Factors affecting the use of hearing protectors in a population of printing workers

Thais C. Morata[1], Ana Claudia Fiorini[2,3], Frida Marina Fischer[3], Edward F. Krieg[1], Luciane Gozzoli[2] and Sergio Colacioppo[3]

[1] *U.S. Department of Health Human Services, Public Health Service, Centers for Disease Control National Institute for Occupational Safety and Health, Division of Applied Research and Technology Cincinnati, OH, United States*

[2] *Division of Education and Rehabilitation of Communication Disorders, Pontifical Catholic University of São Paulo, São Paulo, SP, Brazil*

[3] *Department of Environmental Health, School of Public Health, University of São Paulo, São Paulo, SP, Brazil*

This study examined the reasons offered by rotogravure printing workers from São Paulo, Brazil, for not consistently using hearing protectors. The study group was comprised of 124 workers exposed to various levels of noise. Data on work history, psychosocial aspects of their job, medical history, present health, stress, occupational and non-occupational exposures to noise or chemicals and lifestyle factors were collected through an interview. The participants underwent pure-tone audiometry and had their noise exposures assessed. Seventy-nine workers of a total of 124 noise-exposed (64%) indicated that they wore hearing protectors, but only 16 (20%) of that subgroup stated that they wore the device all the time when noise-exposed. The variables significantly associated with the decision for not consistently wearing hearing protectors included interference with communication, interference with job performance, comfort issues, and self-perception of hearing condition.

Keywords: Hearing protectors, ear muffs, speech, comfort, overattenuation

Introduction

Intense noise is still one of the most common occupational hazards in many industrialized countries. In the United States, for example, the number of workers estimated to be exposed to potentially hazardous noise is between 5 and 30 million (Franks, Stephenson and Merry, 1996; NIOSH, 1998). This number includes farmers and farm workers, oil and gas workers, construction workers, miners, workers in manufacturing and transportation, and workers in the service sector.

In Brazil, as in many countries, employers are required to offer hearing protection devices (HPDs) and respective training for noise-exposed workers enrolled in hearing conservation programs (MT,1997). One widely employed aspect of hearing conservation programs is making HPDs available. While relatively inexpensive and easy to implement, providing HPDs to control noise exposure is not free of problems. It has been shown that in order to achieve the desired attenuation and consequent protection from noise, workers must wear their HPDs consistently, all of the time that they are exposed to noise levels greater than 85 dBA time weighted average, or TWA (Franks, Stephenson and Merry, 1996). However, HPD use is inconsistent and varies widely based on individual and work organization factors. A paper on HPD utilization around the world, reviewed more than 100 publications from 1981 to 1999, and indicated that there are a few success stories, but more predominantly, there is a need for improvement in HPD utilization rates. This review also pointed out those wearing protection amount to less than 50% of those who should be wearing such devices, but the data seems to indicate that the rate of HPD use is on the increase. One of the reviewed studies examined the reasons workers gave for not

wearing the protection, and those included comfort issues and their concern over not being able to hear warning sirens and signals (Lusk et al., 1994). In that investigation, only 40% of the workers used hearing protection all of the time they were noise-exposed. The authors observed that employees tend to use personal protective equipment including HPDs more consistently in areas of the plant where supervising management demonstrated the greatest concern with the issue. The authors recommended that employers address the underlying reasons expressed by workers for not consistently wearing HPDs. Poor strategies in the adoption, facilitation and enforcement of the use of HPDs are likely to be some of the reasons that occupational hearing loss is still one of the most prevalent work-related conditions, despite the 30-year existence of the Occupational Noise Standard.

As part of the University of São Paulo School of Public Health Study of the Effects of Environmental and Organizational Stressors, reported elsewhere (Fischer et al., 1996; Morata et al., 1997), hearing protection usage among rotogravure printing workers was investigated. Workers were interviewed, pure-tone audiometry was performed to evaluate the occurrence of hearing disorders, and noise exposures were measured at a printing facility located in São Paulo, Brazil.

Subjects and Methods

Data were collected through a verbal interview based on a questionnaire comprising approximately 400 questions on psychosocial aspects of work, work history, work organization, medical history, present health, perceived stress, occupational and non-occupational exposure, and lifestyle factors. The interview protocol was developed following site visits, extensive preliminary interviews, and ergonomic evaluation of the workplaces. The protocol included questions concerning demographic data, health information that focused on events that could be related to hearing status, and non-occupational noise exposure data. Questions were primarily closed-ended. The interviews lasted from 40 to 70 minutes.

