Unsound Conditions: Work-Related Hearing Loss In Construction, 1960-75

Norman J. Waitzman, Ph.D.
Department of Economics
University of Utah

Ken R. Smith, Ph.D.
Department of Family and Consumer Studies
University of Utah

January 1999

This research was funded with a $20,000 grant from the Center to Protect Workers' Rights (CPWR), as part of a research agreement with the National Institute for Occupational Safety and Health, NIOSH (grants CCU310982 and CCU312014). The research is solely the responsibility of the authors and does not necessarily represent the official views of NIOSH. CPWR — the research and development arm of the Building and Construction Trades Department, AFL-CIO — is uniquely situated to serve workers, contractors, and the scientific community. A major CPWR activity is to improve safety and health in the U.S. construction industry.

Acknowledgment

The authors would like to thank Göran Engholm, National Institute of Occupational Health (Arbetarskyddsstyrelsen), Sweden, and Scott Schneider, CPWR, for providing background material and insights on various facets of the analysis. We would also like to thank Anne C. Looker and Debra Reed-Gillette, both of the National Center for Health Statistics, for locating the original Health Examination Survey audiometric data and making a special subfile with those data available to us. We are also grateful for the computer programming expertise provided by David Huth, Center for High Performance Computing, University of Utah.

Abbreviations

dBA	Decibels
Hz	Hertz
NHANES	National Health and Nutrition Examination Survey
OSHA	U.S. Occupational Safety and Health Administration

Contents

Background

Noise at excessive levels pervades construction work. Workers are exposed to noise from heavy machinery and equipment, transport vehicles, and power tools. One of the noisier pieces of construction equipment, a pneumatic chip hammer, exceeds 110 decibels (dBA) at 5 feet, which is louder than a rock band (National Institute for Occupational Safety and Health 1986).[1]

Long-term exposure to loud noise, and the resultant hearing loss, hurts a worker's safety on the job, but also the quality of life off the job. Noise is also believed to affect energy levels, blood pressure, and heart disease.

Despite the risks of noise exposure faced by construction workers on the job, the U.S. Occupational Safety and Health Administration (OSHA) has largely neglected to enforce noise-exposure standards in the industry. Federal OSHA conducted more than 18,100 construction inspections in 27 states in fiscal year 1997, but issued only 87 citations on 68 sites, with fines totaling $63,626 for noise violations (John Franklin, OSHA, personal communication, Oct. 21, 1998). (Fines are "current" and some could be lowered upon settlement. The other states are inspected under state plans approved by OSHA.)

Noise levels measured for some construction equipment

Equipment	Decibels	Equipment	Decibels
Pneumatic chip hammer	103-113	Crane	90-96
Jackhammer	102-111	Hammer	87-95
Concrete joint cutter	99-102	Gradeall	87-94
Skilsaw	88-102	Front-end loader	86-94
Stud welder	101	Backhoe	84-93
Bulldozer	93-96	*Garbage disposal (at 3 ft.)*	*80*
Earth Tamper	90-96	*Vacuum cleaner*	*70*

Source: The Center to Protect Workers' Rights.

In 1981, OSHA amended its occupational noise standard of 1971. The amendment permits an average exposure to noise of 90 decibels over an 8-hour period, but requires the establishment of a noise-control/hearing conservation program. The program includes periodic audiometric testing of workers in workplaces where the exposure exceeds 85 decibels for 8 hours (Schneider, Johanning, Bélard, and Engholm 1995); most European countries have a standard of 85 decibels (Møller 1998).[2] According to Møller (1998), the difference between 85 and 90 dBA daily average exposure is that the risk of hearing impairment doubles. It's estimated that, in 1995, more than 650,000 construction workers were exposed to noise levels of 85 dBA or higher daily (Dale Hattis, Clark University, personal communication, October 1998). The National Institute for Occupational Safety and Health, NIOSH, (1986) has found exposure to noise levels of 80 decibels or higher poses risk for hearing loss.

The construction industry, however, was exempted from the OSHA standard amendments of 1981.

---

[1]In some documents, decibels are indicated with "dB." The "A" signifies that the frequency components of the noise have been adjusted to the response of the human ear (National Institute for Occupational Safety Health 1986).

[2]Decibels are measured on a logarithmic scale; 90 is more than twice as intense as 85.

Instead, construction is regulated by a 1983 standard, 29 CFR 1926.52, which requires an “effective” hearing conservation program when noise exceeds 90 dBA for 8 or more hours, but does not specify what such a program should include (Lusk, Kerr, Kauffman 1998).

One study of sheetmetal workers in the United States, based on exams, uncovered a high prevalence of hearing loss among such workers over age 39 years in 1975 (Kenney and Ayer). Seventy-five percent of workers in their 40s and all workers between 50 and 60 years old had what the National Institute for Occupational Safety and Health considers “material hearing loss” — an average of more than 25 dBA loss at 1, 2, and 3 kiloHertz for both ears.

A recent study of hearing loss among Alameda County, California, residents until now has apparently been the only published multivariate regression analysis of hearing loss in the United States (Wallhagen, Strawbridge, Cohen, and Kaplan 1997). The study suggested that hearing acuity had worsened over time and that the source of that trend might rest with occupational exposures; however the study was based strictly on self-rated data, which the following analysis has found unreliable.

Some larger studies have been undertaken in other countries. Studies of nearly 5,000 construction workers in Germany (Arndt and others 1996), of more than 100,000 construction workers in Sweden, and of about 5,000 construction workers in British Columbia, Canada, all found significantly elevated risks of hearing loss resulting from noise exposure among construction workers (Schneider, Johanning, Bélard, and Engholm 1995). Hearing conservation programs, which include ongoing audiometric examinations (hearing tests) of construction workers, have been introduced in Sweden and in British Columbia, based in part on the findings of the studies undertaken in those locations (Schneider, Johanning, Bélard, and Engholm 1995).

The study presented here is believed to be the first multivariate logistic regression analysis based on hearing-test data from national probability samples in the United States in the early 1960s and 1970s. Such data were collected on adults as part of the medical exam on the original Health Examination Survey, conducted in 1960-61, and on the first National Health and Nutrition Examination Survey (NHANES I), which was fielded in 1971-75. Both surveys were conducted under the auspices of the National Center for Health Statistics. Although subsequent surveys continued to collect hearing-test data on youth, no subsequent national survey to the authors’ knowledge has incorporated hearing tests of adults.

One motivation for this study was to assess the extent to which self-rated data on hearing loss, which has been collected on surveys after 1975, could serve as a reliable proxy for hearing-test data for future analyses. The self-rated data proved unreliable as proxies for hearing tests, however; the data are included on tables in annex A and discussed in annex B.

Methods

The authors analyzed hearing loss among construction workers, based on audiometric (hearing-test) and self-rated data.

Hearing-Examination Data

The National Center for Health Statistics published general demographic findings on hearing loss from the hearing tests on adults that were conducted as part of the Health Examination Survey (Glorig and Roberts 1965), but the raw data from that survey module were not made available as a public-use data set. In 1997, the hearing-test data from the Health Examination Survey were made available to the authors from a master file at the National Center for Health Statistics. Summary data from the file replicated those published by Glorig and Roberts three decades earlier.

Of 6,672 Health Examination Survey adult respondents aged 18 to 79 years receiving a medical exam, there were 2,343 males aged 25 to 65 years with relevant hearing-test, occupational, and other covariate data that could be incorporated into the planned analysis. The analysis was restricted to adults 25 to 65 years old, in order to combine the two data sets (the adult medical examination in the NHANES I was restricted to those aged 25-74 years) and because of the extensive absence of occupational reporting after age 65, when many workers retire.

