Prevalence of hearing loss and accuracy of self-report among factory workers

Marjorie C. McCullagh, Delbert Raymond[1], Madeleine J. Kerr[2], Sally L. Lusk

University of Michigan School of Nursing, [1]Eastern Michigan University School of Nursing, [2]University of Minnesota School of Nursing, MI, USA

Abstract

Noise represents one of the most common occupational health hazards. A Healthy People 2020 objective aims to reduce hearing loss in the noise-exposed public. The purpose of this study was to describe and compare perceived and measured hearing, and to determine the prevalence of hearing loss among a group of factory workers. Data collected as part of an intervention study promoting hearing protector use among workers at an automotive factory in the Midwest were used. Plant employees (*n*=2691) provided information regarding their perceived hearing ability, work role, and other demographics. The relationships among audiograms, a single-item measure of perceived hearing ability, and demographic data were explored using chi-square, McNemar's test, Mann-Whitney *U*-test, sensitivity, and specificity. The prevalence of hearing loss among noise-exposed factory workers was 42% (where hearing loss was defined as >25 dB loss at the OSHA-recommended frequencies of 2, 3, and 4 kHz in either ear). However, 76% of workers reported their hearing ability as excellent or good. The difference in perceived hearing ability was significant at each tested frequency between those with and without measured hearing loss. Self-reported hearing ability was poorly related to results of audiometry. Although this group of workers was employed in a regulated environment and served by a hearing conservation program, hearing loss was highly prevalent. These findings, together with national prevalence estimates, support the need for evaluation of hearing conservation programs and increased attention to the national goal of reducing adult hearing loss.

Keywords: *Audiometry, auditory perception, factory workers, hearing loss, prevalence*

Introduction

Perceived and measured hearing ability among factory workers

Noise is a common occupational hazard in the United States (U.S.). Recognizing the widespread risk of noise exposure, the Healthy People 2020 initiative is retaining a Healthy People 2010 objective to prevent hearing loss in the noise-exposed public: "Reduce the proportion of adults who have elevated hearing thresholds or audiometric notches, in high frequencies (3, 4, or 6 kHz) in both ears, signifying noise-induced hearing loss."[1] Nationally there are limited audiometric data on the hearing ability of adults to describe the scope of the problem or measure progress toward preventing noise-induced hearing loss. Population-based approaches sometimes use self-reports to obtain an index of morbidity or risk for a health issue. Because direct audiometric measures of hearing ability are available only on select populations, a self-report measure could more readily provide an estimate of population prevalence. We explored the feasibility of self-reported hearing ability as an index of population hearing health using existing data from a large intervention trial with noise-exposed factory workers. The purpose of this study was to describe and compare the perceived and measured hearing ability among a group of noise-exposed factory workers, and to determine the prevalence of hearing loss in this group.

Access this article online	
Quick Response Code:	Website: www.noiseandhealth.org
	DOI: 10.4103/1463-1741.85504
	PubMed ID: ***

Literature review

Factory settings are known for their noisy environments. According to a recent study by the National Institute for Occupational Safety and Health (NIOSH), an estimated 5.7 million workers in the manufacturing industry are exposed to

Presentation at a Meeting:
National Hearing Conservation Association
Place: Phoenix, AZ, USA
Date: February 25-26, 2011

hazardous work noise, representing 25% of all U.S. workers exposed to noise at work.[2]

The NIOSH hierarchy of controls approach favors engineering controls or administrative controls to reduce noise exposure. Noise exposure can be avoided when purchasing new equipment through a "buy quiet" purchase policy.[3] Such purchasing practices have been mandated in some European countries. In the United States, however, the primary approach has been the use of hearing protection at the individual worker level, the last line of defense in the hierarchy of controls.

The Occupational Safety and Health Administration (OSHA) noise standard 1910.95 mandates a hearing conservation program for employees exposed to an 85 dBA time-weighted average (TWA) or above. The standard defines a comprehensive hearing conservation program including noise exposure monitoring, administrative or engineering controls, audiometric testing of employees, provision of hearing protection, employee training, and record keeping.[4] Although OSHA guidelines define hearing loss for that Standard, many other operational definitions are also in use. For example, definitions may address speech frequencies (0.5-4 kHz) versus high frequencies (3-6 kHz), best ear versus worst ear, and different decibel thresholds.

