National occupational research agenda for Hearing Loss Prevention

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National Occupational Research Agenda for Hearing Loss Prevention

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The National Institute for Occupational Safety and Health (NIOSH) has a mandate to conduct research on occupational safety and health. The research portfolio is organized by industrial sectors and cross- sectors for illnesses and injuries that are found in all sectors. The Hearing Loss Prevention research cross-sector council comprises representatives from government, labor organizations, academia, and industry representatives. The HLP council held several meetings throughout 2018 to determine research needs for occupational hearing loss prevention in the United States. Five topic areas were determined. (1) Provide input for policies and guidelines that will inform best practices for hearing loss-prevention efforts. (2) Develop effective, evidence-based education designed to improve hearing conservation program outcomes for exposed workers and management. (3) Develop, commercialize, and widely implement noise control solutions on jobsites in key industries. (4) Develop audiological tests for hearing loss prevention. (5) Improve occupational hearing loss surveillance. These topic areas will be discussed in detail to help motivate other researchers to join further our knowledge to prevent occupational hearing loss.

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1. NATIONAL OCCUPATIONAL RESEARCH AGENDA

The National Occupational Research Agenda (NORA) is a partnership program to stimulate innovative research and workplace interventions. In combination with other initiatives, the products of this program are expected to reduce the occurrence of injuries and illnesses at work. Unveiled in 1996, NORA has become a research framework for the National Institute for Occupational Safety and Health (NIOSH) and the United States. Diverse parties collaborate to identify the most critical issues in workplace safety and health and develop research objectives for addressing those needs.

NORA entered its third decade in 2016 with an enhanced structure. The ten sectors formed for the second decade continue to prioritize occupational safety and health research by major areas of the United States (U.S.) economy. In addition, seven cross-sectors were organized according to the major health and safety issues affecting the U.S. working population. While NIOSH is serving as the steward to move this effort forward, it is truly a national effort. NORA is carried out through multi-stakeholder councils, which are developing and implementing research agendas for the occupational safety and health community over the decade of 2016 to 2026. These councils address objectives through information exchange, partnership building, and enhanced dissemination and implementation of evidenced-based solutions.

The Hearing Loss Prevention Cross-Sector focuses on reducing occupational hearing loss through research on controlling hazardous noise and ensuring hearing protectors are as effective as possible where dangerous noise exposures have not yet been controlled or eliminated. Hearing loss prevention researchers seek to accomplish the following objectives:

1. Provide input for policies and guidelines that will inform best practices for hearing loss prevention efforts;
2. Develop effective, evidence-based education designed to improve hearing conservation program outcomes for exposed workers and management;
3. Develop, commercialize, and widely implement noise control solutions on jobsites in key industries;
4. Develop audiological tests for hearing loss prevention; and
5. Improve occupational hearing loss surveillance.

2. HEARING LOSS PREVENTION CROSS-SECTOR COUNCIL

The NORA Hearing Loss Prevention Cross-Sector council addresses the needs of many populations and worker groups. Population groups can include persons of different ethnicity, gender, age, education, and socio-economic status. Hearing loss prevalence also varies according to industry and occupation.[1–3] Consequently, the hearing loss prevention target audience includes, but is not necessarily limited to, the following:

- Occupational safety and health professionals, audiologists, hearing conservationists, occupational physicians, occupational nurses, industrial hygienists, and safety officers;

- Researchers from a wide range of specialties in audiology, industrial hygiene, engineering noise control, epidemiology, and basic and applied science;
- Workers in all occupational sectors;
- Management and employers in all occupational sectors;
- Labor organizations and unions concerned with the hearing health of their workers;
- Academic and professional organizations interested in hearing loss prevention, engineering noise control, and improvement of the hearing health of workers;
- National and international consensus standards-setting organizations;
- Health-related agencies in the federal, state, and local levels of the U.S. government; and
- Health-related agencies in non-U.S. governments concerned with occupational hearing loss.