During the interview, all participants were asked whether they wore HPDs at all, and if they responded affirmatively, they were asked how consistently they wore HPDs while in the presence of hazardous noise. Responses were entered in a 4-point scale ranging from “never” to “all the time”. A list of potential reasons for not consistently using hearing protection had been developed based on the information gathered in preliminary interviews that had been used to develop the protocol. Workers were queried about each of the reasons on the list. Each worker could indicate as many reasons as he thought relevant to his decision not to wear a hearing protector all of the time when noise-exposed.

All of the interviewers volunteered to participate in the study. They were graduate students, and were trained and supervised by the field study coordinator (F.M. Fischer). The training consisted of question-by-question review of the questionnaire, mock interviewing, role playing, and a pretest in which each interviewer was requested to demonstrate competence in administering the oral interview according to the established script.

Study Population

Subjects were male workers employed for a minimum of one year at a printing facility in São Paulo, Brazil. All of the workers from the departments of Rotogravure Printing, Paint Preparation, Engraving, Lamination, Color Proofing and Cylinder Preparation were invited to participate in the study and accepted the invitation. These departments were selected because of their documented exposures to noise. One hundred twenty four volunteers met the eligibility criteria and were included in the study. The eligibility criteria were: tenure at the study plant greater than one year, and absence of suspected middle ear problems at the moment of the hearing test.

Table 1. Characterization of the study population (n=124).

Variable (in years)	Mean	Std. Deviation	Minimum	Maximum
Age	34	8	21	58
Tenure	8	6	1	25
Noise exposure	8	6	0	25
Previous noise exposure	2	4	0	26

Characteristics of the study population are presented in Table 1.

Noise Exposure Assessment

Sound pressure level measurements conducted during the present investigation, using a Bruel & Kjær type 2231 sound level meter, were in agreement with the company's historical records. These measurements revealed continuous noise levels in the range of 71 to 93 dBA. Noise level maps and job descriptions were used to plan the noise dosimetry for each subject. Those who worked at the same job during their entire shift wore the noise dosimeter for three hours, and the results were used to estimate their 8-hour noise dose. Workers who performed tasks in different locations wore the noise dosimeter during their full shift. Noise dosimetry, conducted with Bruel & Kjær dosimeters type 4436, indicated doses that ranged from 43 to 300 percent of the limit. The Brazilian (and NIOSH) recommended TWA limit of 85 dBA, and the 5-dB exchange rate were used in these evaluations (MT, 1997).

Table 2. Distribution of the exposure population, by their noise time-weighted averages, by their mean duration of noise exposure.

Noise Time-Weighted Averages (in dBA)	Number of workers	Mean duration of noise exposure (in years)
# 80	20	10
81 to 85	30	10
86 to 90	52	6
∃91	22	7

Table 3. Range of noise levels observed in the studied departments

Departments	Number of workers	Noise levels (in dBA) TWA Minimum	Maximum
Printing (Press 1)	10	89.2	92.7
Printing (Press 2)	9	89.4	90.1
Printing (Press 3)	11	80.7	85.1
Paint Preparation	20	90.1	92.8
Engraving	14	70.5	72.7
Cylinder Preparation	24	83.2	84.5
Lamination (laminator 1)	14	89.4	90.9
Lamination (laminator 2)	16	86.9	87.5
Color Proofing	6	87.1	87.8

Table 2 shows the number and percentage of workers, categorized by their mean duration of noise exposure and the noise time-weighted averages (TWA) that corresponded to their job categories.

Table 2 indicates that the workers with longer tenure are the ones exposed to lower noise levels. Table 3 summarizes the noise levels observed in each of the studied departments and the number of workers in each department.

Hearing protectors (ear muffs, NRR 20 dB) are assigned to workers, but no training regarding hearing protection takes place. Workers are informed that HPDs can be replaced when "damaged." If a worker dislikes muffs, he can request ear plugs, but company personnel indicated that this rarely happens. Only a couple of workers have ever requested ear plugs and they were provided with custom-molded ones. During preliminary site visits conducted by the research team, when workers were unaware of the study objectives, it was observed that few of the workers wore, or even had their protectors by their work area.

Testing Procedures

Otoscopy and pure-tone audiometry were performed on all subjects. Audiologists, under the supervision of an audiology instructor performed these tests. Otoscopy was performed to screen for conditions that would exclude the person from the study, i.e.external otitis or perforated tympanic membrane.