Audiometric (hearing) examinations were incorporated on the original NHANES I (1971-74) as part of the "detailed exam" administered to a subsample of 3,854 respondents, and as part of the medical examination given to all 3,059 respondents on the NHANES I "augmentation" sample (1974-75). Alone and combined, these NHANES subsamples form national probability samples. Of the 6,913 adult respondents receiving an NHANES I hearing exam, 2,569 met the age and gender requirements of this study and had complete covariate data. The combined Health Examination Survey/NHANES I sample therefore contained observations on 4,912 respondents (2,343 + 2,569).

For the Health Examination Survey and the NHANES I survey, hearing thresholds for each ear were determined using air-conduction earphones with standard pure-tone audiometers. A description of audiometric test procedures and equipment and of the acoustic test environment is provided in reports summarizing the general findings from these examinations on the U.S. population (Glorig and Roberts 1965; Rowland 1980). Hearing thresholds were obtained at six frequencies (500, 1,000, 2,000, 3,000, 4,000, and 6,000 Hertz) on the Health Examination Survey and at four frequencies (500, 1,000, 2,000, and 4,000 Hertz) on the NHANES I. Thresholds from the four frequencies used

on the NHANES I were used in the current analysis.[3]
The NHANES I did not provide data indicating length of employment or occupational exposure to noise.

Hearing-Loss Measures Used

Sound intensity and hearing loss are measured in decibels (dBA) on a logarithmic scale. The threshold at which normal hearing begins is 0 decibels. Conversational speech at a distance of 3 feet has an intensity of about 60 dBA (National Institute for Occupational Safety and Health 1986).

Hearing thresholds are determined in audiometric exams based on the lowest audible sound level to the subject at pre-established frequencies. Higher thresholds indicate a greater loss of hearing. An early indicator of early noise-induced hearing loss is typically a threshold shift at around 4,000 Hertz, with little or no threshold shift at lower frequencies. Such beginning loss tends to go unrecognized, as the frequencies involved in understanding normal speech are mainly in the 200 Hz to 2,000 Hz range, although certain consonant sounds and combinations involve frequencies of 3,000 Hz and higher (National Institute for Occupational Safety and Health 1986; Møller 1998). As noise-induced hearing loss advances, there is a threshold shift at lower frequencies in the range critical to understanding speech and the threshold shift at 4,000 Hz typically becomes larger. Ability to discriminate everyday speech is then affected, because the hearing loss at upper frequencies such as 4,000 Hz has become severe or because threshold shifts have extended to the lower frequencies intimately involved in the discernment of speech, or for both reasons.

Several definitions of hearing impairment have been put forward, including those by the American Academy of Ophthalmology and Otolaryngology, the National Institute for Occupational Safety and Health, and the U.S. Environmental Protection Agency (Møller 1998). These standards are based on an average hearing loss in one ear of 25 decibels, over three frequencies in the lower range important to understanding normal speech. Of the three organizations just mentioned, only the Environmental Protection Agency has a standard that recommends including loss at 4,000 Hz. Part of the motivation underscoring the three standards was to set thresholds for compensable damage where the ability to

[3] Audiometers used in the Health Examination Survey were calibrated to “audiometric zero” in accordance with the specifications set forth in 1951 by the American Standards Association, whereas those used in the NHANES I were calibrated according to standards adopted in 1969 by the American National Standards Institute (Glorig and Roberts 1965; Rowland 1980). All thresholds in this study are expressed according to the ANSI standards. Data were provided to the nearest 5 decibels on the Health Examination Survey and to the nearest decibel on the NHANES I. All NHANES I hearing-test measurements were rounded to 5 decibels to maintain comparability between measurements from the two data sets.

understand speech is affected (Møller 1998). This report, with its focus on noise-induced hearing loss, however, needed a measure that would most likely distinguish such loss from hearing impairment due to other causes, such as aging or some diseases. And, the intent here was to adopt a definition that captured stages of hearing impairment, including the early signs of loss resulting from noise exposure, which might not yet affect the discernment of speech.

Thus, following the convention of a large, prospective study of noise-induced hearing loss among Swedish workers in construction (cited in Schneider, Johanning, Bélard, and Engholm 1995), this study used measures of hearing loss based on a scheme developed by Klockhoff, Drettner, and Svedberg (1974). The scheme breaks the audiogram summarizing hearing loss at frequencies of 500, 1,000, 2,000, 3,000, 4,000, and 6,000 Hz into five sectors, two at the lowest-three frequencies critical to the understanding of normal speech, and three at the triad of high-tone frequencies where permanent loss due to noise is often first manifest. The boundary establishing the two sectors at the lower frequencies was set at 35 dBA at 500 Hz and 30 dBA at 1,000 and at 2,000 Hz. Thresholds at 30 dBA and at 65 dBA established boundaries reflecting different levels of hearing loss among the high-tone frequencies.

In the Swedish study, an array of hearing-test results resting exclusively below all thresholds for the lower and higher frequency ranges established the criteria for normal hearing, whereas readings extending beyond the thresholds indicated loss of hearing of varying degrees. Because noise-induced hearing loss is often most pronounced at 4,000 Hz or above, and because the Klockoff measures generally required only one threshold shift reading among the three higher frequencies, the readings at 3,000 Hz and 6,000 Hz were, in effect, redundant.

Using the Klockhoff scheme, the analysis adopted 4 hearing-test measures to show progressive levels of noise-induced hearing loss:

- SLIGHT — Slight high-tone loss; at 4,000 Hz, a threshold shift of 30 dBA or more.
- MODERATE — Moderate high-tone loss; at 4,000 Hz, a threshold shift of 65 dBA or more
- SEVERE1 — SLIGHT loss plus one or two, but not all three, hearing-test readings above the normal threshold at:
  · 500 Hz (35 dBA)
  · 1,000 Hz (30 dBA) or
  · 2,000 Hz (30dBA).

  Noise-induced loss has advanced so the lower frequencies involved in the discrimination of normal speech are affected. (Because two, but not all three, hearing-test readings at the lower frequencies may exceed the normal range, the potential ambiguity arising from hearing loss in that range being due to factors not associated with noise is largely avoided, according to Klockhoff.)
- SEVERE2 — Combination of individuals who meet criteria for MODERATE or SEVERE1. This definition was added as a broader indicator of noise-induced hearing loss affecting understanding of speech; evidence suggests that failure to discern normal speech where there is ambient background noise and for certain consonant combinations occurs when high-tone threshold shifts are as large as those indicated for the MODERATE category alone (Klockhoff,

Drettner, and Svedberg 1974).[4]

For reasons that are apparently not well understood, noise-induced hearing loss generally becomes manifest first in the left ear (Gasaway 1994). For this reason and, again, following the conventions established in the Swedish study, all findings reported here are based on measurements in the left ear. The findings were not significantly altered when separate analyses (not shown) were run on measurements for the right ear, the ear that had the least hearing loss (the "better" ear), or the "worse" ear.

Occupational and Industrial Classifications

[4]The above definition of SLIGHT departed from that provided by Klockhoff, Drettner, and Svedberg (1974) in that slight high-tone loss was restricted under the original scheme to the middle sector among high-tone frequencies, whereas there was no upper-bound restriction of hearing loss at 4,000 Hz for our measure. The motivation of our analysis, however, was not strictly to classify the hearing loss among construction workers, as much as it was to conduct a comparative analysis of hearing loss between such workers and those in other industries. This underlying motivation, along with the use of progressively more restrictive audiometric thresholds in our empirical analysis obviated the need to make such added delineation. Our measure of SLIGHT, and of MODERATE for that matter, also departed from counterparts in the original scheme in that no reading outside of the normal threshold among the lower 3 frequencies was permitted in fulfilling the criteria for these measures under that scheme. Klockhoff maintained that the presence of hearing loss affecting discrimination of speech in the face of just slight loss in the upper-frequency range created ambiguity as to whether the loss was strictly attributable to noise exposure. On the other hand, that scheme permitted just such a pattern in the definition of SEVERE1, above, as long as none of three high-tone frequency measures rested in the sector for normal hearing. As we had available to us only one common high-tone frequency measure in our data, the level of discrimination called for in the above criteria was not possible. On the other hand, the use of several and progressively restrictive measures in our analysis again mitigated the need to strictly adhere to those guidelines. Furthermore, the Swedish study, the largest ever undertaken of noise-induced hearing loss among construction workers, adopted the definition for SLIGHT used in the current analysis (cited in Schneider, Johanning, Bélard, and Engholm 1995; Göran Engholm, Arbetarskyddsstyrelsen, Sweden, personal communication, February 1997).