3. ELEMENTS OF THE NATIONAL OCCUPATIONAL RESEARCH AGENDA FOR HEARING LOSS PREVENTION

The complete NORA Agenda for Hearing Loss Prevention was made available for public comment in early 2019. Following the public comment period, minor changes were made and the document is now available on the NIOSH web site, `https://www.cdc.gov/nora/councils/hlp/agenda.html`.[4]

This section will summarize each of the five agenda objectives identified in Section 1. A list will be given at the beginning of the subsection and a brief overview of the research needs in the area will follow. Given the limitations of a proceedings paper, we encourage the reader to download the agenda to gain a more complete understanding of the reasons for inclusion.

A. PROVIDE INPUT FOR POLICIES AND GUIDELINES THAT WILL INFORM BEST PRACTICES FOR HEARING LOSS PREVENTION EFFORTS

1. Assess exposure limits for mixtures of noise and other ototoxicants.
2. Promote fit testing in industrial hearing loss prevention programs.
3. Use applicable age correction for audiometric data.
4. Establish damage risk criteria for various noise exposures.
5. Develop business cases that demonstrate economic benefit for hearing loss prevention programs.
6. Develop standards for personal exposure monitoring with in-ear dosimetry.
7. Develop better technologies for hearing loss prevention.

For those working in the field of hearing loss prevention, the primary causative factor for hearing loss is noise exposure. The effects of noise have been studied for decades and U.S. regulations have been in place for more than 50 years. Research needs to be informative about how best to implement hearing loss prevention programs and should give clear guidance to regulatory bodies about how to establish policies that are feasible. The economic bottom line is increasingly more important in gaining support for hearing loss prevention in the corporate world. NIOSH, the National Hearing Conservation Association, and the Council for Accreditation in Occupational Hearing Conservation sponsor the Safe-in-Sound Excellence in Hearing Loss Prevention Award highlighting success stories from employers and of individuals who have been innovative and effective in the practice of protecting noise-exposed workers. More examples are needed to show that reducing noise not only reduces instances of hearing loss among workers, but also reduces employer liability and expenses.

Ototoxicants such as organic solvents, heavy metals, or pharmacologic substances when combined with noise exposures present a greater risk to the auditory system than noise or the ototoxicant in isolation. In some cases, the ototoxicant poisons the sensory cells, while in other cases they may affect the myelinization of the nerves. Johnson and Morata[5] published an excellent report that details a number of chemical ototoxicants that should be considered. As these compounds are investigated, better estimates of safe exposure limits may be generated.

Hearing protector fit testing has seen an increased popularity as manufacturers are developing new and innovative methods. The purpose is to determine if the hearing protector is suitable for an individual's particular exposure. Although the Occupational Safety and Health Administration (OSHA) does not require fit testing, a letter of interpretation has been issued that describes its appropriate use in a hearing conservation program.[6] HPD fit-test systems have the potential to be incorporated into the annual audiometric monitoring program. Teaching a worker the proper fitting procedure and selecting the hearing protector that allows the worker to obtain sufficient attenuation are critical to solving the issue of poor HPD use.

In its 1972 criteria document NIOSH proposed age-correction values.[7] These tables potentially yield over corrections for persons who have little or no hearing loss as they age[8] and are being studied for possible revision. Flamme et al. have recently developed age-correction tables from the National Health and Nutrition Examination Survey (NHANES).[9] These tables were validated by applying the corrections to a large longitudinal occupational audiometric database. Figure 1 illustrates one of the issues not addressed with the older age-corrections, a disparity between different ethnicities. The non-Hispanic Black (NHB) occupationally exposed and non-exposed groups had incidence rates that were less than the Other ethnic group comprised of persons that were not identified as non-Hispanic Black.

