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An Epidemiologic Method for Assessing the Effectiveness of Hearing Conservation Programs Using Audiometric Data

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A hearing conservation program (HCP) must include audiometric monitoring. In keeping with this requirement, enormous bodies of audiometric data have been accumulated. However, only a limited number of methods are available for using audiometric data to assess HCP effectiveness. This study illustrates an epidemiologic method. The risk of developing hearing loss (measured by the standard threshold shift) was compared between study and reference populations using the risk ratio. The study population had an increased risk of nearly 3-fold. Epidemiologic risk comparison methods, using reference populations, offer an alternative to current methods for HCP evaluation using audiometric data.

Introduction

In the United States, it is estimated that more than nine million workers are exposed to noise levels that are potentially hazardous to their hearing.[1] In order to protect noise-exposed workers from noise-induced hearing loss, the law requires employers to establish a hearing conservation program (HCP) whenever employee noise exposures equal or exceed an 8-hour time-weighted average (TWA) of 85 decibels measured on the A scale (dBA), or a dose of 50%, known as the Occupational Safety and Health Administration (OSHA) action level.[2] Periodic audiometric evaluations are recognized as a required element of any HCP. In keeping with this requirement, an enormous quantity of audiometric data has been accumulating in the archives of many workplaces. However, in many instances there have not been attempts to assess the risk of occupational noise-induced hearing loss in the entire worker population of a HCP. One reason for this might be due to the paucity of methods available to assess such risks. Recently, however, the American National Standards Institute (ANSI) Working Group S12.13-1990 drafted procedures for evaluating the effectiveness of hearing conservation programs.[3] These procedures are based on the results of serial monitoring audiometry for a noise-exposed population that are then compared to a table of recommended standards. An alternative method proposed in this study is the use of a reference population against which the study population is compared. This epidemiologic method provides the likelihood of developing hearing loss in the study population relative to the reference population, after controlling for the confounding effects of age and other variables.

Subjects and Methods

Populations Evaluated

The study population consisted of 599 workers who received their first audiometric test in 1980 and their last test in 1989, resulting in an approximately 9-year study period. The criterion for entry into the HCP for these study workers was the OSHA action level of at least 85 dBA 8-hour TWA.[2] Workplace exposure was determined by Dupont MKI personal dosimeter twice a year.[4,5] Unfortunately, once records were filed, it was extremely difficult or impossible to link measured workplace exposure levels with specific workers. Audiometric tests were reportedly performed according to the Council for Accreditation in Occupational Hearing Conservation guidelines using audiometric booths meeting ANSI and OSHA criteria.[6–8] Hearing threshold levels were obtained at 0.5, 1, 2, 3, 4, and 6 kHz. Prior to the periodic audiogram, study workers in the HCP completed a questionnaire that included identifying and noise-exposure information. Data on race were not obtained. Study workers enrolled in the HCP were required to use personal pro-

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tective devices and, reportedly, the use of these devices was enforced by shop safety personnel. However, we had no way of evaluating the effectiveness of the enforcement policy.

A reference population of 93 workers had a similar period of follow-up, with their first test occurring in 1972 and their last test in 1981. Reference workers had TWA noise exposures of approximately 87 dBA and reportedly wore hearing-protective devices consistently. The reference population used in this study was selected as one of the reference groups for the ANSI standard on evaluating the effectiveness of hearing conservation programs (S12.13-1990).[3] Reference workers received annual audiograms in their HCP.

Data Analysis

In this study, the standard threshold shift (STS) was used as a measure of hearing loss, and is defined as a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2, 3, and 4 kHz in either ear.[2] Thus, a worker in this study was considered to have experienced hearing loss if the mean of the difference between the first and last audiograms at 2, 3, and 4 kHz was greater than or equal to 10 dB in the left or the right ear:

$$\{(2KL\text{-}2KF) + (3KL\text{-}3KF) + (4KL\text{-}4KF)\}/3 \geq 10\text{ dB}$$

where (2KF, 2KL), (3KF, 3KL), and (4KF, 4KL) represent first (F) and last (L) audiograms at 2, 3, and 4 kHz (K), respectively.

For both the study and reference populations, the cumulative incidence of hearing loss was computed by dividing the number of subjects who developed hearing loss by the total number of subjects at risk. The cumulative incidence of hearing loss in the study population divided by the cumulative incidence in the reference population gave the risk ratio (RR). The RR provides the risk of developing hearing loss among the study population relative to the risk in the reference population. The age-adjusted RR was calculated by means of a stratified analysis using the method of Mantel and Haenszel.[9]

Results

Population Distribution

Workers in the reference population were generally older than those in the study population (Table I). The proportion of reference workers over the age of 39 at last measurement was 64.5% versus 47.5% for the study workers. In addition, none of the reference workers were under the age of 30. The study group contained 11 women, and only 1 woman was in the reference population. Therefore, analyses stratified by gender were limited to men.