There is no U.S. database of occupational hearing measurement; however, some national probability sample studies offer data on hearing ability. Several groups of researchers have recently mined these data in order to estimate prevalence and trends in hearing loss in the United States. Using self-report data from the National Health Interview Survey (NHIS), researchers from NIOSH estimated an 11.4% population prevalence of hearing difficulty; 24% was attributable to employment.[5] Other researchers have estimated different levels of occupational attribution.[6,7] Prevalence of hearing difficulty in manufacturing ranged from a low of 11.1% for chemical and allied products to a high of 22.4% for primary metal industries.[5] Using audiometric data from the most recent National Health and Nutrition Examination Survey (NHANES) dataset (2003--2004), Agrawal and colleagues derived a 31% prevalence of high-frequency hearing loss (equivalent to 55 million Americans) and a 16.1% prevalence of speech frequency hearing loss.[8] In an effort to examine trends in prevalence of hearing loss over 30 years, Ikeda and colleagues corrected for self-report bias in four nationally representative survey series 1976-2006: Medical Expenditure Panel Survey (MEPS), NHANES, NHIS, and the Survey of Income and Program Participation (SIPP). They found that prevalence of hearing loss had decreased from 12% in 1993 to 8.1% for men, and from 7% in 1993 to 4% for women in 2000, and remained stable through 2006.[9] Interpretation of these prevalence findings must consider the divergent definitions of hearing loss among the studies.

Several studies have examined the relationship between self-reported and measured hearing ability to assess sensitivity and specificity of perceptions [Table 1]. Sensitivity and specificity are classic measures that reflect the percent agreement between a true state and a screening test. Sensitivity is the ability of the screening test to accurately identify the presence of true morbidity, while specificity is a measure of a test to accurately identify the absence of morbidity.[10]

Table 1: Studies reporting prevalence of measured hearing loss and congruence with self-reported hearing ability

Authors	Year	Sample	Question used	Measured hearing	Outcome
Agrawal *et al*.	2008	5742 people aged 20-69 in the audiometric component of the National Health and Nutrition Examination Survey (NHANES) 1999-2004 U.S.	Self-reported hearing loss (4-point) dichotomized to no loss (*"good"*) or hearing loss (*"a little trouble hearing," "a lot of trouble hearing," or "deafness"*)	Pure-tone audiometry 0.5—4 kHz > 25dB unilateral and bilateral categories	Prevalence of speech frequency loss 16.1% (8.9% unilateral; 7.3% bilateral) Sensitivity (46% unilateral; 65% bilateral). Specificity (81% unilateral; 83% bilateral).
				3-6 kHz > 25 dB	Prevalence high-frequency loss 31% (12% unilateral; 19% bilateral). Sensitivity 41%, specificity 88%
Kerr *et al*.	2003	*n*=147 construction workers *n*=150 farmers U.S.	How would you rate your ability to hear/How would you rate your overall hearing at the present time? (*"excellent," "good," "fair," "poor"*) dichotomized to excellent/good, fair/poor	Pure-tone audiometry >25 dB any frequency	Prevalence (at 6000 Hz) 63.9% construction; 78.7% farmers. Sensitivity 30-72%, specificity 48-91%.
Nondahl *et al*.	1998	*n*=3556 aged 48-92 Epidemiology of hearing loss study U.S.	Do you feel you have a hearing loss? (*yes, no*)	Pure-tone audiometry 0.5-4 kHz >25 dB worse ear	Prevalence 45.9% Sensitivity 71% Specificity 71%
Sindhusake *et al*.	2001	*n*=2015 aged 55-99 participants in Blue Mountains Hearing Study 1977-1999 Sydney, Australia	Do you feel you have hearing loss? (*"yes," "no," "do not know"*)	Pure-tone average 0.5-4 kHz > 25 dB better ear	Prevalence 39.4% Sensitivity 78% Specificity 67%

There is no standardized measure of self-reported hearing ability. As described in Table 1, single items are the norm, and there are varying approaches to the questions and response formats. One of the earliest measures still in use today in the National health interview study (NHIS) was evaluated in 1970 for the National center for health statistics.[11] The single item asks "Which statement best describes your hearing (without a hearing aid)?" Response options include *good, a little trouble, a lot of trouble,* and *deaf*.