Noise exposures to complex combinations of continuous, intermittent and impulsive noise yield different risks of hearing loss.[10] Research is needed to understand how to assess these complex noise exposures, and exposures to high-level impulse noises from firearms or explosions.

Currently U.S. dosimetry is performed using a standard that requires the microphone to be mounted on the shoulder. The advent of miniature microphones and high quality data acquisition that can fit within the ear has led to in-ear dosimetry. Davis et al. demonstrated the improvement in the assessment of in-ear dosimetry compared to a microphone sampling from just outside the ear.[11] A new standard needs to be developed that will allow for accurate measurements from within the ear canal or underneath a hearing protector.

Finally, better technologies for hearing loss prevention can revolutionize the practice. Tech-

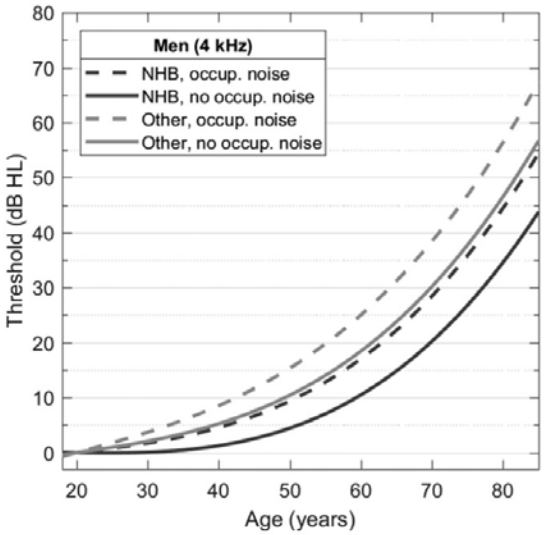

Figure 1: Age adjustments for different ethnicities. An analysis of the National Health and Nutrition Examination Survey (NHANES) has identified that the progression of hearing loss among two ethnic populations with and without occupational noise exposure exhibited disparate rates of hearing loss. The Non-Hispanic Black (NHB) occupationally exposed and non-exposed had incidence rates that were less than the Other ethnic group comprised of persons that were not identified as non-Hispanic Black.[9]

nologies that match a worker to a noise exposure are going to help reduce the uncertainty of exposures. Mobile devices with accurate sound measurement tools allow noise mapping to be integrated with exposure monitoring. The future has many possibilities.

B. DEVELOP EFFECTIVE, EVIDENCE-BASED EDUCATION DESIGNED TO IMPROVE HEARING CONSERVATION PROGRAM OUTCOMES FOR EXPOSED WORKERS AND MANAGEMENT.

1. Recognize noise exposure hazards.
2. Study interaction of medical conditions and/or pharmaceuticals with noise exposures.
3. Assess communication and work performance in noise (application of electronic solutions, localization, and speech intelligibility).
4. Focus on research-to-practice efforts for tinnitus.
5. Improve and promote hearing protector fit testing.
6. Adapt training to various worker groups.

An educated workforce should be an informed workforce. In some industries, the inertia of long-established habits prevents good industrial hygiene practices from taking hold. Some worker populations expect that hearing loss is a natural outcome of their trade.

Figure 2: Three posters from the NIOSH Buy Quiet Program.[13] NIOSH developed an approach to implementing a Buy Quiet program that would allow employers and companies to reduce noise exposures of their employees through a strategic plan of replacing noisy equipment or tools with quieter tools. These posters describe some practical tips that workers and employers can use to reduce employees' noise exposures.

