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Otoacoustic emissions in normal-hearing workers exposed to different noise doses

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Abstract

Introduction: The otoacoustic emission test is useful in monitoring hearing changes not yet detectable in pure--tone audiometry, as well as in monitoring cochlear damage caused by exposure to noise. **Objective:** To evaluate distortion product otoacoustic emissions in normal-hearing workers exposed to different occupational noise doses. **Materials and Method:** This is a cohort prospective study performed in metalworking industries, in which normal--hearing workers were assessed by being divided into three different groups: GI not exposed, GII sporadically exposed and GIII often exposed to occupational noise. **Results:** Otoacoustic emission alterations were found in groups II and III bilaterally. Both in the amplitude and in the signal/noise ratio it was observed that as higher was the frequency, worse were the results of GII and GIII ($p > 0.001$), and the greater the exposure dose is, the lower the averages found in otoacoustic emission. **Conclusion:** The otoacoustic emissions are worse in the exposed groups compared to the unexposed group and the greater are the noise dose, worse are the results.

Keywords: hearing loss, noise, noise monitoring, noise-induced, occupational.

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INTRODUCTION

Due to the ability of the otoacoustic emission (OAE) test to reveal the functioning of the outer hair cells (OHC), this evaluation method has been applied for auditory assessment in several clinical situations[1,2]. Studies have shown that the application of this test is extremely useful in monitoring undetectable minimal pure-tone audiometric changes[3-8], as well as for monitoring cochlear damage resulting from exposure to noise[3,5]. Auditory loss which may be caused by exposure to occupational noise was named High Sound Pressure Induced Hearing Loss (HSPIHL) by Directive no 19/1998, of the Brazilian Labor and Employment Ministry[9]. It is an irreversible sensorineural alteration of the hearing thresholds, with gradual progression, initially impairing the frequency range between 3 and 6 KHz. When the exposure is interrupted, however, the hearing loss does not progress[10,11].

The possibility of early identification of cochlear alterations in normal hearing workers has motivated several scientists to search for the hearing effects of occupational noise by means of the OAE test[12-17].

After analyzing papers related to otoacoustic emissions in the differential diagnosis of HSPIHL, researchers have shown that both transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs) are useful in the detection of HSPIHL, TEOAEs are more sensitive to temporary threshold changes, whereas the DPOAE test stands out in the early diagnosis of HSPIHL in individuals with supposedly normal hearing[18].

Boger et al. conducted a study in 2009 in industries in different fields of activity, among them metalworking industries, and observed that in the daily activities in the company it is common for workers from other sectors to pass through the production areas. It has been noted that workers in the administrative, cleaning, human resources and quality control sectors sporadically pass through the production sector of factories without wearing the intraurricular protection equipment for a quick surveillance of products and other services[10]. These workers sporadically exposed to occupational noise are not considered risk groups and therefore do not use the individual intraurricular protection equipment. The argument used by labor safety technicians responsible for monitoring these tasks is that the time of permanence in the noise sector is so short that according to the table of admissible daily exposure period by sound pressure level in Regulatory Norm 15 of the Labor and Employment Ministry (Brazil), it does not pose risks to hearing. Therefore only helmets are needed as individual protection equipment (IPE).

In the scientific literature, several papers report evoked otoacoustic emissions in workers exposed to noise. However, a large part of those studies involve only the population working 8 hours a day in noisy environment as workers exposed to noise. We include a third group formed by workers who are sporadically exposed to loud noise without the use of hearing protectors, in order to detect possible irreversible damage to their hearing during the short exposures to loud noise in their work day. The purpose of the present study is to assess DPOAEs in normal hearing workers exposed to different doses of occupational noise.

MATERIALS AND METHODS

The present study was submitted to the Ethics Committee for Research with Humans of the College of Health Sciences of the University of Brasília, registered under number 113/10 and approved at the 9th Ordinary Meeting, held on October 05, 2010.

This is a prospective cohort study in which participants are classified into exposed, sporadically exposed and not exposed to a certain interest factor (noise), composed by normal hearing individuals, conducted in metalworking industries in Brasília-Brazil.

The participants were men and women, and the age range was 18 to 35 years. Hearing thresholds were equal or inferior to 25dBNA and there was no previous otological diseases, no prior exposure to occupational noise, no history of diabetes, hypertension, dizzy spells, cancer treatment or thyroid disease. The data were collected by means of occupational anamnesis and information obtained in the human resources sector of the companies, which provided current medical and laboratory results of periodical health tests.

The audiometric assessment was preceded by anamnesis, otoscopy and 14-hour acoustic rest from the occupational noise. This assessment was performed in order to check the audiometric thresholds for the frequencies ranging from 250 Hz to 8 KHz. The equipments used were: a Welch Allyn otoscope, with WA accessories; an Interacoustics clinical audiometer, AC40 model; a Redusom sound-treated booth, model RO-80 Std. All workers were examined; and those who had normal hearing (thresholds equal or inferior to 25 dBNA in all frequencies) and filled the inclusion criteria were submitted to the DPOAE analysis.

