical Analysis

Through the Pearson correlation coefficient matrix, shown in Table 3, it was possible to analyze the correlation between the subconstructs inspect.

The correlation shows the linear relationship between two variables, where values will always be between -1 and +1. The sign indicates the direction and the size of the variable specify the strength of the correlation. An amount above 0,7 module is a strong correlation. Thus, variables with a rejected hypothesis of null relation at 5% level were considered significantly correlated.

Table 3: Matrix of Pearson correlation coefficients between subconstructs

Correlations

Subconstructs		Sex	Age	Risk Index	Ototoxic Chemicals	Training	Safety Culture	Risk Perception	Perception of Effects	Risk Behavior	Use of PPE	Hearing Loss
Sex	Pearson Correlation	1	-,062	-,142*	,011	,032	,010	-,213**	-,082	-,028	,093	-,126*
	Sig. (2-tailed)		,314	,021	,865	,602	,872	,000	,183	,648	,145	,041
	N	264	264	264	264	264	264	264	264	264	248	264
Age	Pearson Correlation	-,062	1	,428**	,142*	-,012	,251**	-,203**	,165**	-,034	-,116	,330**
	Sig. (2-tailed)	,314		,000	,021	,841	,000	,001	,007	,587	,067	,000
	N	264	264	264	264	264	264	264	264	264	248	264
Risk Index	Pearson Correlation	-,142*	,428**	1	,263**	,108	0,0248	0,0521	0,072	-,071	,018	,195**
	Sig. (2-tailed)	,021	3,4E-13		,000	,080	,688	,399	,245	,251	,775	,001
	N	264	264	264	264	264	264	264	264	264	248	264
Ototoxic Chemicals	Pearson Correlation	,011	,142*	,263**	1	,099	,054	-,069	,014	,007	,040	,068
	Sig. (2-tailed)	,865	,021	,000		,110	,383	,265	,816	,904	,533	,268
	N	264	264	264	264	264	264	264	264	264	248	264
Training	Pearson Correlation	,032	-,012	,108	,099	1	,058	,164**	-,102	-,153*	-,004	-,010
	Sig. (2-tailed)	,602	,841	,080	,110		,344	,007	,098	,013	,956	,877
	N	264	264	264	264	264	264	264	264	264	248	264
Safety Culture	Pearson Correlation	,010	,251**	,025	,054	,058	1	-,091	-,103	,047	-,136*	,154*
	Sig. (2-tailed)	,872	,000	,688	,383	,344		,141	,096	,445	,033	,012
	N	264	264	264	264	264	264	264	264	264	248	264
Risk Perception	Pearson Correlation	-,213**	-,203**	,052	-,069	,164**	-,091	1	-,092	-,129*	,200**	,026
	Sig. (2-tailed)	,000	,001	,399	,265	,007	,141		,134	,036	,002	,669
	N	264	264	264	264	264	264	264	264	264	248	264
Perception of Effects	Pearson Correlation	-,082	,165**	,072	,014	-,102	-,103	-,092	1	,185**	-,125*	,136*
	Sig. (2-tailed)	,183	,007	,245	,816	,098	,096	,134		,003	,050	,027
	N	264	264	264	264	264	264	264	264	264	248	264
Risk Behavior	Pearson Correlation	-,028	-,034	-,071	,007	-,153*	,047	-,129*	,185**	1	-,158*	,015
	Sig. (2-tailed)	,648	,587	,251	,904	,013	,445	,036	,003		,013	,814
	N	264	264	264	264	264	264	264	264	264	248	264
Use of PPE	Pearson Correlation	,093	-,116	,018	,040	-,004	-,136*	,200**	-,125*	-,158*	1	-,049
	Sig. (2-tailed)	,145	,067	,775	,533	,956	,033	,002	,050	,013		,438
	N	248	248	248	248	248	248	248	248	248	248	248
Hearing Loss	Pearson Correlation	-,126*	,330**	,195**	,068	-,010	,154*	,026	,136*	,015	-,049	1
	Sig. (2-tailed)	,041	,000	,001	,268	,877	,012	,669	,027	,814	,438	
	N	264	264	264	264	264	264	264	264	264	248	264