Greater awareness of noise hazards both in the workplace and outside of work is needed. Workers who must demonstrate firearm proficiency such as law enforcement officers, public safety officers, and military personnel are at increased risk of developing permanent hearing loss and tinnitus. For unprotected ears, a single shot can produce sudden onset of tinnitus and perhaps temporary threshold shift (TTS). While this would seemingly be a harbinger of permanent damage to the ear, if the TTS recovers within a few minutes, hours, or even a day, the extent of damage is often unrealized. Research is needed to create additional effective interventions, such as The Dangerous Decibels® program, which has a very simple message: Turn It Down, Walk Away, and Protect Your Ears.[12]

The NIOSH Buy Quiet program aims to increase the awareness of both employees and employers. For example, the posters shown in Figure 2 describe actions that can be taken to reduce noise exposures in the workplace. Using quieter tools, wearing hearing protection, and maintaining equipment are basic to the reduction of occupational noise exposures.[13]

Noise exposure is not the only cause for hearing loss. As mentioned previously, ototoxic chemical exposures and some pharmaceuticals can be ototoxic in combination with noise exposure. Chemotherapy compounds such as carboplatinum and cisplatin are especially ototoxic. Organic solvents such as toluene or styrene are used in some industrial processes and present a potential risk of hearing loss in isolation from and/or in combination with noise exposure. Occupational physicians, audiologists, safety, and hearing conservation professionals should be aware of these risks and potentially limit noise exposures for these workers.

The concept of situational awareness has gained prominence in the military environment due to the simultaneous need for audibility of the surroundings, communication, and protection from

hazardous sound. Hearing protection is required whenever firing most weapons, but compromising the ability to hear and respond to critical sounds, or to communicate with colleagues, is of paramount concern. New solutions in electronics, noise cancellation technology, and near field communication networks will likely improve the future of hearing protection devices.

Tinnitus is often a consequence of noise exposure and work in a noisy environment. The Department of Veterans Affairs provides compensation for tinnitus and hearing loss as a primary service-connected disability to millions of veterans at an annual cost of more than four billion dollars.[14,15] Ongoing research to diagnose and effectively treat tinnitus is needed to preserve and improve the quality of life for those who must endure disabling tinnitus.

OSHA regulations mandate that workers be provided education about the proper selection and usage of hearing protection devices. Hearing protector fit testing can help satisfy this requirement. Fit testing can potentially be combined with the audiometric monitoring program. Several issues must be considered by employers and audiometric service providers. Fit testing is not required and it will take time. Time away from the job equates to an expense that may not be recoverable. If the training afforded by fit testing workers can be demonstrated as reducing liabilities and worker compensation costs, then the return on investment may be positive. In addition, providing services such as fit testing may help emphasize an overall culture of safety, as well as potentially bolster employee morale in working for an employer willing to "go the extra mile" for their safety.

Training in hearing protection or noise hazard awareness is not necessarily transferable across worker groups. For instance, providing training in English will be of little value to a population of workers for whom English is not the primary language. The messaging that works for one group of workers may not apply to a different group. Soldiers are concerned with situational awareness. Miners want to be able to hear "roof-talk" - a precursor noise for the collapse of the roof in a mine. Carpenters were more motivated to use hearing protection when the training message was shifted from hearing loss to avoiding tinnitus.[16] The audience for training must be understood and the message must be tailored to fit the audience.

C. DEVELOP, COMMERCIALIZE, AND WIDELY IMPLEMENT NOISE CONTROL SOLUTIONS ON JOBSITES IN KEY INDUSTRIES.

1. Assess feasibility of developing and commercializing low-cost noise control solutions.
2. Evaluate the dissemination and effectiveness of practical engineering noise-control solutions for workers exposed to occupational noise.

The NIOSH hierarchy of controls[17] shown in Figure 3 lists elimination of a hazard, substitution of a safer process for a hazardous process, and engineering control of a hazardous process as the top three elements, respectively. Administrative controls and PPE usage require active involvement of the worker and close supervision by occupational safety and health staff. The hierarchy should be followed when working to reduce hazardous noise exposures. The NIOSH research efforts have focused on identifying potential noise control solutions, developing them into a viable product and then partnering with industrial companies to evaluate how well the solutions work. Integral to the process is determining whether a solution is feasible from an operational viewpoint.