The DPOAE test was performed in a silent room. The right ear was established to be the first ear tested. We used MAICO Ero-Scan equipment for DPOAE records. The noise level, linearity of the stimulus and the appropriate position of the probe were automatically monitored. The DPOAEs were assessed by means of the simultaneous presentation of two distinct pure tones (F1 and F2), set in a 1.22 ratio. The intensity parameters were L = 65 and L = 55 dBNPS and we checked the frequencies of 1.5, 2, 3, 4, 5 and 6 KHz. The analyses of DPOAEs were made according to frequency, following the criteria of

amplitude (DP) higher than -5 dBNPS and signal/noise ratio (S/N) higher than 6 dBNPS. The normality patterns in the present study are based on the pass/fail criterion, according to which the individual is considered normal when the amplitude is higher than -5 dBNPS and the signal/noise ratio is lower than 6 dBNPS, If one of the criteria fails, the result is considered abnormal.

We established three groups of patients: Group I was formed by normal hearing individuals, with similar characteristics to the individuals in the other groups, with no exposure to occupational noise. Group II was composed by normal hearing individuals sporadically exposed to the occupational noise. This group included workers from administrative areas in the industries, having short exposure to noise during their workday by circulating in the production area without using the individual intrauricular protection equipment. Group III included normal hearing workers using individual intrauricular protection equipment, exposed to noise levels above 85 dBNPS for eight hours daily for a total period of exposure ranging from 6 to 18 months.

For the sound pressure environmental assessment, the distribution of the sound intensity was checked by using an appropriately calibrated SIP 95 decibel meter manufactured by *01dB Brasil*. The duration of the data collection at each plant was 8 hours.

In order to calculate the daily noise dose related to the workday, an assessment of the individual exposure of each worker was performed. The device used for this analysis was the*01dB Brasil* dosimeter. The dosimeter remained with the worker for 8 hours. Two workers from the production sectors in metalworking industries were randomly selected for this analysis (GIII) as well as two workers who are sporadically exposed to environmental noise (GII). The equipments were placed so that the microphones should be installed on the shoulders of the workers, near the ears. A noise dose greater than 100% characterizes the exposure limit as having been exceeded.

All the data collected were transported to electronic worksheets and the statistical analysis was performed with the SPSS for Windows® software version 13.0. The descriptive analysis of the data included: frequency, measurement of the central trend (average) and measurement of variance (standard deviation). The possible associations between the variables were assessed by means of the chi-square test. The comparison of the amplitudes and the signal/noise ratio (S/N) was made through mixed-design ANOVA with the factor Group (3 levels) as a measurement between the groups (independent variable) and the factors Frequency (6 levels) and Lateralization of the ears (2 levels) as repeated measurements. The statistical significance level was set at 5% ($p < 0.05$).

RESULTS

One hundred and fifty workers had audiometry with thresholds of 25dB or better, matched to the inclusion criteria for the study and were distributed among the groups as follows: 50 individuals formed GI, 50 workers formed GII and 50 formed GIII, totaling 300 ears that had their DPOAE tests recorded.

The average age of the subjects assessed was 26.2 years (SD ± 5.7). Eighty percent of the workers were male (n = 120), whereas female participants (n = 30) were distributed between groups I and II. In group III all subjects were male.

According to the general results obtained in the DPOAEs, 40% of the 150 individuals showed alterations in both ears (n = 60), 43.3% (n = 65) failed in the left ear and 45.3% (n = 68) in the right ear. There was no statistically significant difference between the sides (right or left) regarding the failure in the DPOAEs ($\chi^2 = 0.05$, GI = 1, $p = 0.816$).

GIII showed the highest prevalence of alterations in DPOAE (66% and 72% in the left and right ear respectively), GI had the lowest failure rate (14% in the left and 16% in the right ear) when compared to the other groups. GII showed high prevalence of alterations in the DPEOAE tests (50% in the left ear and 48% in the left ear). GII showed alterations in the DPOAE test in the left ear ($\chi^2 = 28.887$, GI = 2, $p < 0.001$) and in the right ear ($\chi^2 = 31.851$, GI = 2, $p < 0.001$) which were significantly different from GI.

All groups had general average amplitudes in both ears within the criteria for normality in all frequencies tested. However, the higher the frequency is, the lower the amplitude of the signal. Besides that, one can observe that, from 3 KHz upwards, as subjects are exposed to occupational noise, the averages also decrease, therewith, the higher the exposure is, the lower the amplitude found. GII and GIII had lower amplitudes when compared to GI. This difference was statistically significant (GII $p = 0.001$ and G III $p < 0.001$). The side had no statistically significant effect on the average amplitudes ($F_{1, 146} = 0.631$, $p = 0.428$). GII showed lower amplitudes than GIII only in 5 KHz and 6 KHz. The difference was considered statistically significant ($p < 0.015$).