The standard occupational and industrial classifications used in government surveys were modified from 1960 to 1990. For this analysis, however, with broad industrial categories, the changes are not significant.

The choice of industrial and occupational classification for the analysis reflected both an interest in maintaining consistency in definition across survey years as well as a practical response to the constraint of sample sizes within industries and occupations. Construction and manufacturing were treated as industries. Mining was treated as a separate industry, where the large sample size of the National Health Interview Survey permitted. The "other" industrial category covered workers in all other industries.

To reflect the difference in noise exposures for production versus nonproduction workers, this analysis created, in addition, a broad occupational split between blue- and white-collar jobs. Earlier research on hearing loss in the Swedish construction industry adopted a similar split between office and non-office jobs (Schneider, Johanning, Bélard, and Engholm 1995). *White-collar* here consists of workers in technical, professional, managerial, sales, and clerical jobs. *Blue-collar* includes all other occupations.

The Statistical Model Used

Multivariate logistic regressions were run on the dichotomous hearing-test and self-rated measures of hearing loss described above.[5] The analyses were run on male respondents, 25 to 65 years old. The analysis was restricted to males, because they made up more than 95% of the construction workforce during the period of the analysis (Bureau of the Census 1972, 1989). The analysis was restricted also to the working-age population, because occupational reporting is less prevalent and less reliable during retirement years. Because of the phenomenon of progressive hearing loss associated with aging, the analysis was age adjusted; the statistics were designed to rule out aging as a factor. The authors also ran age-stratified models, one for all workers aged 25 to 44 years, the other covering those aged 45 to 65 years. Age stratification permitted a focus on the approximate age of onset of noise-induced hearing loss and its progression with age. Last, the time between the Health Examination Survey and NHANES I facilitated a tentative assessment of self-rated hearing loss over time for the younger cohort, before and after implementation of the OSHA noise standard in 1971.

The analysis took into account metropolitan status of residence, with rural residence used as the referent compared to urban and suburban residence. Another factor considered was race, white and nonwhite. The industrial categories used were construction, manufacturing and mining, and "other" (industry other than construction, manufacturing, or mining). The class of work that was expected to

---

[5]Given the large quantity of data and a straightforward research question, this study used regression analysis. Regressions use statistical methods to try to show whether there is a connection between two or more factors, known as variables or covariates. The main question in this study is whether being a construction worker is likely to explain someone's being hard of hearing. The study is multivariate because it considers several factors that might contribute to loss of hearing, such as being a production or nonproduction worker, age, or residence in an urban area. Odds ratios show the percentage increase or decrease in the likelihood of hearing loss associated with a given characteristic (see tables 3a-3c).

have the least risk of hearing loss from exposure to noise — white collar, other — was used as the referent.

Additional covariates were entered into certain sub-analyses (not shown) to test the effects of variables that were not available on all data bases used. For instance, status as a veteran of the armed forces, given the likely exposure to impulse noise from explosions or gunfire, was incorporated in separate National Health Interview Survey models. The data showed that being a military veteran was significantly associated with hearing loss, but that status did not significantly alter the reported results. Some findings on the ear from the medical exams — exudate, perforated or malformed ear drum — were also entered into separate Health Examination Survey/NHANES I analyses, again with no significant effect on the reported results.

Results

Audiometric (hearing) test measures of hearing loss show an expected pattern (table 1). The prevalence of loss of hearing in the higher-frequency range probably attributable to noise exposure (SLIGHT) far exceeded the prevalence of more-severe hearing loss that impaired the ability to understand speech (for all groups). For men aged 25 to 65, who were tested in the combined Health Examination Survey/NHANES I surveys:

- 57% had no significant noise-induced hearing loss
- 43% had some high-tone loss (SLIGHT)
    - 11% had moderate high-tone loss (MODERATE)
    - 11% had high-tone loss coupled with significant loss in the lower frequency ranges critical to the understanding of normal speech (SEVERE1)
    - 18% had a significant-enough high-tone threshold shift to affect the understanding of speech of one or some high-tone loss coupled with loss in the lower-frequencies where understanding speech was likely affected. (SEVERE2)

In addition, the breakdown by age clearly demonstrates, as one would expect, progressive hearing loss with age. The rate of hearing loss among the older group, according to the most stringent of the test measures — SEVERE1 and SEVERE2 — was 3 to 4 times the rate of the younger group.

Status as a *blue-collar versus a white-collar* worker served as a critical marker for risk of hearing loss (tables 2a-2c). Higher rates of hearing loss were evident among blue-collar compared with white-collar workers across nearly all tested measures, lending support to the hypothesis that the socioeconomic factor in hearing loss identified in recent research (Ries 1994) may be intimately connected with occupational noise exposure.

In terms of *industry-specific measures* of hearing loss in the two broad occupational groups — production and nonproduction workers — construction workers tended to show higher rates of loss than workers in other industries, especially for hearing-test measures, like MODERATE, that were calibrated to extensive threshold shifts in the frequency range most sensitive to loss due to noise exposure (tables 2a-2c).

On hearing exams, blue-collar workers in each industry group show significantly higher odds of experiencing hearing loss than do white-collar workers in "other" industries, the referent group (table 3a). Indeed, in the all-age analysis (25-65 yrs.), the odds of hearing loss tended to be positive among *white-collar* construction and white-collar manufacturing or mining workers compared with their white-collar counterparts in other industries, but not by a statistically significant amount.

Blue- and White-Collar Workers by Industry

In industry-specific results among blue-collar workers, construction uniformly experienced the greatest risk of noise-induced hearing loss across all hearing-test measures, with manufacturing and mining workers experiencing the next-highest risk. For the measure of hearing loss constructed to capture substantial high-tone threshold shifts related to noise exposure (MODERATE), blue-collar construction workers experienced more than 3.5 times the risk experienced by white-collar workers in “other” industries (1.0). This was also the most elevated relative risk uncovered in all of the multivariate analyses, and one that applied to each age group (tables 3b and 3c).

Blue-collar construction workers also experienced higher odds of hearing loss that extended into the lower frequency range, affecting discernment of normal speech (SEVERE1). But their particularly high risk of experiencing considerable high-tone loss (MODERATE), which can alone affect the understanding of normal speech, made the global relative risk of having hearing problems affecting normal speech (SEVERE2) greater still among such workers.

Blue- and White-Collar Workers by Age Group and Industry

The overall pattern described above for workers aged 25 to 65 years was generally repeated in the analyses broken down by age group (tables 3b and 3c). Among the younger group, the disparity in hearing loss between blue-collar and white-collar workers was just as strong as it was among older workers, suggesting that the onset of such loss begins at an early age.

As with the all-age analysis, the elevated risk of hearing loss across hearing-test measures was greater for blue-collar construction workers than for their counterparts in other industries in the analyses stratified by age. The gap in relative risk of substantial high-tone hearing loss (MODERATE) between blue-collar construction workers and blue-collar manufacturing and mining workers, however, was smaller among the younger group than among the older group, suggesting that young workers in manufacturing and mining are exposed to harmful levels of noise, as well.