Table 1 displays studies examining the relationship between self-reported and measured hearing ability, including the sample description, instruments for self-reported and measured hearing ability, and study outcomes. Agrawal *et al*. evaluated the accuracy of self-report with three different types of hearing loss: bilateral speech frequencies, unilateral speech frequencies, and high frequency loss in either ear. Sensitivity was significantly higher (65%) for bilateral loss, compared to 46% for unilateral loss, and 41% for high frequency loss. Specificity ranged from 81% to 88%.[8]

Kerr *et al*.[12] evaluated the accuracy of perceived hearing ability related to individual frequencies in audiometric results. Sensitivity varied by type of worker and frequency. Sensitivity ranged from 0.30 (at 6000 Hz) to 0.60 (at 2000 Hz) for construction laborers, and 0.46 (at 500 Hz) to 0.72 (at 1000) Hz for farmers. Specificity ranged from 0.79 (at 500 Hz) to 0.91 (at 4000 Hz) for construction laborers, and 0.48 (at 500 Hz) to 0.70 (at 4000) Hz for farmers.

Nondahl *et al*.[13] examined audiometric results and three measures of perceived hearing loss in adults to assess sensitivity and specificity of perceptions. The best performing subjective measure of hearing loss had a sensitivity of 71% and specificity of 71% with respect to the audiometric measure.

Sindhusake *et al*.[14] validated self-report against measured hearing loss in an older population (55-99 years). They found that a single question yielded sensitivity of 78% and specificity of 67%.

As can be seen in the review of these studies, there is wide variability in the methods used to measure self-report, the samples studied, and in the sensitivity and specificity found. These results illustrate the need for further study with a variety of measures of perceived hearing ability and target populations.

In the secondary analysis reported here, we used three alternative methods of interpreting audiogram results, as there is no consensus on this definition in the literature. The goal of the current study was to compare a self-report questionnaire item measuring perceived hearing ability with the gold standard of measured hearing ability, the audiogram. The population was a group of noise-exposed factory workers.

Methods

This investigation used a cross-section of data from manufacturing workers to describe the prevalence of hearing loss, and assess the sensitivity and specificity of the perceived hearing measure to actual audiogram data. The original survey data collection was completed through a computer interface that presented questions in printed format on-screen and offered audio narration of the question. Subjects used a specialized numeric keypad to enter their responses. The employer provided audiogram and noise exposure data linked to subjects. The original study[15] utilized an experimental design to test alternative interventions to increase workers' use of hearing protection. The development of the intervention is discussed elsewhere.[15]

The sample (*n*=2831) consisted of workers at a Midwest automotive factory. To be included in this analysis, all subjects must have been exposed to 80 or greater decibels (A-weighted, 8-hour TWA) of noise at work, and they must have responded to questions regarding their perceived hearing ability (*n*=2691).

Descriptive variables reported in this study included gender, ethnicity, age, education level, years employed at the site, level of noise exposure, rate of hearing protection use, perceived hearing ability, and audiogram data. Noise-level exposure and audiogram data were collected annually by the company in compliance with the OSHA Hearing Conservation Standard requirements.

Perceived hearing ability was measured by subject self-report to the question, "How good is your hearing?" Response categories were *"excellent," "good," "fair," and "poor."* This item was derived from the Philadelphia Geriatric Center multilevel assessment instrument (MAI), an instrument designed to measure well-being of the aged in a number of domains, including health.[16]

Hearing status was determined using subjects' audiograms. Data were available for the frequencies of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz in each ear. The study used three alternative methods of measuring the true state of hearing status, as there is no consensus on this definition in the literature. These methods to calculate hearing status were (a) Kerr *et al*,[12] (b) OSHA, and (c) Prince *et al*.[17] For the Kerr *et al*. approach, the subjects were identified as having hearing loss if their audiograms identified any hearing threshold value of greater than 25 dB in either ear at any single frequency.

For the OSHA-defined hearing loss measure, subjects were identified as having hearing loss if the audiogram identified a hearing threshold value of greater than 25 dB for the mean combined value of the 2000, 3000, and 4000 Hz in either ear.

No comparison with previous hearing threshold measures was made.

In the measure of hearing loss used by Prince,[17] calculation weights were assigned to the frequencies of 1000, 2000, 3000, and 4000 Hz averaged over both ears to obtain a single value. Using the Prince method, hearing loss was defined as having a hearing threshold value of greater than 25 dB for the combined ear value for the weighted frequencies of 1000, 2000, 3000, and 4000 kHz.

