International Journal of Audiology

ISSN: 1499-2027 (Print) 1708-8186 (Online) Journal homepage: http://www.tandfonline.com/loi/iija20

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To cite this article: Emily Mosites, Richard Neitzel, Deron Galusha, Sally Trufan, Christine Dixon-Ernst & Peter Rabinowitz (2016) A comparison of an audiometric screening survey with an in-depth research questionnaire for hearing loss and hearing loss risk factors, International Journal of Audiology, 55:12, 782-786, DOI: 10.1080/14992027.2016.1226520

To link to this article: https://doi.org/10.1080/14992027.2016.1226520

Taylor & Francis
Taylor & Francis Group

International Journal of Audiology 2016; 55: 782–786

International Journal of Audiology

Original Article

A comparison of an audiometric screening survey with an in-depth research questionnaire for hearing loss and hearing loss risk factors

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Abstract

Objective: We assessed the reliability of a hearing risk factor screening survey used by hearing conservation programmes for noise-exposed workers. *Design*: We compared workers' answers from the screening survey to their answers to a confidential research questionnaire regarding hearing loss risk factors. We calculated kappa statistics to test the correlation between yes/no questions in the research questionnaire compared to answers from 1 and 5 years of screening surveys. *Study sample*: We compared the screening survey and research questionnaire answers of 274 aluminum plant workers. *Results*: Most of the questions in the in-company screening survey showed fair to moderate agreement with the research questionnaire (kappa range: −0.02, 0.57). Workers' answers to the screening survey had better correlation with the research questionnaire when we compared 5 years of screening answers. For nearly all questions, workers were more likely to respond affirmatively on the research questionnaire than the screening survey. *Conclusions*: Hearing conservation programmes should be aware that workers may underreport hearing loss risk factors and functional hearing status on an audiometric screening survey. Validating company screening tools could help provide more accurate information on hearing loss and risk factors.

Key Words: Hearing conservation, noise, behavioural measures, demographics/epidemiology

Introduction

Hearing loss is common among adults in the US population, resulting in nearly 1% of total Disability-Adjusted Life Years (Institute of Health Metrics and Evaluation, 2013). Between 7% and 21% of this hearing loss is attributable to occupational noise exposure globally (Nelson et al, 2005). In the USA, noise-induced hearing loss is considered to be one of the most prevalent occupational illnesses.

Under the Occupational Safety and Health Administration hearing conservation standard, US workers who are exposed to average noise levels of 85 decibels (dB) or greater over an 8-h work shift are required to be enroled in a hearing conservation programme (Occupational Safety & Health Administration [OSHA], 1983). Components of these programmes include noise exposure assessment, worker training, use of hearing protective devices, efforts to control noise, and annual audiometric surveillance for hearing loss. As part of audiometric surveillance activities, workers typically are asked to answer a number of questions regarding use of hearing protection, non-occupational noise exposures, and medical risk factors for hearing loss such as head injury and ear infections. Responses to these questions become part of the employee's medical record. They may be taken into consideration when deciding on the need for a medical referral, counselling about avoiding excessive noise outside of work, or when making a determination of work-relatedness for a workers compensation hearing loss claim. Despite the importance of this information to prevent hearing loss, and the association of some responses to such questionnaires with hearing loss outcomes (Rabinowitz et al, 2008), there has been little examination of the validity of the information gathered in this manner. Some studies, furthermore, have questioned the accuracy of worker self-report of hearing status in hearing conservation programmes (McCullagh et al, 2011).

We compared the responses of workers on a short screening survey administered as part of the company's hearing conservation programme to the responses of these same individuals on an

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(Received 22 December 2015; revised 18 July 2016; accepted 16 August 2016)

ISSN 1499-2027 print/ISSN 1708-8186 online
DOI: 10.1080/14992027.2016.1226520

Abbreviations

AMA	American Medical Association
kHz	kiloHertz
dB	Decibel
OSHA	Occupational Safety and Health Administration
CAOHC	Council for Accreditation in Occupational Hearing Conservation

in-depth, confidential research questionnaire regarding hearing loss risk factors.