Once a solution has been developed, the public must be informed about its benefits. NIOSH has championed the use of the Buy Quiet and Quiet-By-Design programs. The concept is simple:

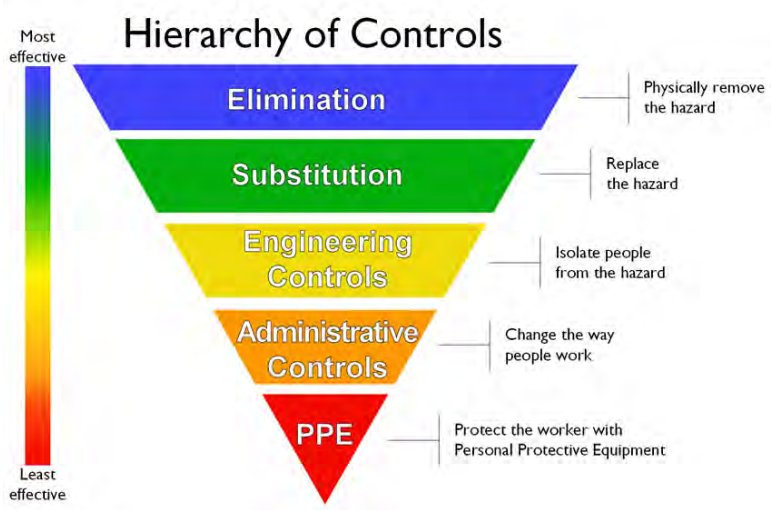

Figure 3: The NIOSH hierarchy of controls.[17] Elimination of a noisy task or operation is most effective. When a quieter operation can be substituted for a noisier one, this is the second most effective approach.

- Take an inventory of equipment or tools that make noise;
- Identify the known sound output levels for those tools;
- Identify potential replacement tools that are substantially quieter and which provide the same functionality; and
- As equipment or tools wear out, replace with quieter alternatives.

The Safe-in-Sound Excellence in Hearing Loss Prevention and Innovation award has identified several companies that have implemented noise control in the workplace. Simple fixes to noisy processes are possible. If employers and workers are aware of these solutions then they can implement their own form of Buy Quiet and Quiet-By-Design.

D. DEVELOP AUDIOLOGICAL TESTS FOR HEARING LOSS PREVENTION.

1. Develop objective mechanisms for early detection of noise-induced hearing loss.
2. Conduct speech-in-noise testing an early indicator of hearing loss.
3. Develop research goals for the understanding of how hidden hearing loss might lead to early identification of noise-induced hearing loss.
4. Develop an acoustic standard for assessment of otoacoustic emissions for hearing loss.
5. Develop an acoustic standard for extended high-frequency audiometry.
6. Develop recommendations for inclusion of these methods into occupational hearing loss–prevention programs.

Figure 4: Two different types of headsets for occupational hearing loss prevention: left panel is the Creare headphone, right panel is the NIOSH HPD Well-Fit hearing protector fit-testing system. The Creare headset includes a signal processing unit that allows a variety of audiometric tests to be performed with the same headset. The HPD Well-Fit system was developed by NIOSH researchers to facilitate hearing protector fit testing that can be incorporated into an industrial hearing loss prevention system. Photo credits: Creare headset, William Murphy CDC NIOSH; NIOSH HPD Well-Fit system, Scott Childress, USAARL Fort Rucker.

7. Assess the tools for early identification of hearing loss in occupational environments.

8. Evaluate mobile technologies.

One of the shortcomings of the current practice of hearing conservation programs is that they tend to document the progression of hearing loss of the workers rather than identify early symptoms of over-exposure to noise. Early identification of at-risk workers is more desirable than allowing these workers to suffer hearing loss. While hearing science has grown increasingly sophisticated, the administration of audiometric monitoring is still rooted in the practices from the late 1960s, using pure-tone audiograms to identify hearing threshold shifts.