Sample descriptive data were summarized using percent distributions, means and standard deviations. For examination of differences between those who perceived hearing loss and those who did not, the perceived hearing ability variable was dichotomized into two groups: those reporting excellent or good hearing (i.e., no perceived hearing loss), and those reporting fair or poor hearing (i.e., perceived hearing loss). The chi-square (for use with categorical variables) and *t*-test (for variables with a quantitative mean score) were used to examine between group differences on distributions of demographic variables for those who perceived hearing loss and those who did not. McNemar's test was used to examine the relationship between the dichotomized perceived hearing groups and each of the alternative approaches to the audiogram-defined hearing status. For each threshold frequency, the Mann-Whitney *U*-test was used to examine for mean score differences on the original perceived hearing variable scale (1 = *excellent,* 2 = *good,* 3 = *fair,* and 4 = *poor*) between those identified with and those without measured hearing loss (>25dB). Sensitivity and specificity were computed for perceived hearing loss against each of the three measures of hearing loss, using the assumption that the audiometric data were the true state.

Results

Table 2 presents the demographic data results for the total sample and grouped by those with and without perceived hearing loss. The sample was primarily Caucasian (74.0%) and male (87.5%), with a mean age of 44.4 years (S.D. = 9.8). The majority had completed high school (89.9%), and reported a mean of 17.4 years worked at the plant. The mean noise exposure level was 91 dBA, and subjects reported using hearing protection about 77% of the time when exposed to hazardous noise. Approximately 24% of the sample reported fair or poor hearing.

When examining for differences on the demographic measures between those who perceived having hearing loss and those who did not, several theoretically expected findings were noted. All demographic measures were significantly different between the two groups. Compared to those without reported hearing loss, the group reporting hearing loss had a higher percent of white males, was older, worked longer at the plant, reported lower use of hearing protection, and had a lower rate of high school graduation. While still at a hazardous level, mean noise exposure was lower for those identified as having hearing loss than those who did not report having hearing loss (90.33 dBA vs 91.26 dBA, respectively). Of those classified as having perceived hearing loss, 19% reported having poor hearing, and 81% reported fair hearing.

Table 2: Demographic variables by perceived hearing loss groups and total sample

	Perceived hearing loss (*n*=636)	No perceived hearing loss (*n*=2055)	Total (*n*=2691)
Age [mean (SD)]*	49.1 (7.4)	42.9 (9.9)	44.4 (9.8)
Years at plant [mean (SD)]*	22.2 (15.7)	16.0 (14.9)	17.4 (15.3)
Noise level (dBA) [mean (SD)]*	90.3 (4.3)	91.3 (4.7)	91.0 (4.6)
Use of HP [mean (SD)]*	69.0 (34.9)	79.8 (30.1)	77.2 (31.6)
Gender as male [% (*n*)]*	92.9 (591)	85.8 (1764)	87.5 (2355)
Ethnicity [% (*n*)]**			
Asian	0.8 (5)	0.5 (10)	0.6 (15)
African-American	9.3 (59)	12.9 (263)	12.0 (322)
Caucasian	78.2 (496)	72.1 (1482)	74.0 (1978)
Hispanic	6.5 (41)	9.0 (183)	8.4 (224)
Native American	3.2 (20)	2.6 (54)	2.8 (74)
Other	2.1 (13)	2.3 (47)	2.2 (60)
Education level [% (*n*)]*			
Not high school graduate and no GED	14.5 (92)	8.6 (176)	10.0 (268)
High school graduate or GED	47.8 (304)	55.0 (1130)	53.3 (134)
Trade school	26.1 (166)	20.8 (426)	22.0 (592)
Associate degree	6.3 (40)	7.9 (163)	7.5 (203)
Bachelor degree	4.2 (27)	6.9 (141)	6.2 (168)
Graduate degree	1.1 (7)	0.8 (17)	0.9 (24)
Perceived hearing [% (*n*)]*			
Excellent	NA	29.9[b] (613)	22.8 (613)
Good	NA	70.2[b] (1442)	53.6 (1442)
Fair	81.0[a] (515)	NA	19.1 (515)
Poor	19.0[a] (121)	NA	4.5 (121)

[a]Results for those reporting perceived hearing loss. [b]Results for those reporting no perceived hearing loss. *$P < 0.001$; **$P < 0.05$

Table 3 summarizes the audiogram data for the subjects. The percent of cases with a threshold value greater than 25 dB in either ear is reported by each frequency. The McNemar's test identified a significant difference in the distribution of hearing loss between the left and right ears. There was a greater prevalence of hearing loss in the left ear compared to the right for all frequencies except at the frequency of 8000 Hz. The overall prevalence of hearing loss in either ear demonstrated an audiometric notch,[1] consistent with noise-induced hearing loss.