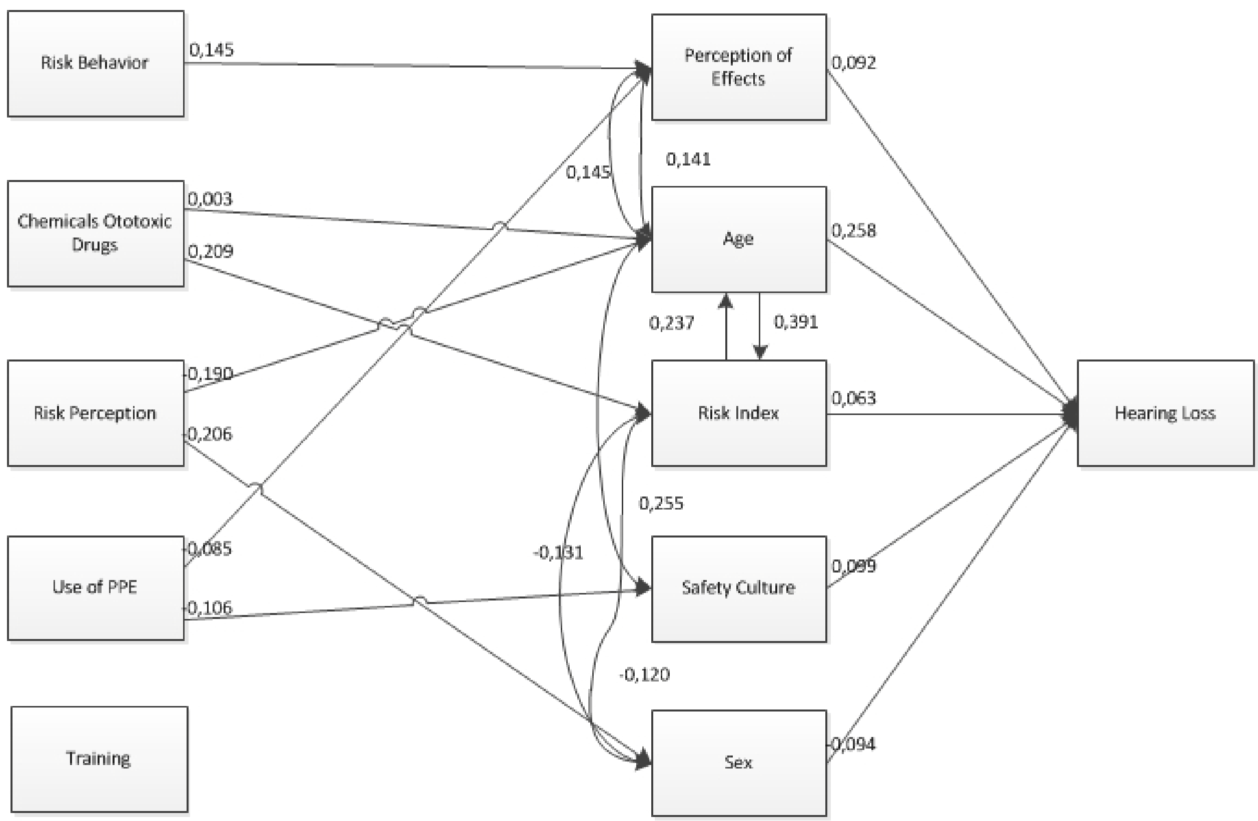
*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Source: The author.

Thus, considering the above, the research screen in this study uses the multivariate analysis of multiple regression analysis (MRA) data, using the data generated by the questionnaires. Five equations of multiple linear regressions were adjusted, with the dependent subconstructs: *Perception of Effects; Age; Risk Index; Safety Culture; and Sex.*

After, the technique of path analysis was used, as the summary presented in Figure 3. This diagram symbolizes paths for subconstructs evaluated.



Source: The author.