The pure tone audiogram is an assessment of sound detection, however there are other aspects of hearing ability or disability that need different diagnostic testing. Cochlear synaptopathy and hidden hearing loss have been revealed as possible byproducts of over exposure to noise affecting both persons in the general population and noise-exposed workers.[18] Research is needed to characterize synaptopathy in humans, its relation to early identification of noise injury and its effect on noise-induced hearing loss. Synaptopathy may be correlated with decreases in otoacoustic emissions (OAEs). Tests for synaptopathy and auditory processing deficits need to be incorporated into hearing loss prevention programs.

In some persons, the audiogram might be within normal limits, but individuals may find it difficult to communicate in noisy environments. Testing a person's speech-in-noise performance may identify early deficits not captured by pure-tone testing.

The existence of hidden hearing loss is an important issue for the hearing loss prevention community. Research is needed to determine whether noise-exposed workers are at a higher risk of hidden hearing loss than the general population. As well, the underlying mechanisms for hearing-in-noise deficits are not yet understood.

Otoacoustic emissions are becoming increasingly practical in a screening environment. The ideal test characteristics need to be determined for early identification of hearing loss in noise-exposed workers. Standards of practice for incorporating OAEs into a hearing loss prevention program need to be developed and evaluated. The calibration of the stimuli for OAEs has been a topic of debate for decades. Initially the OAE probes were calibrated in ear similators, but positioning of the probe proved to be a source of variability in the level of the probe tones at the eardrum. Recent developments have led to a forward pressure calibration in the ear canal that provides a more consistent measurement with placement of the OAE probe. Similarly, extended high frequency audiometry suffers from a problem of calibration issues when coupling a transducer to the ear canal. At frequencies above 8 kHz, the acoustics of the pinna, ear canal and middle ear can substantially affect the levels presented to the ear.

For each of these new methods, recommendations need to be made for how best to include technological advances in existing hearing loss prevention programs. These new tools should be assessed in well-designed studies. Mobile technologies have the potential to bring the test to the worker rather than the worker to the test. Many new boothless and wireless solutions for audiometric testing have been developed in recent years. As advances are made, the technologies need to be evaluated and verified (See Figure 4).

E. IMPROVE OCCUPATIONAL HEARING LOSS SURVEILLANCE

1. Improve exposure surveillance, including measuring and monitoring worker noise and ototoxic chemical exposures and the use, effectiveness, and cost of worker protections, while preserving and improving the quality of the data collection.

2. Improve outcome surveillance, including measuring worker hearing loss, tinnitus, and related health outcomes, while preserving and improving the quality of the data collection.

Surveillance of occupational hearing loss and related health conditions, exposures, and protections among U.S. workers is an ongoing need and must be improved. Surveillance includes monitoring the burdens and trends within industries and occupations to identify high-risk groups, hazards, and worker protections, to guide prevention and research priorities, and to evaluate progress in hearing loss prevention efforts. Current mechanisms for collecting surveillance data need expansion, and new sources need to be identified to include additional worker populations, exposures, outcomes, and protections.

Systematic collection of noise measurement data by OSHA is limited to regulatory inspections. Access to this information is restricted and these data are not statistically representative of exposures for any particular industry, occupation, or region. Systematic collection of data on worker chemical exposures is similarly limited. Not all ototoxic chemicals have been identified, and no requirement exists for audiometric testing, record keeping, or hearing conservation activities based on an ototoxic chemical exposure. Systematic data collection regarding the use of hearing protection is limited as well. No mechanism exists that documents the exposures and types of worker protection (e.g. earmuffs, earplugs, engineering controls, and administrative controls).