Discussion

This analysis conclusively demonstrates that blue-collar workers faced elevated risk of hearing loss in 1960-75, the only years for which national hearing test data are available. Occupational exposure to noise among such workers was likely responsible, in part, for recent studies that have shown a connection between socioeconomic status and hearing loss (Ries 1994). The multivariate analysis of hearing-test data for the 1960s and 1970s demonstrates that such elevated risk of hearing loss began relatively young. Where self-rated surveys are considered, it appears that the loss was often at frequencies where those affected were unaware of the progressive damage to their hearing (see annexes A and B). This risk for noise-induced hearing loss was particularly heightened among blue-collar construction workers where, by certain measures, younger and older workers were more than 3 times as likely to suffer such loss as white-collar workers in industries outside of construction.

The gap in relative risk of substantial high-tone hearing loss (MODERATE) between blue-collar workers in construction and those in other industries, however, was smaller among the younger group than among the older group.

Limitations of the Study

To the authors' knowledge, this analysis is the most comprehensive and detailed account of hearing loss resulting from noise exposure by industrial category in the United States. Limitations in the data and analysis, however, prevented a comprehensive and precise assessment of hearing loss due to noise exposure in construction. The small size of the statistical sample on the surveys containing hearing-test results prevented separating out the relative risks for detailed occupations, in and out of construction. Because of a lack of data on job tenure, the analysis did not consider duration of occupational exposure, except to use age as a crude proxy. Yet, duration of exposure is clearly critical with respect to permanent threshold shifts in hearing due to noise exposure (Møller 1998; Schneider, Johanning, Bélard, and Engholm 1995).

As noted earlier and detailed in annex B, comparison of self-rated data with hearing-test results has shown that self-rated data are inadequate for detecting beginning and, even, moderate hearing loss due to noise exposure. Also, the self-rated data provide only a rough, ex-post picture of the pattern of hearing loss across different occupations and industries.

Comparison with Swedish Results

The prevalence of slight hearing loss of 38% for construction workers at 25 to 44 years is nearly identical to the roughly 40% of Swedish sheet-metal workers reportedly having such loss in 1971-80 at the midpoint of the same age range (Schneider, Johanning, Bélard, and Engholm 1995).[6] On the other hand, more than 80% of sheetmetal workers in the older age group reportedly had such hearing loss compared to 71% of blue-collar construction workers in the United States (table 2c) (Schneider, Johanning, Bélard, and Engholm 1995). The 80-to-71 discrepancy may be due in part to greater exposure to noise among sheetmetal workers than among construction trade workers as a whole, and also to a likely longer occupational tenure, and hence exposure, among the older sheetmetal workers.

The prevalence of slight beginning hearing loss among Swedish office workers in construction companies, on the other hand, was closer for each respective age group to the prevalence reported for "other" industry white-collar workers than for white-collar construction workers in the United States. Many white-collar construction workers in the United States are not office workers, but managers of their own construction businesses, where they participate on site, and are thus more exposed to noise and susceptible to hearing loss than are office workers.

The Role of OSHA Regulation

[6] A study in Germany by Arndt and others (1996) set different parameters in its hearing tests — for instance, setting a threshold of an additive total of 105 decibels across 3 frequencies— and focused on 6 construction occupations that might not be representative of the industry as a whole. The study also used a different control group. Thus the results from this analysis are not directly comparable.

Although federal occupational noise standards have been notoriously weaker and less-stringently enforced in construction than in manufacturing in the United States (Schneider, Johanning, Bélard, and Engholm 1995), this analysis using the combined Health Examination Survey/NHANES I surveys indicates that the higher relative risk of hearing loss among construction workers predated OSHA and the federal noise standard. (OSHA began enforcing the noise standard in June 1971, adopting the provisions of the 1969 Amendment of the Walsh-Healy Public Contracts Act permitting a weighted exposure to noise of 90 decibels over an 8-hour period. An amendment to the OSHA standard in 1981 mandated a hearing conservation program if noise exceeded 85 decibels; this applied to industrial, but not construction workers. Construction is regulated by a 1983 standard, 29 CFR 1926.52, which requires an "effective" hearing conservation program when noise exceeds 90 dBA for 8 or more hours, but does not specify what such a program should include. [Lusk, Kerr, Kauffman 1998])

Safety and Financial Costs of Hearing Loss

Certainly there are easily identifiable costs associated with hearing loss. A projection of workers' compensation claims for occupational hearing loss among construction workers of about $20 million (Canadian) prompted British Columbia to introduce a hearing conservation program in that province in the mid-1980s (Schneider, Johanning, Bélard, and Engholm 1995). Such claims for all industries in the United States were estimated to be $835 million from 1978 to 1987 (National Institute for Occupational Safety and Health 1986).

A full analysis of the benefits associated with a strengthened regulatory effort to conserve hearing in the construction industry, however, would recognize several of the often unrecognized effects associated with noise and hearing loss. For instance, there are adverse effects of hearing loss other than permanent threshold shifts, such as tinnitus (ringing in the ears) and temporary threshold shifts (Møller 1998; Sataloff and Sataloff 1993).

One study among ironworkers showed that balance and hearing loss were intimately connected, and that the rate of accidental falls on construction sites, one of the most prevalent occupational injuries in construction, might have an association with hearing loss (Kilburn, Warshaw, and Hanscom 1992). Other studies have shown a relationship between noise and high blood pressure, circulatory problems, and hormonal imbalances (Møller 1998). Reduction in hearing is also associated with psychological problems that can have a profound effect on one's social integration and overall sense of well-being (Meadow-Orlans 1985). Any study undertaking a cost-benefit analysis of extending a hearing conservation program to construction trade workers ought to be as sensitive as possible to this context of hearing loss in the larger etiology of safety and illness.

Recommendations

The study was limited in scope, but the findings point up three clear needs. First, there is a clear rationale for a broad and concerted effort to gather new hearing-test data so as to accurately assess the current status of hearing loss in the country, to pinpoint particular occupations that are especially problematic, and to fill in the large gaps regarding trends since the 1970s.

Second, the large relative risks associated with occupational noise exposure pointed up by this study, particularly in the construction industry, suggest that renewed attention be given to the federal effort in noise conservation at the construction worksite. However, the persistent gap in hearing loss between production workers in manufacturing, where federal enforcement has been well targeted, and nonproduction workers in all other industries, even after implementation of an OSHA standard, demonstrates that enforcement alone may not solve the problem.

Third, and perhaps most fundamental to reducing work-related hearing loss, would be the introduction of a comprehensive hearing conservation program in the construction industry (and other industries that demonstrate elevated hearing loss). Such a program would include on-site, periodic audiometric testing of workers, as well as worker education. Hearing conservation programs in construction have been in place in British Columbia, Canada since the mid-1980s, and in Sweden since 1969 (Schneider, Johanning, Bélard, and Engholm 1995). In British Columbia, from 1988 to 1997, average hearing loss has been significantly reduced, particularly for workers having 16 to 25 years of exposure, in these groups: carpenters, electricians, equipment operators, laborers, and welders (Christine Harrison, Workers' Compensation Board of British Columbia, personal communication, October 1998). The prevalence of hearing loss among construction workers has dropped across age groups for each decade of the Swedish program (Schneider, Johanning, Bélard, and Engholm 1995).

References

Arndt, V., D Rothenbacher, H. Brenner, E. Fraisse, B. Zschenderlein, U. Daniel, S. Schuberth, and T. Fliedner. 1996. Older Workers in the construction industry: results of a routine health examination and a five year follow up. *Occupational and Environmental Medicine*, 53:686-91.

Bureau of the Census, U.S. Department of Commerce. 1972. *1970 Occupation and Industry Classification Systems in Terms of Their 1960 Occupation and Industry Elements*. Washington, D.C.: U.S. Government Printing Office, Technical Paper 26.

———. 1989. *The Relationship Between the 1970 and 1980 Industry and Occupation Classification Systems* (Technical Paper No. 59) U.S. Government Printing Office, Washington, D.C.