Figure 3: Path analysis summary

Table 4 presents the results of all the calculated effects values (direct, indirect, and total) of the subconstructs studied in the proposed model.

Table 4: Direct, indirect, and total effects summary on Hearing Loss construct

Variable	Indirect Effect	Direct Effect	Total Effect
Risk Behavior	0,013	-	*0,013*
Safety Culture	-	0,099	*0,099*
Training	-	-	-
Sex	-0,008	-0,094	*-0,102*
Age	0,063	0.258	*0,321*
Risk Index	0,061	0,063	*0,124*
Risk Perception	-0,030	-	*-0,030*
Perception of Effects	0,036	0,092	*0,128*
Hearing Loss	-	-	-
Chemicals Ototoxic Drugs	0,014	-	*0,014*
Use of PPE	-0,018	-	*-0,018*

Source: *The author.*

IV. Discussion

Table 4 shows the following results:

a) Risk Behavior

The study of the factor related to *Risk Behavior* of the sample has small effect on the development of hearing loss (0,013), where this parameter totally contemplates the indirect consequence arising from the interaction with the subconstruct *Perception of Effects*. This parameter may be positive, i.e., the higher the irresponsible behavior that puts the employee at risk of acquiring irreversible lesion in his auditory system, more significant these attenuations are.

b) Safety Culture

The *Safety Culture*, which contains only the direct component (0,099), presents a significant contribution to the construct parameter. As a positive value, it oddly reflects that the higher the presence of safe work procedures, the higher the level of hearing loss encountered. Perhaps this positive effect is justified by the conjuncture of the companies evaluated, which hada history of compromising workers' hearing and therefore implemented hearing conservation policies, such as HCP (Hearing Conservation Program).

c) Formation

The study of *formation* did not contribute to the model since it presented no direct or indirect components in this evaluation.

As for the characterization of this factor, we used questions to prior knowledge of the interviewee in areas such as safety and hygiene, as well as any previous training in the prevention of noise-induced hearing loss and about the correct use of earplugs and muffs.

d) Sex

The factor that symbolizes the worker´s *Sex* has presented a significant value (-0,102), with a negative sign and contributed predominantly by the direct effect (-0,094) and the remainder coming from the indirect reaction through subconstruct *Risk Index* (-0,008). Its negative sign indicates that hearing loss tends to be lower in females and higher in the male sex, a fact which goes against table 7 (PPE use by sex).

Regarding the sex distribution in the study sample, the vast majority of workers were male, a common factor in the industrial sector, and that may contribute to explain the results. I am giving a strong tendency for a higher incidence of hearing loss among females, when compared to the same sample of males.

e) Age

The *Age* factor presents the highest of values (0,321), originated mostly by the direct effect (0,258) by the reaction of subconstructs Safety *Culture, Risk Index, and Perception of Effects.* It is of positive module, means that the higher the age of the employee, the greater is his degree of hearing loss. In this subconstruct study, the SPSS software used for the multiple linear regression automatically excluded the subconstruct *Safety Culture*, which seemed initially to collaborate indirectly to the composition of the factor.

f) Risk Index

The *Risk Index* also contributes to the study of the components associated with occupational hearing loss, presenting a significant factor (0,136), with the direct and indirect effects (influenced by factors *Age* and *Sex*) having same values: 0,063. This parameter is related to the sound pressure level at work (dB), with the noise exposure time (years). The higher this indicator, the greater the average hearing loss of the worker.

g) Risk Perception

The *Risk Perception* presents only one discrete factor (-0,030) of indirect effect arising from variables *Age* and *Gender*. As a negative number, it indicates the serious sensitivity of the employee against the risk of hearing loss, the lower will be the harm to the employee´s auditory system. The results collaborate to the trend that, the higher the perceived risk is (specifically through dimensions: Identification of risk sources, Knowledge about the noise, Perception of the efficiency of PPE and Means of protection), the smaller will be the chances of damaging the employee´s hearing.