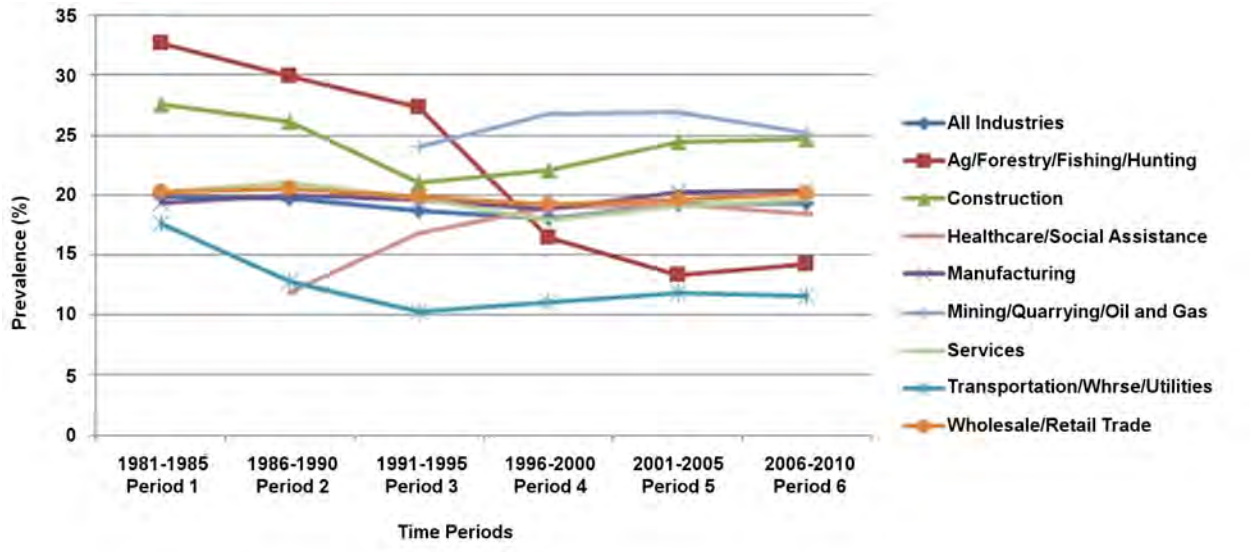

Figure 5: The prevalence of hearing loss by time period and industry sector, 1981-2010, for noise-exposed workers (Figure 1. from Masterson et al. 2015).[2]

Basic surveillance of the effectiveness, costs, or cost-benefits of the different types of worker protections is essentially non-existant.

Exposure surveillance can be improved by 1) using existing data sources to analyze noise and ototoxic chemical exposure data and data regarding the use, effectiveness, and costs of personal protective equipment, engineering controls, and other worker protections; and 2) collecting new surveillance data and improving existing surveillance systems to capture noise and ototoxic chemical exposure data, as well as data regarding the use, effectiveness, and costs of different worker protections. Figure 5 displays the trends for prevalence of hearing loss by five-year time increments for data collected through the NIOSH Occupational Hearing Loss Surveillance Project.[2] The prevalence in some industries has decreased considerably over the time span 1981 to 2010. In other sectors, notably Mining and Construction, the prevalence is approaching 25%. While these data are not statistically representative, they provide information about what sectors have a higher burden and need for continued efforts to prevent hearing loss.

Outcome surveillance can be improved by 1) using existing data sources to analyze information on worker hearing, cardiovascular health, mental health, and other related health conditions; and 2) collecting new surveillance data and improving existing surveillance systems to capture data on worker hearing, cardiovascular health, mental health, and other related health conditions.

4. CONCLUSION

The NORA Agenda for Hearing Loss Prevention is not a stagnant document. As we interact with scientists and practitioners, we will learn what elements may be missing. The scope of this agenda is broad and cannot be completed by a few researchers in NIOSH. Rather it will require a collaboration across private industry, academia and government to address these issues. We anticipate successful outcomes from this agenda and hope that in future years these successes (and failures) can be shared.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention or 3M Company. Mention of any company or product does not constitute endorsement by NIOSH, CDC, or 3M.

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