Gasaway, DC. 1994. Noise-Induced Hearing Loss. In: McCunney, RJ, and PW Brandt-Rauf, eds.. *A Practical Approach to Occupational and Environmental Medicine, 2nd Edition.* New York: Little, Brown and Company, 230-47.

Glorig, A, and J. Roberts. 1965. Hearing Levels of Adults by Age and Sex, United States, 1960-62. *Vital and Health Statistics,* 11(11).

Kenney, GD, and HE Ayer. 1975. Noise exposure and hearing levels of workers in the sheet metal construction trade. *American Industrial Hygiene Association Journal,* 28:626-32.

Kilburn, Kaye H., RH Warshaw, and B Hanscom. 1992. Are hearing loss and balance dysfunction linked in construction iron workers? *British Journal of Industrial Medicine* 49:138-41.

Klockhoff I, B Drettner, and A Svedberg. 1974. Computerized Classification of the Results of Screening Audiometry in Groups of Persons Exposed to Noise, *Audiology* 13:326-34.

Lusk, S.L., M.J. Kerr, and S.A. Kauffman. 1998. Use of Hearing Protection and Perceptions of Noise Exposure and Hearing Loss Among Construction Workers. *American Industrial Hygiene Journal,* 59:466-70.

Meadow-Orlans, KB. 1985. Social and Psychological Effects of Hearing Loss in Adulthood. In: H. Orlans, ed. *Adjustment to Adult Hearing Loss*. San Diego, Ca: College-Hill Press, 35-57.

Møller, Aage R. 1998. Effects of the Physical Environment: Noise as a Health Hazard. In: R.B. Wallace, B.N. Boebbeling, and others, eds., *Maxcy-Rosenau-Last Public Health & Preventive Medicine.* Stamford, Conn.: Appleton & Lange, 14th edition, 637-44.

National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services. 1986. Leading Work-Related Diseases and Injuries–United States: Noise-Induced Loss of Hearing. *Journal of the American Medical Association* 255(16):2133.

Ries, PW. 1985. The Demography of Hearing Loss. In: H. Orlans, ed., *Adjustment to Adult Hearing Loss.* San Diego: College Hill Press, 3-22.

———. 1994. Prevalence and characteristics of persons with hearing trouble: United States, 1990-91. *Vital Health Statistics,* 10(188).

Rowland, M. 1980. Basic Data on Hearing Levels of Adults, 25-74 Years: United States, 1971-75, *Vital and Health Statistics* 11(215).

RT Sataloff and J Sataloff. 1993. *Occupational Hearing Loss, 2nd Edition.* New York: Marcel Dekker, Inc.

Schneider, Scott, Eckhart Johanning, Jean-Louis Bélard, and Göran Engholm. 1995. Noise, Vibration, and Heat and Cold. *Occupational Medicine: State of the Art Reviews* 10(2):363-83.

Wallhagen MI, WJ Strawbridge, RD Cohen, and GA Kaplan. 1997. An Increasing Prevalence of Hearing Impairment and Associated Risk Factors over Three Decades of the Alameda County Study. *American Journal of Public Health* 87:440-42.

Annex A: Tables

1. Weighted sample proportions and average age, by survey and age group

	HES (1960-62)/NHANES I (1971-75)						NHIS (1990, 1991)					
	Ages 25-65		Ages 25-44		Ages 45-65		Ages 25-64		Ages 25-44		Ages 45-65	
	Mean	Std. Dev	Mean	Std Dev	Mean	Std Dev.	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Age (years)	43.8	11.3	34.5	5.8	54.1	5.6	41.6	11.0	34.3	5.6	53.8	5.8
Urban	0.29	0.45	0.28	0.45	0.31	0.46	0.30	0.46	0.31	0.46	0.25	0.49
Suburban	0.39	0.49	0.43	0.50	0.34	0.47	0.47	0.50	0.47	050	0.47	0.50
Rural	0.32	0.47	0.29	0.45	0.36	0.48	0.22	0.42	0.21	0.41	0.24	0.43
Race (White)	0.87	0.34	0.87	0.34	0.86	0.34	0.85	0.36	0.85	0.36	0.85	0.36
White collar												
Construction	0.02	0.12	0.01	0.12	0.02	0.13	0.02	0.14	0.02	0.14	0.02	0.14
Man/Mining	0.07	0.25	0.08	0.27	0.05	0.22	0.08	0.27	0.08	0.27	0.08	0.26
Other	0.21	0.40	0.22	0.41	0.19	0.39	0.28	0.45	0.29	0.45	0.27	0.34
Blue collar												
Construction	0.08	0.27	0.08	0.27	0.08	0.27	0.08	0.27	0.09	0.28	0.06	0.23
Man/Mining	0.21	0.41	0.23	0.42	0.19	0.39	0.15	0.35	0.16	0.36	0.13	0.34
Other	0.42	0.49	0.38	0.48	0.47	0.50	0.40	0.49	0.37	0.48	0.44	0.50
Hearing Loss												
Slight	0.43	0.50	0.27	0.44	0.61	0.49	N/A		N/A		N/A	
Moderate	0.11	0.31	0.05	0.21	0.18	0.38	N/A		N/A		N/A	
Severe1	0.11	0.31	0.05	0.21	0.17	0.38	N/A		N/A		N/A	
Severe2	0.18	0.38	0.09	0.28	0.28	0.45	N/A		N/A		N/A	
Self-rated scale	0.14[b]	0.34[b]	0.08[b]	0.27[b]	0.19[b]	0.39[b]	0.08	0.28	0.05	0.22	0.14	0.35
GALDET-1	N/A		N/A		N/A		0.08	0.27	0.05	0.21	0.14	0.34
GALDET-2	N/A		N/A		N/A		0.03	0.16	0.01	0.11	0.05	0.21
Sample Size (N)	4,912		2,573		2,339		55,651		34,956		20,695	

(N) = number.

N/A = not applicable.

Note: All measures of hearing loss are on the left ear, except for GALDET-1 and GALDET-2, which are on both ears.

2a. Sample sizes and weighted sample proportions for selected audiometric and self-rated measures, left ear, by industry group, by survey, ages 25-65

	HES/NHANES I audiometric measures					NHANES I self-rated measure		NHIS self-rated measures		
Industry group	Sample size	Slight	Moderate	Severe1	Severe2	Sample size	Self-rated scale (SRS)	Sample size (SRS/ Galdet-2)	Self-rated scale (SRS)	Galdet-2
White collar										
Construction	75	0.47	0.12	0.09	0.19	39	0.18	1,124/1,119	0.07	0.027
Man/Mining	326	0.31	0.08	0.07	0.12	170	0.08	4,343/4,323	0.07	0.014
Other	1,010	0.35	0.07	0.08	0.13	609	0.12	15,704/15,644	0.06	0.015
Blue collar										
Construction	381	0.54	0.17	0.13	0.23	196	0.17	4,256/4,238	0.09	0.029
Man/Mining	1,041	0.46	0.10	0.13	0.19	510	0.15	8,198/8,151	0.10	0.028
Other	2,079	0.46	0.13	0.11	0.19	1,039	0.14	22,026/21,910	0.10	0.035

SRS = self-rated scale.

HES is the Health Examination Survey; NHANES I, the first National Health and Nutrition Examination Survey; and NHIS, National Health Interview Survey (NHIS)

Note: GALDET-1 and GALDET-2 are ratings based on hearing in both ears; other surveys are based on hearing in left ear. Hearing thresholds for audiometric measures were: SLIGHT, >30 dBA at 4 kHz; MODERATE, >65 dBA at 4,000 Hz; SEVERE1, [SLIGHT or MODERATE] and one or two, but not all three, of the following triad [>35 dBA at 500 Hz, >30 dBA at 1,000 Hz, >30dBA at 2,000 Hz]; SEVERE2, SEVERE1 or MODERATE. Hearing thresholds for self-rated measures were: SRS, has "little trouble hearing" or worse; GALDET-1, "has trouble hearing whisper across quiet room" or worse; GALDET-2, "has trouble hearing normal speech across quiet room" or worse.