h) Perception of Effects

Regarding the *Perception of Effects* factor, there is a significant level (0,128) of participation, with a serious part being of direct effect (0,092) and the remainder (0,036) coming from the indirect interaction with the *Age* factor. As a positive number, it indicates that the higher the degree of perception of negative health effects for occupational noise, the higher is the degree of hearing attenuation.

i) Chemicals Ototoxic Drugs

The impact study of *Chemicals Ototoxic Drugs* factor provides one of the lowest factors (0,014) of this model. Derived exclusively from indirect effects, it operates through the variables *Age* and *Risk Index*. As a positive value, it symbolizes the larger presence of these agents that are proven harmful to human hearing, the higher the occurrence of hearing loss of employees.

j) Use of PPE

Finally, the impact study of the *Use of PPE* provides a discrete factor (-0,018) in this model. Coming exclusively from indirect effects, it operates through the variables *Perception of Effects* and *Safety Culture*. Negative value symbolizes the higher use of hearing protection devices – provided by the company to workers, the lower will be the occurrence of hearing loss in employees.

V. Conclusions

Multivariate analysis was adequate and essential in the study of risk factors associated with occupational noise-induced hearing loss in the industry. There is a need for research on risk perception and mitigation strategies in the context of noise-induced hearing loss. Such is found tied to the increased probability of occurrence associated with the risk factors identified in the study. The development of risk management strategies to reduce NIHL requires both knowledge of the physical environment, and the social, psychological and economic processes that can affect people's responses to environmental conditions of danger.

Noise-induced hearing loss (NIHL) is a cumulative, insidious disease that grows over the years of exposure to noise associated with the workplace - causing damage to organ of Corti, usually bilateral, with progressive and irreversible loss and symptoms such as hearing loss, tinnitus, ear fullness, ear pain, dizziness, transient changes in blood pressure, stress, vision and mood disturbances, directly related to the exposure time, with sound pressure levels (SPL) and individual susceptibility.

NIHL is caused by any exposure to a daily average of 85dB, for several years. Noise is responsible for about 20% of global hearing loss, including being the second leading cause of the occupational disease that affects more American workers.

In an attempt to investigate the variables that impact on noise induced hearing loss, an analysis was developed taking into account the independent variable hearing loss, related to the variables dependent on metrics: *Perceived Effects, Age, Risk Index, Culture of Safety and Sex.*

In order to predict any changes in the dependent variables - due to changes in the independent variable. The statistical analysis was applied to identify the latent dimensions of significant effect on the variable in the analysis of known risk factors, such as: *Risk Behavior, Culture Security, Education, Sex, Age, Risk Index, Risk Perception, Perceived Effects, Chemical Substances, Ototoxic Drugs and Use of PPE*.

To test these associations were used Pearson correlation coefficient and multiple linear regression on the subconstructs identified. Through path analysis, was performed a factor analysis of direct and indirect factors related to NIHL effects.

In this context, the present study examined the possible approaches that relate to understanding the exposure to noise risk in the workplace.

The study enabled us to verify that Hearing Conservation Programs (PCA), and other campaigns, to be developed by companies, particularly in the industrial field, are based on modifiable factors identified. Thus, promoting actions that encourage the expansion of perception of the effects of hearing loss induced by occupational noise, will contribute to the prevention of the risk to workers' health.

The path analysis showed how the exceptional impact variable on hearing loss, both direct and indirect effects aspect, the *Age* variable - demonstrating the effect of natural hearing loss related to aging-presbycusis. At the other extreme, the dependent minor indirect effect were variable *Chemicals Ototoxic drugs*.

According to the results obtained in the present study, the individual perception of the risk of job exposure to noise is an important issue with regard to safe behavior, in particular, to avoid the involvement of occupational hearing loss by noise in the industry. Workers seem to avoid exposure to noise based on their perceptions of the risk. Unfortunately, it appears that they are bad appraisers this risk.

Finally, other investigations may complement the study performed here. As this research was limited to the study of continuous or intermittent noise found in industrial environments surveyed, further research can evaluate the work environment whose employees are subject to impact noise.

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