Methods

This analysis was conducted using the research questionnaire of a voluntary intervention study of daily noise exposure monitoring which was initiated in 2008. The data were collected from three company locations of Alcoa Inc., a producer of aluminum and other industrial products. These locations included two aluminum smelters and one turbine component factory. These plants were selected for the study in a convenience fashion due to their willingness to have employees participate in the voluntary intervention study. The ongoing research collaboration between Alcoa, the Yale University School of Medicine, the University of Washington and Stanford University School of Medicine has been described elsewhere (Rabinowitz et al, 2013).

Volunteers were recruited if they were noise-exposed workers currently enroled in the company hearing conservation programme and no further exclusion criteria were used. Enrolment was rolling over an 8-year period for both the parent study and this sub-study. Upon enrolment, all workers who provided consent were asked to answer a baseline research questionnaire about previous occupational and non-occupational risk factors for hearing loss with approximately 100 items regarding medical history, relatives with hearing loss, previous work exposures, and recreational activities with noise or chemical exposures. The participants were allowed to answer the questionnaire at home and take as much time as necessary. The reading grade level was 5.4 (see Appendix A). Because participants took the survey at home, it was possible for them to leave questions blank, thereby creating some missing data.

The screening tools were administered at the time of yearly audiometric testing as part of the company's hearing conservation programme (see Appendix B). The screening questions that were available for comparison are outlined in Table 1. Due to wording differences, we linked the screening question about ''noises in ears'' to a research survey question that asked about ''tinnitus (ringing in ears)''. The screening question about ''dizziness'' was linked to a research question about ''unexpected problems with balance'', and the screening question regarding ''mycins, quinine, and excessive aspirin'' was compared to a composite ototoxic drug response from a list of drugs on the research questionnaire. The question regarding noisy hobbies was linked to a composite of hobbies that the research questionnaire asked about explicitly, including use of power tools, motorcycles, heavy equipment, snowmobiles, or attending dances or concerts. The screening tool further asked questions regarding whether or not the worker reported another noisy job either currently or in the past. Even though there were questions regarding prior noise exposure in jobs in the research questionnaire, we were unable to link these to the screening survey due to wording conflicts in the temporality of the question. The baseline research questionnaires were administered at the time of enrolment into the intervention study, which did not necessarily correspond to the time of annual audiometry and the screening tool administration. For comparison to the baseline research questionnaire, we selected each worker's most recent audiometric testing and screening questionnaire (within 1 year prior or 6 months after enrolment in the research study).

We assessed the intra-method reliability of the workers' most recent screening answers, as well as whether the employee ever answered yes over the course of the previous 5 years of screening answers. We compared each of these to the in-depth research questionnaire using proportion agreement and Kappa statistics. These tests were not stratified by any variables. The Landis and Koch cut-offs were used to determine the extent of agreement (poor (<0.00), slight (0.00–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80)) (Landis & Koch, 1977). Wald statistics were calculated for the Kappa results, and significant agreement was considered at $\alpha = 0.05$.

We also compared self-reported hearing loss responses for both the screening questionnaire (using the 5-year screening estimate for higher accuracy) and the research questionnaire to the participants' audiometric hearing thresholds using kappa statistics, sensitivity and specificity measures. The audiometric testing was conducted by in house audiometric technicians certified by the Council for

Table 1. Comparison of company screening survey questions and corresponding research questionnaire items.

Screening survey questions	*Research questionnaire items*
Do you have difficulty hearing?	Self-assessment of hearing: Fair or Poor (Other option: Good)
Have you ever had mycins, quinine, or excessive aspirin?	Please indicate any prescription and nonprescription medications that you are currently taking (open answer)
Have you ever had any noisy hobbies?	For each of the following activities, please indicate whether or not you participate in them: use power tools, motorcycles, snowmobiles, or heavy equipment, attend dances or concerts
Have you ever had a head injury or unconsciousness?	Have you ever had a head injury?
Have you ever had dizziness?	Have you ever had any unexpected problems with balance?
Do you currently wear a hearing aid?	Do you wear a hearing aid?
Have you ever had ear infections?	Do you have a history of ear aches/or ear infections as an adult (18 years or older)?
Have you ever had noises in ears?	Have you ever had tinnitus (ringing in the ears)?
Have you ever had ear surgery?	Have you ever had ear surgery?
Did you ever hunt or shoot?	For each of the following activities, please indicate whether or not you participate in them: shoot firearms? (Other options: ride motorcycles, ride snowmobiles, drive heavy equipment, attend dances, concerts, races, or commercial events)