Pure-Tone Audiometry

Pure-tone audiometry was performed for all subjects at the frequencies of 0.5, 1, 2, 3, 4, 6 and 8 kHz. Testing was preceded by a period of at least 14 hours without exposure to occupational noise. Bone conduction testing was performed for the affected frequencies in the range of 0.5 to 4 kHz. The subjects were tested in a sound-insulated chamber which met the requirements of ANSI S 3.1-1999 for audiometric testing environments (ANSI, 1999). The Maico MA-41 audiometer was calibrated following ISO R389 -1998 norm (ISO, 1998) prior to the data collection. Daily biological calibration checks were also performed immediately before testing subjects. Audiograms were classified using a clinical criteria. Thresholds of 25 dB HL or less were considered normal. Thresholds of 30 dB HL or greater at the 3 to 8 kHz frequency range was considered in assigning a high-frequency hearing loss classification to the audiograms.

Data Analysis Strategies

A computer program written in Clipper® was used to enter the data into dBase IV+® files. Extensive checks and rechecks were made for invalid codes or consistency errors. The data were analyzed using the Statistical Analysis System (SAS, 1996).

Results

The prevalence of bilateral high-frequency sensorineural hearing loss in the study group was 49%. The risk factors found to be associated with hearing loss in the studied group are described elsewhere (Morata et al., 1997). The

Table 4. Reasons presented by workers for not consistently using hearing protectors in the presence of noise.

Reported Reason for not using HPs	Number of Workers	Percentage
Causes headache	19	24
Pressures head	29	37
Causes itching	34	43
Interferes w/ job performance	36	46
Interferes w/communication	55	70

use of hearing protection both on and off the job was assessed in the questionnaire, and reported to be low. Seventy-nine workers of a total of 124 noise-exposed (64%) indicated that they wore HPDs, but when asked how often they used HPDs, only 16 (20%) of that subgroup stated that they wore the device all the time when noise-exposed. Table 4 lists the reasons presented by workers for not using hearing protection all the time in the presence of noise.

Other potential reasons than the ones presented in Table 4 were examined in relation to HPD use. They included age, tenure, if a worker considered good hearing as necessary for him to be able to perform his job well, self-reported hearing status, actual hearing condition assessed by audiometric evaluation, tinnitus, how the subjects perceived the noise level, and measured noise level. Pearson correlation tests indicated a statistically significant relationship between the decision to wear or not wear hearing protection and actual noise level ($r=0.34$, $p<0.0001$). As the noise levels increased, the more likely was the individual to use HPDs. However, actual noise levels were not significantly correlated with the *consistency* of HPD use. Table 5 shows correlation's between several of the studied variables and the consistency of wearing hearing protectors.

The relationships between perceived noise levels and measured noise levels, and between self-reported hearing status and measured hearing status were also examined. In both instances there were statistically significant relationships ($r=0.21$, p0.01, and $r=0.19$, p0.03 respectively).

Discussion and Conclusions

In the area of hearing loss prevention, there is a consensus that the most effective way to prevent hearing disorders from noise exposure is to remove the noise source from the workplace or to remove the worker from hazardous noise. However, hearing protection devices are often adopted in lieu of controlling noise exposure. This strategy, if not carefully implemented, can impede the success of preventive efforts (Berger, 1980a, b; 2000; Royster and Royster, 1990; NIOSH, 1998). Barrenäs et al. (1998) reviewed hearing conservation practices in Europe. Hearing protector manufacturers have indicated that sales of hearing protectors have increased substantially in Scandinavia in the past decade, but the occurrence of noise-induced hearing loss (NIHL) has also increased. The authors argued

Table 5. Pearson correlation coefficients between consistency of hearing protector use and reasons offered by subjects for their decision.

Variable correlated with consistency of HP use (always to rarely 4 pt.-scale)	r	p
Causes itching	0.31	**0.005**
Causes headache	0.06	0.584
Pressures head	0.25	**0.024**
Interferes with communication	0.21	0.057*
Interferes with job performance	0.22	**0.051**
Perception of noise level (acceptable to excessive 4 pt.-scale)	0.11	0.329
Measured (actual) noise level	0.13	0.232
Self-reported hearing status (normal to hearing loss)	0.21	0.058*
Measured hearing status (normal to hearing loss)	0.09	0.391
Tinnitus	0.08	0.450

Numbers in bold indicate variables that met the significance level criterion (p#0.05), while asterisks indicate variables that approached the criterion.

that if the HPDs were used effectively, the opposite trend should have been registered.