Regarding the ears with altered DPOAEs, the frequency of 6 KHz showed the lowest amplitudes in the left and right ears in the three groups (the difference was considered statistically significant $p < 0.001$) and GII showed the lowest amplitude compared to GIII for 5 KHz in both ears (not statistically significant $p > 0.042$) (Table 1). No difference was found between the ear sides ($F´s < 1.758$, $p´s > 0.069$).

Regarding the general average of the DPOAEs in the signal/noise ratio, the side and the frequencies assessed, it was observed that in both ears and at all

Table 1. Averages of the amplitudes of the altered DPOAEs, according to side and the frequencies assessed in groups I, II and III.

Amplitude of the altered DPOAEs												
	Left ear						Right ear					
Groups	GI		GII		GIII		GI		GII		GIII	
Freq. (KHz)	Average	± SD	Average	± SD	Average	± SD	Average	± SD	Average	± SD	Average	± SD
1.5	6.5	7.1	4.4	6.3	2.6	6.1	9.9	3.1	4.3	5.4	3.2	6.2
2	5.6	3.6	4.1	5.9	3.6	6.1	5.3	3.9	4.7	6.7	4.1	6.7
3	0.5	3.4	0.3	6.2	0.6	6.7	2.6	4.0	1.0	6.7	0.5	7.3
4	0.5	3.8	-2.2	6.6	-3.2	6.3	2.3	3.9	-2.3	6.5	-2.9	6.2
5	1.2	2.9	-3.8	7.3	-3.1	7.2	4.2	4.7	-4.4	7.3	-2.9	6.5
*6	-6.1	5.8	-7.3	9.0	-8.1	8.8	-5.3	4.3	-6.1	8.6	-7.9	7.8

± SD: standard deviation. * Significant differences.

frequencies the averages are higher than 6 dB, a criterion which represents normality. GI had higher S/N ratio than GII and GIII ($p = 0.008$ and $p = 0.021$ respectively), and no difference between the sides was found ($F_{1, 147} = 0.633$, $p = 0.428$).

Regarding the ears with altered DPOAEs, the frequency of 6 KHz showed S/N ratio lower than 6dB in all groups, and it was lower in GII and GIII, that is to say, the greater the exposure is, the lower the S/N ratio ($p < 0.001$) (Table 2).

The sound pressure levels in this industrial environment was (Leq) of 91 dBNPS. The dose measured in GII and GIII exceeded 100% of the reference value (290% and 1422% respectively).

According to the noise dose evaluated for GII and GIII, the tolerance period of time for the permanence of a worker in the production environment without wearing hearing protectors for GIII is 37 minutes and for GII is 135 minutes, that is to say that workers from others sections that are sporadically exposed to occupational noise should not remain in the noisy environment more than 2.25 hours approximately (Table 3).

DISCUSSION

DPOAEs are considered to be an important, fast, objective, non-invasive, and accurate method of evaluating early cochlear damage caused by occupational noise. In this study, we recorded the DPOAEs in metalworking industries subjects with normal audiograms under exposure to different noise levels in order to monitor early hearing impairment in occupational medicine. In many countries as well as in Brazil, occupational health laws are based only in audiometric monitoring of hearing for high risk individuals. It is reported that minimal cochlear changes in the OHC functioning are associated to normal audiograms. DPOAEs might be a useful tool for occupational medicine for early detection and monitoring hearing in individuals exposed to different sound pressure levels in the industries[3,5,7]. We believe both methods, pure-tone audiometry and DPOAEs, should be performed and they might complement each other.

We found in our sample 40% of workers showing alterations in the DPOAEs in both ears. The high prevalence of abnormalities found in the present study

Table 2. Averages of the signal/noise ratio of the altered DPOAEs, according to side and the frequencies assessed in groups I, II and III.

Signal/noise ratio of the altered dpoaes												
	Left ear						Right ear					
Groups	GI		GII		GIII		GI		GII		GIII	
Freq.(KHz)	Average	± SD	Average	± SD	Average	± SD	Average	± SD	Average	± SD	Average	± SD
1.5	13.1	5.1	12.7	7.5	11.1	7.1	13.3	4.8	11.6	5.5	12.2	6.1
2	16.3	6.6	13.3	7.1	13.4	6.6	20.5	3.4	12.6	7.6	13.2	7.6
3	18.2	5.2	14.3	8.0	14.7	8.1	16.7	6.5	14.9	7.0	15.1	7.7
4	13.1	6.2	12.9	7.1	13.1	6.6	19.5	3.4	15.0	6.6	13.3	6.1
5	14.1	7.9	12.6	8.1	13.9	9.2	15.9	6.0	12.4	7.1	12.9	8.2
*6	4.1	7.9	2.8	8.0	1.3	8.8	5.0	3.3	2.3	8.6	1.4	7.3

± SD: standard deviation; * Significant differences.