Accreditation in Occupational Hearing Conservation (CAOHC). For this comparison we determined whether a subject's audiometric thresholds fulfilled American Medical Association (AMA) criteria for hearing impairment (average of 0.5, 1.2 and 3 KHz >25 dB) (Dobie, 2011). We also identified whether participants exhibited an audiometric high frequency ''notch'' as defined by Coles et al (2000); as an additional metric of hearing health. The Coles notch criteria include a hearing threshold level at 3 and/or 4 and/or 6 kHz that was at least 10 dB greater than at 1 or 2 kHz and at 6 or 8 kHz (Coles et al, 2000).

All data were analysed in Stata/SE11 (Statacorp, LP, College Station, TX).

Results

Two hundred and seventy-four plant workers at three sites were included in this analysis (Table 2). These volunteers had been recruited from among approximately 1228 workers enroled in hearing conservation programmes at these three facilities.

According to the research questionnaire, non-occupational noise and other hearing loss risk factor exposures were common. Eighteen percent of individuals reported ear infections as a child or adult, and 4.9% reported ear surgery at any point. Other major medical history exposures included allergies (35.0%), high cholesterol (20.4%), mumps (16.8%), and hypertension (16.3%). Participants commonly reported recreational activities such as listening to music (91.4%), using power tools (59.5%), and using firearms (42.9%). Twenty-eight percent of participants reported fair or poor hearing and 19.8% reported tinnitus. The mean average 2, 3, 4 k threshold (the minimum level of pure tone audible to the employee) was 15.4 dB, and 34.7% of participants exhibited audiometric Coles ''notch'' patterns. Because participants took the research questionnaire on their own, some data points were missing where questions were left blank. These missing data are enumerated in Table 2.

The majority of in-company screening questions showed fair to moderate agreement with the research questionnaire (Table 3). For nearly all questions, workers were more likely to respond affirmatively on the research questionnaire. The largest discrepancy in the

Table 2. Demographics and hearing loss risk factors among workers by site.

Characteristics	*Branford* N = *28*	*La Porte* N = *100*	*Massena* N = *146*	*Missing,* n *(%)*[a]
Age, mean (SD), years	48.8 (9.7)	48.1 (9.3)	43.9 (10.6)	1 (0.4%)
Married, *n* (%)	15 (60%)	55 (55%)	97 (68%)	8 (2.9%)
White race, *n* (%)	13 (56%)	82 (84%)	132 (94%)	12 (4.4%)
Hispanic ethnicity, *n* (%)	12 (50%)	2 (3%)	3 (2%)	8 (2.9%)
Ever smoked, *n* (%)	12 (48%)	57 (58%)	72 (51%)	10 (3.7%)
Regularly use alcohol, *n* (%)	14 (56%)	43 (44%)	82 (58%)	10 (3.7%)
Past military service, *n* (%)	4 (16%)	7 (7%)	26 (18%)	6 (2.2%)
Potential noise exposures outside of work				
Snow mobiles, *n* (%)	1 (4%)	9 (9%)	37 (26%)	9 (3.3%)
Motorcycles, *n* (%)	4 (17%)	19 (20%)	37 (26%)	13 (4.7%)
Fire arms, *n* (%)	5 (21%)	25 (26%)	82 (58%)	13 (4.7%)
Music, *n* (%)	20 (80%)	92 (92%)	133 (93%)	6 (2.2%)
Concerts, *n* (%)	5 (22%)	29 (30%)	61 (43%)	12 (4.4%)
Power tools, *n* (%)	9 (36%)	46 (46%)	108 (75%)	0 (0.0%)
Ear medical history				
Ear infections as an adult, *n* (%)	0 (0%)	4 (4%)	11 (8%)	29 (10.6%)
Ear infections as a child, *n* (%)	5 (23%)	15 (17%)	21 (16%)	31 (11.3%)
Ear surgery, *n* (%)	1 (4%)	5 (5%)	7 (5%)	8 (2.9%)
Ear injury, *n* (%)	1 (5%)	5 (5%)	8 (6%)	19 (6.9%)
Current use of potential ototoxic drugs, *n* (%)	1 (4%)	9 (9%)	14 (10%)	0 (0.0%)