Source: The National Center for Health Statistics, Department of Health and Human Services.

2b. Sample sizes and weighted sample proportions for selected audiometric and self-rated measures, by industry group, by survey, ages 25-44

	HES/NHANES I audiometric measures					NHANES I self-rated measure		NHIS self-rated measures		
Industry group	Sample Size	Slight	Moderate	Severe1	Severe2	Sample Size	Self-rated scale (SRS)	Sample size (SRS/ Galdet-2)	Self-rated scale (SRS)	Galdet-2
White collar										
Construction	36	0.25	0.00	0.00	0.00	16	0.13	684/681	0.05	0.02
Man/Mining	207	0.22	0.04	0.04	0.07	89	0.06	2,783/2,777	0.04	0.01
Other	562	0.21	0.02	0.04	0.06	319	0.08	10,092/10,076	0.04	0.01
Blue collar										
Construction	199	0.38	0.09	0.07	0.14	90	0.13	3,056/3,049	0.06	0.02
Man/Mining	600	0.32	0.05	0.06	0.10	277	0.08	5,480/5461	0.07	0.02
Other	969	0.26	0.06	0.05	0.09	401	0.07	12,861/12,815	0.05	0.02

SRS = Self-rated scale.

HES is the Health Examination Survey; NHANES I, the first National Health and Nutrition Examination Survey; and NHIS, National Health Interview Survey (NHIS)

Note: GALDET-1 and GALDET-2 are ratings based on hearing in both ears; other surveys are based on hearing in left ear.

Hearing thresholds for audiometric measures were: SLIGHT, >30 dBA at 4,000 Hz; MODERATE, >65 dBA at 4,000 Hz; SEVERE1, [SLIGHT or MODERATE] and one or two, but not all three, of the following triad [>35 dBA at 500 Hz, >30 dBA at 1,000 Hz, >30 dBA at 2,000 Hz]; SEVERE2, SEVERE1 or MODERATE. Hearing thresholds for self-rated measures were: SRS, has at least a “little trouble hearing”; GALDET-1, has at least “trouble hearing whisper across quiet room”; GALDET-2, has at least “trouble hearing normal speech across quiet room.”

Source: The National Center for Health Statistics, Department of Health and Human Services.

2c. Sample sizes and weighted sample proportions for selected audiometric and self-rated measures, by industry group, by survey, ages 45-65

	HES/NHANES I audiometric measures					NHANES I self-rated measure		NHIS self-rated measures		
Industry group	Sample size	Slight	Moderate	Severe1	Severe2	Sample size	Self-rated scale (SRS)	Sample size (SRS/ Galdet-2)	Self-rated scale (SRS)	Galdet-2
White collar										
Construction	39	0.67	0.23	0.18	0.36	23	0.22	440/438	0.11	0.04
Man/Mining	119	0.45	0.13	0.13	0.21	81	0.10	1,560/1,546	0.12	0.03
Other	448	0.51	0.13	0.14	0.21	290	0.17	5,612/5,568	0.10	0.03
Blue collar										
Construction	182	0.71	0.26	0.21	0.34	106	0.20	1,200/1,189	0.16	0.07
Man/Mining	441	0.66	0.17	0.23	0.32	233	0.23	2,718/2,690	0.17	0.05
Other	1,110	0.62	0.19	0.16	0.28	638	0.19	9,165/9,095	0.16	0.06

SRS = Self-rated scale.

HES is the Health Examination Survey; NHANES I, the first National Health and Nutrition Examination Survey; and NHIS, National Health Interview Survey (NHIS)

Note: GALDET-1 and GALDET-2 are ratings based on hearing in both ears; other surveys are based on hearing in left ear. Hearing thresholds for audiometric measures were: SLIGHT, >30 dBA at 4,000 Hz; MODERATE, >65 dBA at 4,000 HZ; SEVERE1, [SLIGHT or MODERATE] and one or two, but not all three, of the following triad [>35 dBA at .5 kHz, >30 dBA at 1 kHz, >30 dBA at 2,000 Hz]; SEVERE2, SEVERE1 or MODERATE. Hearing thresholds for self-rated measures were: SRS, has "little trouble hearing" or worse; GALDET-1, "has trouble hearing whisper across quiet room" or worse; GALDET-2, "has trouble hearing normal speech across quiet room" or worse.

Source: The National Center for Health Statistics, Department of Health and Human Services.

3a. Odds ratios from logistic multivariate regressions on audiometric and self-rated measures of hearing loss, ages 25-65

	HES (1960-62)/NHANES I (1971-75)				NHANES I (1971-75)		NHIS (1990, 1991)		
Covariate	Slight	Moderate	Severe1	Severe2	Severe1	Self-rated scale	Self-rated scale	Galdet-1	Galdet-2
Age	1.08***	1.08***	1.08***	1.08***	1.07***	1.04***	1.06***	1.06***	1.07***
Urban	0.55***	0.61***	0.95	0.75***	0.90	0.63	0.67***	0.62***	0.67***
Suburb	0.64***	0.68***	0.92	0.74***	1.03	0.74**	0.80***	0.74***	0.81***
Race (White)	2.31***	3.37***	1.67***	2.24***	1.60*	1.44	2.62***	2.43***	1.80***
HES Sample	0.79***	1.24**	1.19*	1.24***	N/A	N/A	N/A	N/A	N/A
White-collar									
Construction	1.47	1.48	1.20	1.32	0.80*	2.20**	1.09	1.21	1.65**
Man/Mining	0.98	1.41	1.09	1.21	0.82*	0.60*			
Manufacturing							1.14*	1.06	0.93
Mining							1.71**	1.55*	1.33***
Other	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Blue-collar									
Construction	2.90***	3.57***	2.06***	2.47***	2.28***	1.55*	1.64***	1.80***	2.32***
Man/Mining	2.19***	2.22***	1.91***	2.10***	1.71***	1.43**			
Manufacturing							1.90***	1.95***	2.06***
Mining							2.70***	2.90***	2.38***
Other	1.59***	2.09***	1.46***	1.74***	1.72***	1.00	1.53***	1.63***	2.12***
Hearing Loss (N)	2,113	536	526	871	318	350	4,671	4,442	1,443
Sample Size (N)	4,912	4,912	4,912	4,912	2,569	2,563	55,385	55,542	55,542

*p<.10 ** p<.05 *** p<.01

(N) = Number.

HES is the Health Examination Survey; NHANES I, the first National Health and Nutrition Examination Survey; and NHIS, National Health Interview Survey (NHIS)

Note: GALDET-1 and GALDET-2 are ratings based on hearing in both ears; other surveys are based on hearing in left ear. An odds ratio of 1.0 is the norm. An odds ratio of 1.47 shows a 47% increase in risk of hearing loss associated with the given characteristic (such as being a white-collar construction worker). Hearing thresholds for audiometric measures were: SLIGHT, >30 dBA at 4,000 Hz; MODERATE, >65 dBA at 4,000 Hz; SEVERE1, [SLIGHT or MODERATE] and one or two, but not all three, of the following triad [>35 dBA at 500 Hz, >30 dBA at 1,000 Hz, >30dBA at 2,000 Hz]; SEVERE2, SEVERE1 or MODERATE. Hearing thresholds for self-rated measures were: SRS, has “little trouble hearing” or worse; GALDET-1, “has trouble hearing whisper across quiet room” or worse; GALDET-2, “has trouble hearing normal speech across quiet room” or worse.

Source: The National Center for Health Statistics, Department of Health and Human Services.