Table 3. Sound pressure equivalent level, daily exposure level and maximum dose and tolerance period according to the groups of workers exposed and sporadically exposed to occupational noise.

Groups	Leq(dB)	Lexp (dB)	Dose (%)	Tolerance period (min)
Exposed	103.3	103.8	1422.0	37
Sporadically exposed	90.1	90.6	290.0	135

Leq: sound pressure equivalent level. Lexp: daily exposure level.

is in agreement with other reports that demonstrated the high sensitivity of the DPOAE test in the early detection of cochlear alterations caused by noise exposure, unidentified by pure-tone audiometry[3-8,15,18]. It was also observed that the greatest failure rates in DPOAEs were found in groups II and III, that is, those sporadically exposed and those often exposed to occupational noise. That is to say, the more exposed to the noise, the higher the risk for developing alterations in DPOAE tests. These data are in agreement with previous reports which showed that subjects not exposed to occupational noise had higher prevalence of normal DPOAE records, when compared to the groups exposed and that the DPOAEs are more sensitive to detect the effects of noise in the auditory system than pure-tone audiometry[14-16]. We included in our investigation individuals sporadically exposed to the noise - GII, and we showed an incidence of abnormal DPOAE greater than in the non-exposed group, GI.

There was no association between the DPOAE test results and the side of the ear studied. This finding shows a uniform exposure to noise in both ears of the metalworker. The analyses of general averages of amplitudes of the DPOAEs, showed in both ears the averages decrease with the increase of the frequency analyzed. This result was also found in other studies[13,17]. In the present research the averages of the amplitudes in GI were higher than those in GII and GIII at all the frequencies analyzed. This is in agreement to the aforementioned authors[13,14,16,17], who also found lower values for amplitudes in the group exposed to noise.

Considering only the averages of the amplitudes of subjects with abnormal DPOAE tests, we observed that the damage was found mainly at the frequency of 6 KHz. This finding corroborates the observation of other authors, who showed this frequency to be one of the first to be affected as the result of exposure to occupational noise [9,17]. Moreover GII showed in some cases lower amplitude than GIII at the frequency of 5 kHz. Even though there were no statistically significant differences between groups II and III concerning this frequency, we believe that GII should be considered high risk as well as GIII to develop HSPIHL and preventive efforts should be taken as well as for GIII. Furthermore the averages of signal/noise ratios in GI were higher than in GII and GIII. This finding shows that the group not exposed to the noise presented better responses than the group exposed and it was also reported by Atchariyasathian, Chayarpham and Saekhow (2008)[17]. We observed that the averages of signal/noise ratio recorded for groups II and III were not different, suggesting that both groups have worse results than the non-exposed group and should be considered high risk groups for developing auditory damage.

One of the most striking points in the present study is the result of GII. This group is composed generally by administrative staff not directly involved in the production field, who usually pass through the noisy area of the metal industry. They might be usually exposed without the use of hearing protectors. We observed in almost all hearing analyses that there was a similarity between groups II and III, which points to the fact that these workers are exposed and show cochlear damage as a result of their exposure to noise, yet they are not considered to be a risk group according to the criteria currently used by Brazilian Labor and Employment Ministry. The measurement of the occupational noise in the production field showed that the maximum period of time recommended to stay in the noisy environment without hearing protectors was 37 minutes for GIII and 135 minutes for GII. According to several countries' laws, and particularly in Brazil, it is allowed for the workers to remain in the production fields exposed to 90dB SPL for a period up to 4 hours with unprotected ears[9].The results point to the fact that following the law strictly might not prevent HSPIHL among the studied workers.

In this study we measured the noise in the production environment by placing the dosimeter close to the ear of the workers in order to have a more precise evaluation of the real sound level that could damage the OHC. With this assessment, we showed the sound pressure to be more intense than the decibel meter measurement in the central position of the production plant. The placement of the equipment in the center of the production field could not reflect the real sound pressure that hit the OHC during the working time.

Finally, when comparing the groups, it was observed that, in the criteria studied, there were significant differences, and they were highlighted with GI that showed better records than GII and GIII. These findings are in agreement with the hypothesis that all parameters evaluated in our study may suffer a negative effect of the exposure to the occupational noise. This effect might cause damage to OHC of frequent and occasionally exposed metalworkers in industry.

CONCLUSION

Distortion product otoacoustic emissions in normal hearing workers exposed to different doses of occupational noise revealed that workers exposed to noise show worse results when compared to those non-exposed, and the higher the dose of exposure to noise, the worse the DPOAE records.

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