Several reasons why HPDs can fail in their purpose have been known for years, and they include discomfort, interference with hearing speech and warning signals, incorrect use with other safety equipment, deterioration and abuse (Berger, 1980a, b; Helmkamp, 1986). Prevention of NIHL requires certain behaviors to be adopted in the present, taking into consideration future health benefits. Diverse psychological and health models have been investigated in relation to the process involved in the decision of wearing or not wearing HPDs (Zohar, Cohen, Azar, 1980; Lusk et al., 1998, 1999; Hallberg, 1998).

In the present study, the use of HPDs and the reasons presented by workers for not wearing them consistently in the presence of intense noise were examined. Also examined were the use of HPDs in conjunction with results from noise measurements, audiometric results, and workers perception of noise levels and their hearing status.

Among the reasons presented by workers for not wearing HPDs consistently, interference with communication was the one most workers (70%) selected. The second most common reason presented was the fact it interfered with job performance (46%), by making certain sounds from the machinery undetectable. These findings suggest that when the company selected a HPD, it did not take into consideration what effect the HPD has on the wearer's ability to communicate verbally or his ability to detect certain machinery sounds. Historically, in the selection of HPDs, emphasis has been placed on hearing protector attenuation, even to the exclusion of other qualities that are just as necessary for the HPD to be effective (NIOSH, 1998). Companies still seek the device that offers the highest attenuation, even in circumstances when only few dB of attenuation is needed. Consideration of the noise levels observed in the studied company (up to 93 dBA) and the NRR of the HPD that the company offered (20 dB, laboratory test), leads to the conclusion that the device selected by the company overprotects the ear. Therefore, it can be argued that the poor selection of HPD was the primary reason the devices were not used effectively.

Other variables that were correlated with the workers decision not to wear HPDs involved mainly comfort. This study was conducted in an area where temperature and humidity are high for most of the year. These environmental factors can make ear muffs more uncomfortable, and thus harder to use, than ear plugs.

Another factor that was correlated with the use of HPDs was the workers' self-perception of their hearing status, but not the actual audiometric result. This maybe due to limitations of pure-tone audiometry in offering information regarding the impact of a loss in an individuals' overall hearing abilities. Those that perceived having some hearing disorder were more likely to try to wear the HPD consistently. This information should be used when programs for raising the awareness and specific training regarding HPD use are developed. Workers' use of hearing protection devices (HPDs) and their perceptions of noise exposure and hearing loss were investigated previously (Lusk et al., 1998). Bivariate analyses identified significant differences in mean use of HPDs by age, years of employment, and trade group. The authors recommended considering HPD use and exposure levels, demographics, and trade group membership in designing hearing conservation programs.

NIOSH recommends that the selection of HPDs should take into consideration several factors (NIOSH, 1998), including attenuation characteristics, the need for compatibility with other safety equipment, and workplace conditions (temperature, humidity, atmospheric pressure). It has also been recommended that a variety of styles be provided so that workers may select a device on the basis of comfort, ease of use and handling and impact on communication (Casali and Park, 1990; Royster and Royster, 1990; Franks, Stephenson and Merry, 1996). Moreover, each worker should receive individual training in the selection, fitting, use, repair, replacement of the HPDs (Gasaway, 1985;

Royster and Royster, 1990; Franks, Stephenson and Merry, 1996).

The results of the present study, indicating that the most common reasons reported by workers for not wearing HPD include interference with hearing speech and other important sounds, and discomfort, are consistent with previous reports (Berger, 1980a, b, 2000; Helmkamp, 1986). This underscores the need for careful planning and implementation of hearing loss prevention strategies. NIOSH describes in detail each component of a hearing loss prevention program in two recent publications (Franks, Stephenson and Merry, 1996; NIOSH, 1998). A wealth of information addressing each of these topics is also available on the internet, providing professionals easy access to needed information. This availability of information should boost the potential for HPDs to be appropriately used in the quest for noise-induced hearing loss to be reduced or eliminated in the workplace.

Acknowledgements

This study was financially supported by grants number 50.1831/91-6 and 52.0704/94-0 from the Brazilian Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPq) and by the United States National Institute for Occupational Safety and Health (NIOSH). The authors wish to thank the workers that agreed to participate in the study for their time, interest, and cooperation, and Drs. John Franks, Carol Merry, David Byrne and Greg Lotz, from NIOSH, for helpful critiques of the manuscript.