3b. Odds ratios from logistic multivariate regressions on audiometric and self-rated measures of hearing loss, ages 25-44

	HES (1960-62)/NHANES I (1971-75)				NHANES I (1971-75)		NHIS (1990, 1991)		
Covariate	Slight	Moderate	Severe1	Severe2	Severe1	Self-rated scale	Self-rated scale	Galdet-1	Galdet-2
Age	1.08***	1.08***	1.09***	1.09***	1.10***	1.05***	1.07***	1.07***	1.08***
Urban	0.52***	0.82	0.56**	0.68**	0.23***	0.49***	0.67***	0.61***	0.65***
Suburb	0.71***	0.61**	0.92	0.71**	1.20	0.53***	0.75***	0.70***	0.76**
Race (White)	2.31***	15.89***	1.88*	3.83***	2.09	1.16	3.13***	2.81***	2.16***
HES Sample	0.70***	0.90	1.31	1.11	N/A	N/A	N/A	N/A	N/A
White-collar									
Construction	0.85	0.00	0.00	0.00	0.00	3.18**	1.09	1.28	2.05**
Man/Mining	0.91	1.45	1.17	1.14	1.33	0.51			
Manufacturing							1.10	0.99	0.80
Mining							1.53	1.43	1.48***
Other	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Blue-collar									
Construction	2.79***	3.50***	2.34**	2.65***	2.64**	2.00*	1.63***	1.80***	2.10***
Man/Mining	2.01***	3.03***	1.94**	2.40***	1.91*	1.20			
Manufacturing							1.99***	1.99***	2.19***
Mining							2.55***	2.57***	2.64***
Other	1.38**	2.42***	1.92**	1.95***	1.72	0.82	1.54***	1.66***	2.25***
Hearing Loss (N)	694	122	124	220	64	96	1,760	1,625	443
Sample Size (N)	2,573	2,573	2,573	2,573	1,195	1,096	34,859	34,912	34,469

$^{*}p<.10$ $^{**}p<.05$ $^{***}p<.01$

(N) = Number.

N/A = Not applicable

HES is the Health Examination Survey; NHANES I, the first National Health and Nutrition Examination Survey; and NHIS, National Health Interview Survey (NHIS)

Note: GALDET-1 and GALDET-2 are ratings based on hearing in both ears; other surveys are based on hearing in left ear. An odds ratio of 1.0 is the norm. An odds ratio of 0.52 shows about half the normal risk of hearing loss associated with a given characteristic (such as living in an urban area). Hearing thresholds for hearing-test measures were: SLIGHT, >30 dBA at 4 kHz; MODERATE, >65 dBA at 4,000 Hz; SEVERE1, [SLIGHT or MODERATE] and one or two, but not all three, of the following triad [>35 dBA at 500 Hz, >30 dBA at 1,000 Hz, >30dBA at 2,000 Hz]; SEVERE2, SEVERE1 or MODERATE. Hearing thresholds for self-rated measures were: SRS, has “little trouble hearing” or worse; GALDET-1, “has trouble hearing whisper across quiet room” or worse; GALDET-2, “has trouble hearing normal speech across quiet room” or worse.

Source: The National Center for Health Statistics, Department of Health and Human Services.

3c. Odds ratios from logistic multivariate regressions on audiometric and self-rated measures of hearing loss, ages 45-65

	HES (1960-62)/NHANES I (1971-75)				NHANES I (1971-75)		NHIS (1990, 1991)		
Covariate	Slight	Moderate	Severe1	Severe2	Severe1	Self-rated scale	Self-rated scale	Galdet-1	Galdet-2
Age	1.08***	1.07***	1.07***	1.08***	1.06***	1.04***	1.05***	1.05***	1.07***
Urban	0.57***	0.54***	1.12	0.78**	1.20	0.73*	0.68***	0.63***	0.68***
Suburb	0.57***	0.69***	0.89	0.73***	0.93	0.93	0.83***	0.77***	0.83**
Race (White)	2.39***	2.40***	1.56**	1.83***	1.54*	1.61*	2.36***	2.24***	1.66***
HES Sample	0.90	1.40***	1.17	1.32***	N/A	N/A	N/A	N/A	N/A
White-collar									
Construction	2.50***	2.17*	1.68	2.18**	1.24	1.32	1.08	1.16	1.45
Man/Mining	1.02	1.43	0.98	1.25	0.579	0.656			
Manufacturing							1.83***	1.10	1.00
Mining							1.90**	1.67	1.25
Other	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Blue-collar									
Construction	3.08***	3.54***	1.98***	2.38***	2.20***	1.31	1.69***	1.82***	2.50***
Man/Mining	2.33***	1.86***	1.88***	1.90***	1.62**	1.60**			
Manufacturing							1.16	1.91***	1.98***
Mining							2.97***	3.36***	2.18*
Other	1.84***	1.94***	1.40**	1.69***	1.78***	1.12	1.60***	1.67***	2.07***
Hearing Loss (N)	1419	414	402	651	254	254	2,911	2,817	1,000
Sample Size (N)	2,339	2,339	2,339	2,339	1,374	1,371	20,526	20,630	20,630

*p<.10 ** p<.05 *** p<.01

(N) = Number

N/A = Not applicable.

HES is the Health Examination Survey; NHANES I, the first National Health and Nutrition Examination Survey; and NHIS, National Health Interview Survey (NHIS).

Note: GALDET-1 and GALDET-2 are ratings based on hearing in both ears; other surveys are based on hearing in left ear. An odds ratio of 1.0 is the norm. An odds ratio of 2.5 shows a 250% increase in risk of hearing loss associated with a given characteristic (such as being a white-collar construction worker). Hearing thresholds for audiometric measures were: SLIGHT, >30 dBA at 4,000 Hz; MODERATE, >65 dBA at 4,000 HZ; SEVERE1, [SLIGHT or MODERATE] and one or two, but not all three, of the following: [>35 dBA at 500 Hz, >30 dBA at 1,000 Hz, >30 dBA at 2,000 Hz]; SEVERE2, SEVERE1 or MODERATE. Hearing thresholds for self-rated measures were: SRS, has "little trouble hearing" or worse; GALDET-1, "has trouble hearing whisper across quiet room" or worse; GALDET-2, "has trouble hearing normal speech across quiet room" or worse.

Source: The National Center for Health Statistics, Department of Health and Human Services.

Annex B: Self-Rated Surveys

The measures of self-rated hearing loss used in this analysis were developed in the mid-1960s after the fielding of the original Health Examination Survey (Ries 1985). Self-rated data on hearing status were taken from the interview portion of the first National Health and Nutrition Examination Survey (NHANES I) and from the 1990 and 1991 National Health Interview Survey. Of the 2,569 respondents receiving a hearing test on the NHANES I who were included in this analysis, 2,563 provided self-rated data. Data are shown on tables in annex A.

Scales and Methods Used

National Health Interview Survey. Like the NHANES, the National Health Interview Survey is a national probability sample of the civilian non-institutionalized U.S. population. The survey is conducted yearly, however, covering a far larger sample than the NHANES — about 50,000 households and about 100,000 related people. Thus, in 1990-91, 93,237 households containing 239,663 people were included (Ries 1994). Of those, 55,385 were males 25 to 65 years old, with complete covariate data and thus were included in this analysis. Unlike in the NHANES, not all data on the National Health Interview Survey came from the individual being described. While an attempt was made to have all adult family members participate in the interview, data were gathered from reports by responsible family members (Ries 1994). The authors thus integrated a separate control into the multivariate analyses of National Health Interview Survey data, indicating whether the data came from self-response.

The so-called self-rated scale consists of a classification by respondents of their hearing in each ear without a hearing aid into one of four categories:

- Good
- Little trouble
- Lot of trouble
- Deaf.

The self-rated scale was developed after the original Health Examination Survey was fielded in 1960-62. A drawback of the self-rated scale is its imprecision in assessing understanding of normal speech (Ries 1994).