The relationship between measured hearing status and sound frequency (Hz) was also examined by self-reported (i.e., perceived) hearing. Table 4 summarizes the perceived hearing status scores (and standard deviations) for subjects with measured hearing loss and those without. The Mann-Whitney *U*-test for differences in the rank ordinal scores was significant at all frequencies, and perceived hearing scores were all in the expected direction. For all frequencies, subjects identified as having no measured hearing loss reported better perceived hearing scores. Highest scores for perceived hearing ability (indicating poorer hearing) were associated with lower frequencies (i.e., 500–2000 Hz).

Table 3: Percent of workers with measured hearing loss (>25 dB) by frequency for loss in either ear and by each ear

Frequency (Hz)	Left (%)	Right (%)	P^a	Either ear (%)
500	5.1	3.9	0.008	7.4
1000	6.9	5.1	<0.001	8.7
2000	16.8	14.2	<0.001	20.7
3000	36.6	30.3	<0.001	41.9
4000	49.1	43.3	<0.001	54.6
6000	43.5	39.3	<0.001	51.7
8000	39.5	38.6	0.359	48.8

[a]McNemar's test *P* value testing for differences in hearing loss case distribution between left and right ears

Table 4: Means (and standard deviations) of perceived hearing scores[a] by frequency for subjects with measured hearing loss (>25 dB) in either ear and those with no loss

Frequency (Hz)	No hearing loss	Hearing loss	P^b
500	2.00 (0.74)	2.72 (0.85)	<0.001
1000	1.99 (0.73)	2.73 (0.84)	<0.001
2000	1.89 (0.69)	2.66 (0.77)	<0.001
3000	1.75 (0.64)	2.47 (0.74)	<0.001
4000	1.66 (0.62)	2.38 (0.73)	<0.001
6000	1.70 (0.64)	2.38 (0.75)	<0.001
8000	1.76 (0.65)	2.37 (0.76)	<0.001

[a]Perceived hearing where 1 = *excellent*, 4 = *poor*. [b]Mann-Whitney *U*-test

Table 5: Agreement between perceptions of hearing loss and measured hearing loss (> 25 db) by frequency for each ear

Frequency (Hz)	Left ear		Right ear	
	Sensitivity (%) (hearing loss)	Specificity (%) (no hearing loss)	Sensitivity (%) (hearing loss)	Specificity (%) (no hearing loss)
500	60.4	78.4	61.9	77.9
1000	57.8	78.9	66.7	78.7
2000	58.5	83.4	57.9	82.0
3000	45.6	89.1	47.8	86.9
4000	39.1	91.2	42.1	90.4
6000	41.1	89.8	42.6	88.7
8000	41.3	87.9	41.3	87.5

The agreement between perceptions of hearing loss and measured hearing loss is shown in Table 5. Sensitivity by frequency ranged from 39.1% to 60.4% for the left ear, and 41.3% to 66.7% for the right ear. The sensitivity of the self-reported measure with the frequencies of 4000, 6000, and 8000 Hz was similar for both ears, ranging from 39.1 to 41.3 in the left ear and 41.2 to 42.6 in the right ear. The frequencies associated with the highest (best) sensitivity levels were 500 Hz for the left ear, and 1000 Hz for the right ear. Overall, the sensitivity levels of the self-report measure were less than 67%, suggesting low congruence for all frequencies between measured hearing loss and perceived hearing loss.

Specificity by frequency ranged between 78.4% and 91.2% for the left ear, and 77.9% and 90.4% for the right ear. The 4000 Hz frequency was associated with the highest value for the specificity measures for both ears. At just over 90%, the 4000 Hz measure suggests a high congruence between measured and perceived hearing ability among those with no measured hearing loss. These findings suggest that although sensitivity was highest in the lower frequencies, it was low overall. In contrast, specificity was higher than sensitivity in all frequencies.