[a]The percent of respondents who did not answer this particular question.

Table 3. Kappa statistics for 1 and 5 years of responses to company audiometric screening questionnaire compared to research questionnaire.

	Research questionnaire	*Five years of screening answers*			*One year of screening answers*		
Indicator	*% yes*	*% yes*	*Kappa*	p *Value*	*% yes*	*Kappa*	p *Value*
Self-report of poor hearing[a]	28%	18%	−0.02	0.609	5%	−0.04	0.847
Current ototoxic drug use	9%	17%	0.13	0.01	5%	0.29	<0.001
Noisy hobbies	76%	39%	0.22	<0.001	20%	0.09	0.003
Head injury	13%	9%	0.30	<0.001	2%	0.24	<0.001
Balance (dizziness)	11%	5%	0.31	<0.001	2%	0.17	<0.001
Use of hearing aid	2%	3%	0.32	<0.001	2%	0.21	0.001
Ear infections as an adult	18%	12%	0.35	<0.001	5%	0.19	0.002
Tinnitus (noise in ears)	20%	19%	0.55	<0.001	11%	0.56	<0.001
Ear surgery	5%	5%	0.57	<0.001	5%	0.50	<0.001
Firearms (hunting/shooting)	43%	47%	0.57	<0.001	24%	0.44	<0.001

[a]Self-reported hearing as ''poor'' or ''fair'' on the research questionnaire.

Table 4. Clinical audiometric outcomes compared to screening survey and research questionnaire answers.

	Screening survey		*Research questionnaire*		
	''Do you have difficulty hearing?''[a]		*''Self-assessment of hearing''*		
	''Yes''	*''No''*	*''Poor'' or ''Fair''*	*''Good''*	*No answer*
2, 3, 4 k threshold, mean dB HTL (SD)	15.8 (1.8)	15.3 (1.0)	27.0 (2.1)	10.1 (0.6)	21.3 (3.4)
Coles notch, *n* (%)	18 (36.7)	77 (34.2)	41 (56.9)	43 (23.6)	11 (55.0)
AMA hearing disabled, *n* (%)	5 (10.2)	27 (12.0)	23 (31.9)	4 (2.2)	5 (25.0)
Kappa for AMA concordance	-0.021, $p = 0.639$		0.37, $p < 0.001$		–

[a]Ever yes vs. not ever yes over the past 5 years.

percentage answering affirmatively was the self-report of engaging in noisy hobbies (37% difference in proportion answering yes). The kappa statistics ranged from -0.04 to 0.57, and the 5-year screening responses had better agreement with the research questionnaire than to the 1-year responses. All but two questions had significant correlation between the 5-year screening answers and research answers. The two questions that scored a lower kappa statistic on the 5-year screening answers compared to the 1-year screening answers were the question regarding current use of ototoxic drugs (1-year kappa 0.29, 5-year kappa 0.13) and the question regarding self-reported tinnitus (1-year kappa 0.56, 5-year kappa 0.55). The highest 5-year kappa statistics were for whether the workers reported any ear surgery and whether they reported using firearms (0.57 each, $p < 0.001$), while the lowest in both the 5-year and 1-year screening responses was whether the worker reported poor hearing.