Threshold Shift and Risk Ratio

The cumulative incidence of hearing loss was consistently higher for the study than for the reference population in each of five separate age groups (Fig. 1). For the study population, the incidence rose gradually with age from a low of 29.2% in the under-30 age group to a high of 57.1% in the 60–69 age range. Reference workers had relatively less hearing loss, ranging from 12% in those under the age of 40 to 25% in the 60–69 age group. Although the cumulative incidence generally increased with age for both the study and reference populations, within-population comparisons with the youngest age category (<30 years) were not statistically significant for either the study or reference workers.

Men were twice as likely to develop hearing loss than women (RR = 2.0; 95% CI: 0.6–7.2) (Table II). Study workers were nearly three times more likely to develop hearing loss in contrast to reference workers (RR = 2.8; 95% CI: 1.7–4.9) before adjustment for age (Table II).

After stratification by gender, study men were nearly three times more likely to develop hearing loss compared with reference men (RR = 2.8; 95% CI: 1.7–4.9) (Table III). Since no additional information could be obtained by studying the female workers, further analysis was restricted to men and stratified by age (Table III). The men were grouped into three age categories (<40, 40–49, >49), and the highest risk of developing hearing loss was in the 40–49 age group (RR = 6.9; 95% CI: 1.8–26.7). After controlling for age using the Mantel-Haenszel (MH) method of stratified analysis, study workers were three times more likely to develop hearing loss in contrast to reference workers (RRMH = 3.0; 95% CI: 1.8–5.2).[9] This adjusted value was essentially unaltered from the crude value (RR: 3.0 vs. 2.8).

TABLE I

DISTRIBUTION OF STUDY AND REFERENCE WORKERS ACCORDING TO AGE AND GENDER

Demographic Factors	All Workers *N* = 692 (%)	Study Workers *N* = 599 (%)	Reference Workers *N* = 93 (%)
Age (years):			
<30	24 (3.5)	24 (4.0)	0 (0.0)
30–39	323 (46.7)	290 (48.4)	33 (35.5)
40–49	219 (31.6)	184 (30.7)	35 (37.6)
50–59	108 (15.6)	87 (14.5)	21 (22.6)
60–69	18 (2.6)	14 (2.3)	4 (4.3)
Gender			
Men	680 (98.3)	588 (98.2)	92 (98.9)
Women	12 (1.7)	11 (1.8)	1 (1.1)

Discussion

The age-adjusted risk of developing hearing loss among the study workers, relative to the reference workers, was 3.0. This risk ratio would be expected to approach 1.0 if the risk was similar for both the study and reference groups. Study men in the 40–49 age range had the highest risk of developing hearing loss (RR = 6.9) relative to reference men. The reason for such a large magnitude of risk is not known (Fig. 1). However, the reason is likely related to an unstable cumulative incidence, reflected by a wide 95% CI, resulting from the small number of workers with hearing loss in the 40–49 age reference population (Table III). In both the <40 and the >49 year age groups, the risk of developing hearing loss was more than twice in the study population relative to the reference population, but the risk was not as impressive as in the 40–49 age group.

Although we used the OSHA STS in this method as an outcome or dependent variable, a different outcome variable that reflects early noise-induced hearing loss before the worker actually develops a confirmed STS (for example, the incidence of

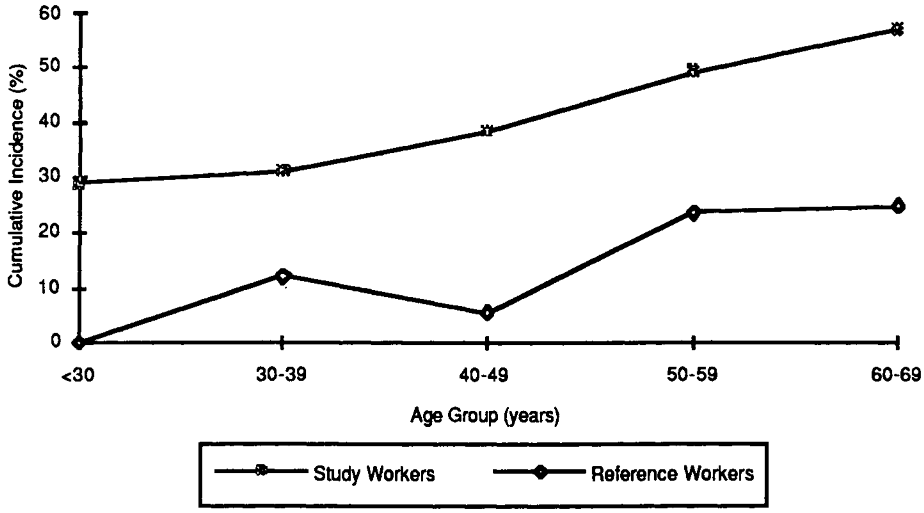

Fig. 1. Cumulative incidence of hearing loss by age. (The STS was used as a measure of hearing loss.)

TABLE II

INCIDENCE OF HEARING LOSS AND RISK RATIO BY GENDER AND WORKER STATUS

Variable	Cumulative Incidence (%)	Risk Ratio (95% CI)
Women	12 (16.7)	1.0 (Ref)[a]
Men	680 (33.8)	2.0 (0.6–7.2)
Reference workers	93 (12.9)	1.0 (Ref)[a]
Study workers	599 (36.7)	2.8 (1.7–4.9)[b]

[a]Value for this group was used as the reference (Ref).
[b]Statistically significant ($p < 0.01$).