Table 6 presents the percent of cases identified as having loss using each of the three alternative analysis methods. The greatest number of hearing loss cases were identified using the Kerr *et al*. method, while the Prince *et al*. method identified the fewest. Table 6 also reports the agreement between measured hearing ability (using the three alternative approaches) and perceived hearing loss. Additionally, McNemar's test found that the distribution of measured hearing loss differed significantly (*P*<0.001) from the subject's perceived hearing loss for each of the three alternative definitions studied.

Sensitivity of perceived hearing loss was low regardless of which of the three methods was used to classify hearing loss. In contrast, specificity of perceived hearing ability was high for all three measures. Of the three approaches to measured hearing loss, the Kerr *et al*. method was superior for agreement between subject perceptions of good hearing and audiometric data suggesting good hearing ability. Specificity with this measure was 94.6%. Meanwhile, this measure attained the lowest level of sensitivity (31.9%). Sensitivity of the OSHA method was 10% greater than that reported for the Kerr *et al*. measure. Specificity with the OSHA method was slightly lower than the Kerr *et al*. method. Sensitivity with the Prince *et al*. method was the highest of the three audiogram analysis

Table 6: Prevalence of hearing loss and percent agreement between perceptions of hearing loss and audiogram analysis results (*n*=2691)

Audiogram analysis criteria applied	Workers with measured hearing loss % (*n*)	Sensitivity (perceived hearing loss) (%)	Specificity (no perceived hearing loss) (%)
Kerr *et al*.	68.9 (1854)	31.9	94.6
OSHA	42.1 (1132)	44.4	91.5
Prince *et al*.	29.7 (798)	52.1	88.4

methods. While still quite low, the sensitivity of the Prince *et al*. measure was 52.1%. Specificity was lowest with the Prince *et al*. method.

Discussion

Workers in this study sample were protected by a workplace hearing conservation program in compliance with the OSHA Hearing Conservation Amendment designed to protect noise-exposed workers from the negative effects of their exposure. However, despite this protection, results of this analysis were sobering. Indeed, all three methods of analysis demonstrated high rates of hearing loss in the sample studied. Although the results cannot determine the sources of their hearing loss (i.e., work-related, other environmental exposures, biologic, chemical, and pharmacologic factors), these findings demonstrate the need for continued policy and program development to protect workers' hearing, even in regulated industries.

Results of the current study can be compared to that of Kerr *et al*. Prevalence of hearing loss in the sample studied here was somewhat lower than that reported by Kerr *et al*. for farmers and construction laborers. The best sensitivities were at the middle frequencies (1000-2000 Hz) in the farmers (72%) and construction (60%) workers. In the factory worker group, sensitivity was best at 500-2000 Hz (58%-67%). The best specificities were at 4000 Hz in all three worker groups: farmers (91%), construction laborers (70%), and factory workers (90%-91%). While the self-report instruments were similar in these two studies, differences in sensitivity and specificity between studies may be explained by the differences in measured hearing ability between these two groups. Although the sensitivity of the questionnaire was low in all three groups studied (construction laborers, farmers, and factory workers), it performed somewhat better in the farmer group. This difference may be related to higher levels of hearing loss in speech frequencies (up to 37%) in this worker group.

Prevalence of hearing loss in the present study can be compared to NHANES. Using a sample of adults ages 20 to 69 years. Agrawal[12] found that 16% of US adults experienced speech-frequency hearing loss (i.e., pure tone average of 25 dB or higher at 500, 1000, 2000, and 4000 Hz in either ear). Although not identical, the definition of hearing loss used in this study most comparable to that used by Agrawal is the OSHA definition. The worker group in this study showed a higher rate of hearing loss (42%) than in the Agrawal study. This difference may be explained, in part, by differences between samples in noise exposure, as well as measurement methods.

Due to the challenges inherent in obtaining adequate numbers of audiometric results for workers, there is a need for development of reliable and valid self-report measures of hearing ability. Our single-item measure of perceived hearing ability resulted in low sensitivity, and is therefore a poor measure of actual hearing loss. Although NHANES surveys 5000 Americans annually, it conducts audiograms on only a subset of this sample, which includes but is not representative of the US workforce. Therefore, there remains a need for future development of a non-audiometric, subjective measure of hearing ability. For example, Ikeda[9] suggests extrapolating actual hearing ability from a measure of perceived hearing, then correcting for self-report bias.