The agreement between the AMA impairment outcome and the 5-year screening responses to whether or not the worker had any difficulty hearing was poor (Table 4; kappa $= -0.02$, $p = 0.639$), with a sensitivity of 16% and a specificity of 81%. However, the research questionnaire responses of self-reported poor hearing had fair agreement with the AMA impairment criteria (kappa $= 0.37$, $p < 0.001$), with a sensitivity of 85% and a specificity of 78%. Seven percent of participants did not answer the self-reported hearing health research question. These participants had audiometric profiles that were more similar to those who answered that they had ''fair or poor'' hearing than those who responded that they had ''good'' hearing (Table 4).

Discussion

The results of this study suggest that the company hearing conservation audiometric risk factor screening tool was moderately reliable compared to an in-depth research questionnaire. Report of tinnitus and use of firearms had the best alignment, which are factors that may be helpful for hearing conservation programmes to be aware of among employees. However, many hearing loss risk factors were potentially underreported using the company screening questionnaire, which could have important implications for hearing conservation programmes' ability to screen and counsel high risk workers. This type of underreporting may hamper the prevention efforts of a hearing conservation programme, and may be one reason why systematic reviews have questioned the effectiveness of such programmes (Verbeek et al, 2014). The accuracy of the screening questionnaire may be improved by using a consolidation of several years of worker responses to screening questions.

Employees were more likely to answer affirmatively for hearing loss risk factors on the research questionnaire compared to the in-company screening survey. This may reflect the fact that the research questionnaire asked several probing questions and was conducted with a flexible amount of time allowed for the employee to develop responses. On the other hand, the screening survey was administered by an audiometric technician. Although survey probes may have been used, they were not specified in the screening tool document. Further, the research questionnaire was conducted confidentially, which might have led to higher affirmative responses to known hearing loss risk factors compared to a screening survey used within the company. It is possible, for example, that employees would be reluctant to report non-occupational risk factors for hearing loss that could affect a later work-relatedness determination.

Self-reported poor hearing status had the poorest agreement between the in-company screening and research questionnaire. The screening survey hearing status question also demonstrated very weak agreement with the AMA impairment audiometric outcome. This is consistent with previous study findings of underreporting of hearing loss by industrial workers (McCullagh et al, 2011). Self-reported hearing difficulty and audiometry have been extensively compared in several contexts (Kerr et al, 2003; Hong et al, 2011; McCullagh et al, 2011; Kamil et al, 2015). Single-item self-perceived hearing loss measures tend to perform moderately well compared to audiometry (Valete-Rosalino & Rozenfeld, 2005), as demonstrated by the correspondence between the research questionnaire and the audiometric outcomes. The phrasing of the screening tool question may have played a role in the lack of agreement with audiometric outcomes; the screening question could be interpreted to relate to perceived disability from hearing loss, rather than as a self-assessment of hearing impairment. Alternatively, it is possible that employees underreported hearing difficulties on a company questionnaire due to fear of job reprisals. Hearing conservation programmes should be aware of the tendency for employees to underreport hearing difficulties and consider issues related to the denial of hearing loss when considering how employees may best benefit from accommodation of hearing loss in the workplace (Rawool, 2012). Additionally, programmes could review worker responses to such questions over the course of multiple years, as in our analysis, 5 years of ever answering yes on screening questions had higher agreement with the research questionnaire compared to using just the most recent year of screening answers.

A limitation of this study was that the research questionnaire is not a gold standard for evaluating hearing loss risk factors. At the same time, research questionnaire responses about self-reported hearing loss had much higher agreement with clinical audiometric outcome compared to the company screening questionnaire. An additional limitation of this study was the limited number of items in the screening survey compared to the research questionnaire. While the survey included many of the important non-occupational

risk factors identified in the research questionnaire, it was notably lacking a question regarding chemical exposures and we were unable to compare this information. Although chemical exposures such as solvents are only one potential cause of hearing loss, prior studies in the same company found that workers with exposure to organic solvents had higher rates of hearing loss (Rabinowitz et al, 2008), and other researchers have advocated for including information about solvents in hearing conservation programme databases (Pyykko et al, 2000).