Gallaudet Hearing Scale. The Gallaudet Hearing Scale was developed in the mid-1960s to provide greater refinement. The Gallaudet scale presents a cascade of questions to assess the ability to understand speech, ranging from whether one can, without a hearing aid,

> • Usually hear and understand what person says without seeing his face if that person whispers to him from across a quiet room at one extreme,

to whether one can, without a hearing aid,

> • Usually hear and understand a person if that person speaks loudly into his better ear.

The two dichotomous measures of hearing that were constructed from the Gallaudet scale to be included in the logistic regression analyses were GALDET-1 and GALDET-2. GALDET-1 was set equal to 1 if a respondent indicated that he could not understand a whisper from across a quiet room, zero otherwise. GALDET-2 was a more restrictive measure, set at 1 if the respondent could not understand a normal voice from across a quiet room, zero otherwise.

Incorporation of the self-rated scale on the NHANES I permitted a direct comparison of hearing loss based on both testing and self-rating from that survey, as well as a link to self-rated hearing loss using the same scale on the 1990 and 1991 National Health Interview Survey. For the logistic regression analysis used here, the self-rated scale results were split into "good" and "worse than good."

The only two surveys, to the authors' knowledge, that administered both an audiometric test and a self-assessment, according to the Gallaudet scale, were for a small sample of 256 adults in the Philadelphia metropolitan area in the mid-1960s, and for the so-called "augmentation sample" of the NHANES I conducted in 1974-75 (Ries 1985). The NHANES I subsample consisted of 3,059 respondents aged 25 to 74, and was too small to incorporate with the desired occupational detail in the present analysis.

Results and Discussion

This analysis clearly demonstrates the inadequacy of the self-rated scale for accurately capturing the relative risk of hearing loss as a result of noise exposure, let alone substantial high-tone loss that, by itself, threatens the comprehension of normal conversation. The results on the hearing exam (SEVERE1) and the self-rated scale from the NHANES I also challenge the precision by which the self-rated scale can identify the relative risk of hearing loss in the lower-frequency range where the discernment of normal conversation is affected.

The prevalence of hearing difficulty reported on the NHANES I self-rated scale is consistently within the range of prevalence among the more stringent test measures (SEVERE1 and SEVERE2) that are designed to indicate some impairment in ability to understand normal speech. But some high-tone hearing loss (SLIGHT) was clearly measurable on hearing tests before respondents on the self-rated surveys reported a problem.

It also appears that older people may be less aware of hearing loss than their younger counterparts. The prevalence of hearing trouble based on the self-rated scale is situated more closely to the lower bound of the range where understanding of speech is affected that was established by SEVERE1 among the elderly, but more closely to the upper bound established by SEVERE2 among the younger group.

Some improvement in hearing in recent decades among the population is suggested by the lower prevalence of hearing trouble shown on the self-rated scale for each age group on the National Health Interview Survey relative to the corresponding prevalence on the Health Examination Survey/NHANES I. This finding is in contrast to recent research showing an increase in self-rated hearing loss from the early 1970s to the early 1990s in the United States, based on the Gallaudet scale from the National Health Interview Survey (Ries 1994) and an analysis of self-rated data on Alameda

County, California, residents from 1965 to 1994 (Wallhagen Strawbridge, Cohen, and Kaplan 1997). One demographic change may have influenced the survey results: the industrial shift from goods- to service-producing jobs from the 1970s to the 1990s is apparent in table 1 in the smaller proportion of the male labor force in blue-collar manufacturing and mining industry jobs, and a higher proportion in "white-collar, other" industry jobs on the National Health Interview Survey relative to the Health Examination Survey/NHANES I.

The blue-collar:white-collar difference was most pronounced for the hearing loss measures with the stiffest self-rated criteria, suggesting that the risk of progressive hearing loss was also associated with class of employment. Except for construction work, for instance, the risk for incurring hearing loss such that one had, at a minimum, difficulty hearing a normal conversation from across a quiet room (GALDET-2), was more than twice as high for blue-collar as for white-collar workers across industries. The blue-collar:white-collar disparity for the risk of simply having a "little trouble" (GALDET-1) hearing, on the other hand, was not as great. As noted earlier, white-collar construction workers spend more time literally in the trenches compared with other white-collar workers.

On the National Health Interview Survey, however, rates of self-rated hearing loss among blue-collar workers (tables 2a-2c) did not reflect a comparative disadvantage among construction workers that were evident from regression results on hearing test data, except for older workers (age 45-65 years) (table 3c).

Once again, the prevalence of hearing loss according to the self-rated scale on the NHANES I, both among the younger and the older age groups, generally fits within the range of the two hearing-test measures most attuned to loss in understanding normal speech (SEVERE1 and SEVERE2). Younger workers tend to more-readily recognize loss in hearing affected strictly by substantial high-tone loss (SEVERE2), regardless of occupational class and industry, whereas older workers' appraisals of their own hearing falls closer to SEVERE1, for which low-frequency hearing loss is always a factor.

However, *the results on the self-rated scale on the NHANES I depart significantly from those of the hearing-test*. Indeed, the odds ratio of self-rated hearing loss among blue-collar construction workers, although exceeding one, was smaller and closer in magnitude to that of manufacturing and mining workers than in the hearing-test results and barely achieved statistical significance.

Limitations

The results on the self-rated scale from the National Health Interview Survey (table 3a, columns 7-9) should thus be put into the context of the potential weaknesses of the self-rated scale. While showing a generally higher relative risk for hearing loss for blue-collar than for white-collar workers, the self-rated scale by industry breakdown shows, contrary to the hearing-test results from the earlier survey, blue-collar construction workers having *lower* odds of hearing loss than their counterparts in mining or manufacturing**.**

Results from regressions on the self-rated scale did not reinforce the hearing-test results. The self-rated measure for which the results patterned most closely after the hearing-test results (for instance, SEVERE2) was GALDET-2. However, the marked elevated risk of substantial high-tone loss among construction workers (MODERATE) did not translate into a distinctly elevated risk compared with other blue-collar workers for GALDET-2, particularly for the younger group. Only in the older group did the odds ratio of hearing loss on GALDET-2 for blue-collar construction workers exceed that for blue-collar workers in each other industry, as in the hearing-test analysis. Furthermore, GALDET-2 is an indicator of a relatively rare event, occurring at about one-quarter the rate of substantial high-tone hearing loss (MODERATE) for both younger (table 2b) and older (table 2c) blue-collar construction workers.

GALDET-2 showed a notable elevated risk for hearing loss among the younger white-collar construction and mining workers. Small sample size for younger white-collar construction workers on the earlier surveys may explain why such hearing loss was not as evident as on the hearing-test results. Among the older group of white-collar workers, a significantly elevated relative risk of hearing loss was evident from the hearing-test measures of high-frequency hearing loss, but from none of the self-rated results. Such heightened risk of high-frequency loss in the older group could result from several factors, including occupational noise exposure as blue-collar workers in the industry prior to advancing to white-collar positions where the risk was reduced; to some exposure, even as a white-collar worker, over a long tenure to the generally elevated on-site noise within the construction industry; or to the idiosyncratic nature of occupational classification in construction, where many independent contractors are “managers” in the technical sense, but are also production workers directly subject to the on-site environment. The heightened risk for the younger age group according to GALDET-2 uncovered on the National Health Interview Survey for white-collar construction and mining workers might also be attributable to such direct exposures.

Those who were in the younger age group in the 1971-75 NHANES analysis would roughly fit into those in the older age group in the National Health Interview Survey analysis. But, because of the absence of hearing-test data after 1975, it is especially difficult to decipher reliably a pattern in the results (tables 3b and 3c). The odds ratios for SEVERE1 and SEVERE2 across industries for the younger group are similar to those for GALDET-2, in particular, for the older group. But the respective odds ratios across surveys within each age group also display similar patterns, as discussed earlier.

Although not as reliable as hearing test results, the results from self-rating of hearing reinforce the need, discussed above, for formal hearing tests integrated into hearing conservation programs in construction and other industries where workers are exposed to levels of noise that pose risk of hearing loss.