TABLE III

CUMULATIVE INCIDENCE OF HEARING LOSS AND RISK RATIO ACCORDING TO GENDER AND AGE IN STUDY AND REFERENCE WORKERS (N=692)

Gender and Age	Study and Reference Workers	Cumulative Incidence (%)	Risk Ratio (95% CI)
Gender			
Men	Study	588 (37.1)	
	Reference	92 (13.0)	2.8 (1.7–4.9)[a]
Women	Study	11 (18.2)	
	Reference	1 (0.0)	—
Age (men only):			
<40	Study	306 (31.4)	
	Reference	32 (12.5)	2.5 (1.0–6.4)[a]
40–49	Study	181 (39.2)	
	Reference	35 (5.7)	6.9 (1.8–26.7)[a]
>49	Study	101 (50.5)	
	Reference	25 (24.0)	2.1 (1.0–4.3)[a]

Age-adjusted relative risk for men = 3.0 (1.8–5.2).
[a]Statistically significant comparisons by Pearson chi-square test ($p < 0.05$).

a 10-dB shift at 4 kHz only) could have been chosen. The objective of such an approach would be to identify workers beginning to experience hearing problems from exposure to hazardous noise in time to benefit from preventive measures.

This study is not without its limitations. First, important data on potential confounding variables such as race, chronic ear disease, middle ear infections, hereditary hearing loss of a progressive nature, head trauma, and noise exposure outside the work environments were not available. Second, although the period of follow-up for both groups was approximately 9 years, both populations were not followed with the same intensity of periodic audiometric evaluation, nor were they followed during the same time period (1980–1989 for study workers and 1972–1981 for reference workers). Consequently, the study and reference populations may vary with regard to audiometric test-taking experiences and exposures to non-occupational noise. It should be noted, however, that while the limitations of the data are recognized, these data do serve to illustrate an epidemiologic method for assessing the effectiveness of hearing conservation programs using audiometric data.

It is recommended that the method proposed in this study be applied to other populations and compared to other methods of evaluating group audiometric data, including the methods of ANSI Standard S12.13-1990.[3,10–17] Efforts also need to be made to establish current databases of non-industrially noise-exposed populations for use in making comparisons as in this study. It is also possible to use the method described in this paper to make internal comparisons of workers with noise exposures above and below the OSHA action level after taking into account as many of the potential confounders as possible.

Assessing the risk of hearing loss, as proposed in this method, may be an attractive alternative, particularly if circumstances prevent application of the ANSI methods. When applied with an understanding of and consideration for the potential effects of confounding variables, the proposed method will contribute greatly to the overall assessment of the effectiveness of hearing conservation programs.

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Clients, Problems, and Diagnoses in a Military Community Mental Health Clinic: A 20-Month Study

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A descriptive epidemiologic study was performed using intake data from an Army community mental health clinic. This clinic was on a U.S. Army nontraining post; data were collected over a 20-month period. Two diagnoses, occupational problem and phase of life or other life circumstance problem, were utilized by clinicians in 51% of all cases. Axis I diagnoses were found in 21% of the cases and medication was prescribed in 7%. Women were over-represented relative to men. We concluded that the patterns of diagnoses reflected the demand characteristics of the military environment. One implication of this study is that psychiatric care must be examined in the context of the community and not just as an administrative or economic system.

Research in military community mental health has often emphasized the need for an activist, consultative role for the military mental health professional.[1] Rodriguez[2] advocated a wide-ranging role for the military psychiatrist, from direct care to education and a variety of community consultations, as the most effective means for providing comprehensive mental health services. Research on direct care in the community mental health center has been rare. Quirk et al.[3] reported the demography of patients at an Army Community Mental Health Center (CMHC) in an attempt to promote services that could be targeted toward high-risk populations. In a study of the mental health practices in several U.S. Army clinics in Europe, the most frequently provided diagnoses were adjustment disturbances; the most common complaints involved work, housing, or marital issues.[4] The only other recent study of military mental health clinical practices we were able to find was one of psychiatric and physical disorders of patients referred to the Psychiatric Consultation Liaison Service in a military hospital. Their results were quite similar to those found in civilian services.[5]

From our own experience as well as observations, we knew that most U.S. Army mental health professionals spend almost all of their time in some aspect of direct patient care. We were interested in learning about these practices as well as combining the clinical and community points of view in a study of the characteristics of the clients seen at intake and the clinical decisions made at that time. The setting for this research was a large CMHC at a U.S. Army post that served a stable population of more than 40,000 active duty personnel. Intake data were collected over a 20-month period, from August 1988 to May 1990.

U.S. Army CMHCs are located in troop areas of an Army post so as not to be identified with hospital psychiatric care. The objective of Army community mental health care is to return soldiers to full duty as soon as possible, comparable to the goal of civilian psychiatrists, to maintain or restore an individual's

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