There was great disparity in the prevalence of hearing loss depending on the definition of hearing loss used. Specifically, the Kerr *et al* method identified 1854 cases, while the Prince method identified 798 cases. Lacking a standard definition of hearing loss allows under- or over-reporting of prevalence, depending on approach. Researchers and clinicians need to clearly describe their definition of hearing loss when reporting prevalence and screening results.

To be effective in prevention of noise-induced hearing loss, hearing protection must be used nearly all of the time a person is exposed to high noise. In the sample studied here, workers reported use of hearing protection between 69% and 80% of the time they were exposed to high noise. This rate of use of hearing protection is therefore lower than ideal, and is not expected to fully protect workers from the negative effects of noise exposure. NIOSH[3] estimates that failure to use hearing protection during just 30 minutes of daily noise exposure results in a 50% loss in effectiveness of hearing protection. Although programs to support full worker adherence to hearing protection device use are laudable, engineering, and administrative measures to reduce noise exposure are also needed.

In the sample studied here, lower perceived hearing ability was associated with the speech frequencies (500-2000 Hz). Unfortunately, this is consistent with the insidious nature of NIHL, where the early losses in the higher frequencies are less likely to be detected by the affected person. This suggests that those workers with measured low frequency loss likely demonstrate large losses across all frequencies, and in the speech range frequencies in particular. Hence, perceptions of hearing loss are likely to be increased (and very real) for those who demonstrate measured low frequency losses.

Perceived hearing ability had low sensitivity regardless of the definition of measured hearing loss used. This finding is consistent with audiometric screening tests identifying hearing loss before the subject identifies it. The low sensitivity suggests that perceived hearing as measured in this study is a poor measure of hearing ability and is not an acceptable substitute for audiometric screening. Further development of methods of measurement of perceived hearing (e.g., functional ability self-assessment) for use in prevalence estimates is warranted. Although the specificity of the self-report instrument was better than the sensitivity in the study sample, the lower sensitivity precludes its use in screening for hearing loss.

Although regulations and programs are in place to protect workers' hearing, the status of workers' hearing and effectiveness of these policies and programs (e.g., across employers and within industries) is unknown. While individual employers with hearing conservation programs may examine their databases of serial audiograms for changes over time, these data are not currently aggregated across employers and industries. Moreover, the United States does not currently has a worker hearing status surveillance program. Surveillance data are needed to evaluate the effectiveness of hearing conservation policies and programs, and to make recommendations to improve their effectiveness. The Healthy People 2020 benchmark using NHANES data is a step in this direction.

NIOSH has advocated a hierarchy of controls approach, which prioritizes alternative control measures. For example, this hierarchy gives higher preference to engineering controls (such as preventing or containing noise hazards). Since at least 1996, NIOSH has advocated "buy quiet" programs in industry as a means of reducing workers' noise exposure.[3] Buy quiet programs involve consideration of noise levels of equipment prior to the selection for purchase of new equipment. This engineering control technique is preferred over use of personal protective equipment, as it reduces ambient noise levels as well as reliance on workers' adherence to hearing protector use in environments where noise hazards are present. The extent of implementation of this NIOSH recommendation, as well as its effectiveness, is to date unknown. More information is needed about the use and effectiveness of this and other engineering and administrative measures to protect worker hearing. For example, the European Commission has initiated collaborations among local, national, and EU levels, aimed at reducing noise exposure through strategies such as developing noise exposure databases, expert groups, and research.[18] This approach is in contrast to that in the United States, where policy relies heavily on noise level monitoring and use of hearing protection devices in the workplace. This heavy reliance on the least desirable of control measures is contrary to the hierarchy of hazard controls.

Monitoring the effectiveness of hearing conservation programs is problematic. Healthy People 2020 has identified the annual National Health and Nutrition Examination Survey (NHANES) as the mechanism for collecting data on progress on Objective ENT-VSL-6 (increase use of hearing protection devices). However, the annual sample size for selected segments of the working population is too small to provide reliable estimates, requiring the aggregation of several years of data for reliable estimates.[1,3] Development of EU-style collaborations between local, state, and national governments and industries may facilitate the development of noise and hearing databases that would assist in assessing progress on national hearing health objectives, and provide direction for development of public policy in this area.