Correspondence Address

Thais C. Morata
National Institute for Occupational Safety and Health, Division of Applied Research and Technology, 4676 Columbia Parkway/ MS C27 Cincinnati, OH 45226-1998 USA

References

American National Standards Institute (ANSI). Maximum permissible ambient noise levels for audiometric test rooms. ANSI S3.1.-1999. New York, ANSI, 1999.

Barrenäs M.L., Hellström P-A, Starck J. (1998) Hearing conservation. In Prasher D., Luxon L., Pyykkö I. Advances in Noise Research, Vol. II, Protection Against Noise, Whurr Publishers, Ltd: London, 263 p.

Berger E. H. (1980a) EARLog #3 - The effects of hearing protectors on auditory communications. *Sound Vibration* 14(1), 16-7.

Berger E. H. (1980b) EARLog #5 - Hearing protector performance: how they work - and – what goes wrong in the real world. *Sound Vibration* 14(10), 14-7.

Berger E.H. (2000). Hearing Protector Devices. In The Noise Manual. In Berger E.H., Royster L.H., Royster J.D., Driscoll, D.P., and Layne, M. American Industrial Hygiene Association, Fairfax, VA, pp.379-454.

Berger E.H. (2000). Hearing protection device utilization around the world. Proceedings of the 25th Annual Hearing Conservation Conference, Denver, CO, Feb 17-19, 2000, National Hearing Conservation Association.

Casali J.G., Park M.Y. (1990) Attenuation performance of four hearing protectors under dynamic movement and different user fitting conditions. *Hum. Factors*. 32(1):9-25.

Fischer F.M. Morata T.C., Liber R., Colacioppo S., Fiorini A.C., Gozzoli L. (1996) Efeitos combinados de estressores ambientais e organizacionais na saúde dos trabalhadores em empresa do setor gráfico. Research Report- Dept. de Saúde Ambiental- Faculdade de Saúde Pública da Universidade de São Paulo.

Franks J.R., Stephenson M.R., Merry C.J. (1996) Preventing Occupational Hearing Loss- A Practical Guide. DHHS(NIOSH) publication no.96-110.

Gasaway D.C. (1985) Documentation: the weak link in audiometric monitoring programs. *Occup. Health Saf*.54(1):28-33.

Hallberg L.R-M. (1998) Lack of awareness of the risks of noise exposure in men and women. In Prasher D., Luxon L., Pyykkö I. Advances in Noise Research, Vol. II, Protection Against Noise, Whurr Publishers, Ltd: London, 263 p.

Helmkamp J.S. (1986). Why workers do not use hearing protection? *Occ. Health Saf.* 55(10):52.

International Standardization Organization (ISO). Acoustics- Standard reference zero for the calibration of pure-tone audiometers. ISO 389- 1998. Geneva, ISO, 1998.

Lusk SL, Kerr MJ, Kauffman SA (1998) Use of hearing protection and perceptions of noise exposure and hearing loss among construction workers. *Am. Ind. Hyg. Assoc. J.* 59(7):466-70.

Lusk S.L., Kerr M.J., Ronis D.L., Eakin B.L. (1999) Applying the health promotion model to development of a worksite intervention. *Am. J. Health Promot.*13 (4):219-27.

Lusk S.L., Ronis D.L., Kerr M.J., Atwood J.R. (1994) Test of the Health Promotion Model as a causal model of workers' use of hearing protection. *Nurs. Res*. 43 (3):151-7.

Morata T.C., Fiorini A.C., Fischer F.M., Colacioppo S., Wallingford K.M., Krieg E., Dunn, D.E., Gozzoli L., Padrao M.A., Cesar C. (1997) Toluene-induced hearing loss among rotogravure printing workers. *Scand. J. Work Environ. Health*. 23:289-98.

Ministério do Trabalho, MT (1997) Manuais de Legislação Atlas. Segurança e Medicina do trabalho. 36ª ed., v. 16. São Paulo: Atlas, Brasil.

National Institute for Occupational Safety and Health, NIOSH (1998) Criteria for a recommended standard. Occupational exposure to noise. Revised Criteria. Cincinnati: USDHHS, PHS, CDC, NIOSH, publication no.98-126.

Statistical Analysis System, SAS (1996). Cary, NC, USA.

Royster J.D., Royster L.H. (1990) Hearing Conservation Programs: practical guidelines for success. Chelsea, MI: Lewis Publishers, pp.73-5.

Zohar D, Cohen A, Azar N (1980) Promoting increased use of ear protectors in noise through information feedback. *Hum. Factors*. 22(1):69-79.