This study evaluated the reliability of a company screening survey compared to an in-depth, confidential research questionnaire. We demonstrated that the screening survey for hearing loss risk factors was in moderate agreement with an in-depth research questionnaire, but that workers may be underreporting some of their non-occupational noise exposures and hearing loss symptoms. In light of this evidence, workplace hearing conservation programmes should assess their hearing risk factor screening tools in order to optimise history-taking. Such efforts can help move hearing conservation efforts from compliance to effectiveness by focusing on health promotion and reduction of hearing loss risk factors.

Declaration of interest: Authors Rabinowitz and Galusha have received salary support in the past from Alcoa Inc. under a contract between Alcoa and Yale University. The other authors declare no conflicts of interest concerning the materials or methods reported in this study.

Funding

This study was supported by National Institute for Occupational Safety and Health (NIOSH) grant 2R01OH008641-05A1.

References

Coles, R.R., Lutman, M.E. & Buffin, J.T. 2000. Guidelines on the diagnosis of noise-induced hearing loss for medicolegal purposes. *Clin Otolaryngol Allied Sci*, 25, 264–273.

Dobie, R.A. 2011. The AMA method of estimation of hearing disability: A validation study. *Ear Hear*, 32, 732–740.

Hong, O., Ronis, D.L. & Antonakos, C.L. 2011. Validity of self-rated hearing compared with audiometric measurement among construction workers. *Nurs Res*, 60, 326–332.

Institute of Health Metrics and Evaluation. 2013. *Global Burden of Disease* [Online]. University of Washington. Retrieved March 3, 2015: http://vizhub.healthdata.org/gbd-compare.

Kamil, R.J., Genther, D.J. & Lin, F.R. 2015. Factors associated with the accuracy of subjective assessments of hearing impairment. *Ear Hear*, 36, 164–167.

Kerr, M.J., Mccullagh, M., Savik, K. & Dvorak, L.A. 2003. Perceived and measured hearing ability in construction laborers and farmers. *Am J Ind Med*, 44, 431–437.

Landis, J.R. & Koch, G.G. 1977. The measurement of observer agreement for categorical data. *Biometrics*, 33, 159–174.

McCullagh, M.C., Raymond, D., Kerr, M.J. & Lusk, S.L. 2011. Prevalence of hearing loss and accuracy of self-report among factory workers. *Noise Health*, 13, 340–347.

Nelson, D., Nelson, R., Concha-Barrientos, M. & Fingerhut, M. 2005. The global burden of occupational noise-induced hearing loss. *Am J Ind Med*, 48, 446–458.

Occupational Safety & Health Administration [OSHA]. 1983. *Occupational Noise Exposure: Hearing Conservation Amendment; Final Rule*. Washington (DC): US Department of Labor.

Pyykko, I.V., Toppila, E.M., Starck, J.P., Juhola, M. & Auramo, Y. 2000. Database for a hearing conservation program. *Scand Audiol*, 29, 52–58.

Rabinowitz, P.M., Galusha, D., Dixon-Ernst, C., Clougherty, J.E. & Neitzel, R.L. 2013. The dose-response relationship between in-ear occupational noise exposure and hearing loss. *Occup Environ Med*, 70, 716–721.

Rabinowitz, P.M., Galusha, D., Slade, M.D., Dixon-Ernst, C., O'Neill, A., et alet al. 2008. Organic solvent exposure and hearing loss in a cohort of aluminium workers. *Occup Environ Med*, 65, 230–235.

Rawool, V.W. 2012. *Support for Workers with Noise-Induced Hearing Loss. Hearing Conservation: In Occupational, Recreational, Educational, and Home settings*. New York: Thieme.

Valete-Rosalino, C.M. & Rozenfeld, S. 2005. Auditory screening in the elderly: Comparison between self-report and audiometry. *Braz J Otorhinolaryngol*, 71, 193–200.

Verbeek, J.H., Kateman, E., Morata, T.C., Dreschler, W.A. & Mischke, C. 2014. Interventions to prevent occupational noise-induced hearing loss: A Cochrane systematic review. Int *J Audiol*, 53, S84–S96.