Conclusions

Results of this study demonstrate that the congruence between the single-item measure of perceived hearing loss used in this study and the gold standard of audiometric tests is low. This is consistent with other studies[8,13,14] that demonstrate a discrepancy between measured and perceived hearing loss.

Because not all noise-exposed workers benefit from hearing conservation programs, there is a need for the development and implementation of surveillance methods, policies, and programs that address the needs of all segments of labor. These surveillance measures will be useful in the identification of hearing health needs among workers, prioritization of these needs, evaluation of effectiveness of hearing conservation programs, and prevention of hearing loss.

Address for correspondence:
Dr. Marjorie C. McCullagh,
400 N. Ingalls, Suite 3182, Ann Arbor, MI 48109, USA.
E-mail: mcculla@umich.edu

References

1. DHHS. *Healthy People 2020*. Washington, DC: DHHS; 2010.
2. Tak S, Davis RR, Calvert GM. Exposure to hazardous workplace noise and use of hearing protection devices among US workers-NHANES, 1999-2004. Am J Ind Med 2009;52:358-71.
3. NIOSH. Preventing occupational hearing loss: A practical guide (publication no. 96-110). Washington, DC: NIOSH; 1996.
4. US Department of Labor, Occupational Safety and Health Administration. Standards - 29 - CFR. Available from: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDSandp_id=9735. [Last accessed on 2011].
5. Tak S, Calvert GM. Hearing difficulty attributable to employment by industry and occupation: an analysis of the National Health Interview Survey--United States, 1997 to 2003. J Occup Environ Med 2008;50:46-56.
6. Dobie RA. The burdens of age-related and occupational noise-induced hearing loss in the United States. Ear Hear 2008;29:565-77.
7. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. Am J Ind Med 2005;48:446-58.
8. Agrawal Y, Platz EA, Niparko JK. Prevalence of hearing loss and differences by demographic characteristics among US adults: data from the National Health and Nutrition Examination Survey, 1999-2004. Arch Intern Med 2008;168:1522-30.
9. Ikeda N, Murray CJ, Salomon JA. Tracking population health based on self-reported impairments: Trends in the prevalence of hearing loss in US adults, 1976-2006. Am J Epidemiol 2009;170:80-7.
10. Dever G. Epidemiology in health services management. Rockville, MD: Aspen; 1984.
11. National Center for Health Statistics. Development and evaluation of an expanded hearing loss scale questionnaire. Rockville, MD: National Center for Health Statistics; 1970. Public Health Service Publication No. 1000, Series 2, No. 37.
12. Kerr MJ, McCullagh M, Savik K, Dvorak LA. Perceived and measured hearing ability in construction laborers and farmers. Am J Ind Med 2003;44:431-7.
13. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BE.

Accuracy of self-reported hearing loss. Audiology 1998;37:295-301.
14. Sindhusake D, Mitchell P, Smith W, Golding M, Newall P, Hartley D, *et al*. Validation of self-reported hearing loss: The Blue Mountains Hearing Study. Int J Epidemiol 2001;30:1371-8.
15. Lusk SL, Ronis DL, Kazanis AS, Eakin BL, Hong O, Raymond DM. Effectiveness of a tailored intervention to increase factory workers' use of hearing protection. Nurs Res 2003;52:289-95.
16. Lawton MP, Moss M, Fulcomer M, Kleban MH. A research and service oriented multilevel assessment instrument. J Gerontol 1982;37:91-9.
17. Prince MM, Stayner LT, Smith RJ, Gilbert SJ. A re-examination of risk estimates from the NIOSH Occupational Noise and Hearing Survey (ONHS). J Acoust Soc Am 1997;101:950-63.
18. European Commission. Environment: Noise: The green paper. Available from: http://ec.europa.eu/environment/noise/greenpap.htm. [Last accessed on 2011 Mar 10].

How to cite this article: McCullagh MC, Raymond D, Kerr MJ, Lusk SL. Prevalence of hearing loss and accuracy of self-report among factory workers. Noise Health 2011;13:340-7.

Source of Support: Primary study was conducted at the University of Michigan, Grant sponsor: NIH, NINR; Grant number: 2 R01 NR 0205., Sally L. Lusk, Principal Investigator, **Conflict of Interest:** None declared.