HEARING CENTER OF EXCELLENCE

NOISE AND MILITARY SERVICE: IMPLICATIONS FOR HEARING LOSS AND TINNITUS

INSTITUTE OF MEDICINE OF THE NATIONAL ACADEMIES

2005

Complete report available from the National Academies Press:
http://www.nap.edu/catalog/11443.html

HCE

HCE INTRODUCTION

- The Department of Defense established the Hearing Center of Excellence (HCE) to focus on the prevention, diagnosis, mitigation, treatment, and rehabilitation of hearing loss and auditory injury.

- HCE was legislated by Congress in the National Defense Authorization Act (2009) and directed to partner with the Department of Veterans Affairs (VA), institutions of higher education, and other mission-minded public and private organizations.
  - *Mission: To heighten military readiness to optimize quality of life through collaborative leadership and advocacy for hearing and balance health initiatives*

- This informational packet is aimed at facilitating the development of clinical best practices and encouraging/facilitating hearing health research in the DoD and VA.

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INTRODUCTION – NOISE AND MILITARY SERVICE

- Page numbers throughout this document reference complete report available from the National Academies Press: http://www.nap.edu/catalog/11443.html

- Committee on Noise-Induced Hearing Loss and Tinnitus Associated with Military Service from World War II to the Present
  - Charge to the Committee (pg. 16) – Public Law 107-330 (6 Dec 2002)
  - Committee membership (pg. v)
    - *Larry E. Humes, Lois M. Joellenbeck, and Jane S. Durch, Editors*
    - *National Research Council, Institutes of Medicine, Centers for Disease Control, academia (with assistance from DoD, VA, NARA and others)*
  - Committee investigated available resources through completion in 2005 (pg. 3)
    - Peer-reviewed journals
    - Books
    - Reports prepared by/for military services
    - Documents and data provided by military services
    - Testimony and presentations from veterans and military services
  - Comprehensive review by SMEs (pg. vii)
  - Project completed in 2005 (15 month effort)

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NOTE: Page numbers throughout this document reference complete report available from the National Academies Press: http://www.nap.edu/catalog/11443.html

1 – OVERVIEW OF THE PROBLEM AND INTRODUCTION

- The first chapter lays out the rationale for investigating the causes of hearing loss and tinnitus in military settings, *Statement of Task* and methods of investigation.
- Concerns about the noise hazards associated with military service and questions about the relationship between noise exposure and hearing loss or tinnitus led Congress to direct VA to contract with the National Academies for a study of these issues (pg. 15-16).
- The committee convened by the Institute of Medicine of the National Academies to conduct this study was charged with reviewing the period from World War II (WWII) to present as charged in Section 104 of Public Law 107-330 (6 Dec 2002).
- The investigation does not consider the effects of noise other than upon the auditory system, including hearing loss and tinnitus, nor of the issues surrounding assisted hearing through hearing aids or prosthetic devices.
- The study committee included members with expertise in audiology, bioacoustics, military preventive medicine, occupational medicine, industrial hygiene and hearing conservation programs, epidemiology, and otology.

1 – OVERVIEW OF THE PROBLEM AND INTRODUCTION

Charge to the Committee
The National Academies shall:
1. Review and assess available data on hearing loss that could reasonably be expected to have been incurred by members of the Armed Forces from the beginning of WWII.
2. Identify the different sources of acoustic trauma that members of the Armed Forces could reasonably be expected to have been exposed to from the beginning of WWII.
3. Determine how much exposure to each source of acoustic trauma identified is required to cause or contribute to hearing loss, hearing threshold shift, or tinnitus, and at what noise level.
4. Determine whether or not such hearing loss, hearing threshold shift, or tinnitus, is—immediate or delayed onset; cumulative; progressive; or any combination.
5. Identify age, occupational history, and other factors which contribute to an individual's noise-induced hearing loss.
6. Identify the period of time at which audiometric measures used by the Armed Forces became adequate to evaluate individual hearing threshold shift; and the period of time at which hearing conservation measures to prevent individual hearing threshold shift were available to members of the Armed Forces, shown separately for each of the Army, Navy, Air Force, Marine Corps, and Coast Guard, and, for each such service, shown separately for members exposed to different sources of acoustic trauma identified.

Public Law 107-330 (6 Dec 2002), Section 104 provided in Appendix A (pg. 209)

1 – OVERVIEW OF THE PROBLEM AND INTRODUCTION

- At end of fiscal year 2003, 2.5 million veterans were receiving disability compensation for approximately 6.8 million separate military service-related disabilities (pg. 1).
  - *Further information can be found at: http://www.va.gov/vetdata/Utilization.asp*

- Disabilities of the auditory system, including tinnitus and hearing loss, were the third most common type of compensable disability reported, accounting for nearly 10% of the total number of disabilities.
  - Annual payments to veterans for **hearing loss** (2004) as the "major form" of disability = $**660 Million** (approx.) (pg. 1)
  - Annual payments to veterans for **tinnitus** (2004) as the major form of disability = $**190 Million** (approx.) (pg. 2)

1 – OVERVIEW OF THE PROBLEM AND INTRODUCTION

Research Categories

Prospective studies of temporary hearing loss in humans

- *Studies of Temporary Threshold Shift (TTS; pg. 23)*

Retrospective analyses of permanent hearing loss in humans

- *Studies of Permanent Threshold Shift (PTS; pg. 23)*

Laboratory animal studies of both temporary and permanent effects of noise on the auditory system

- *Laboratory Animal Studies (pg. 24)*

2 – NOISE-INDUCED HEARING LOSS (NIHL)

- The purpose of this chapter is to provide background on NIHL to facilitate understanding of the evidence in military personnel presented in Chapter 3. This includes (pg. 33):
  - A general discussion of the structure and function of the auditory system, with particular emphasis on the periphery, and the impact of noise on the peripheral auditory system.
  - The effects of noise on hearing thresholds as well as the time course for the development of hearing loss from noise exposure.
  - Exogenous and endogenous risk factors that may alter an individual's susceptibility to noise-induced hearing loss are reviewed.
  - A discussion of national and international standards that have been developed to estimate the amount of NIHL to be expected from a given noise exposure and to separate the effects of noise from age-related changes in hearing.

- Noise-induced hearing loss (NIHL)
  - Key acoustic parameters of noise exposure (pg. 40)
  - *Intermittent and Continuous Exposures to Steady-State Noise (pg. 38)*
  - *Impulse/Impact Noise (pg. 36)*

2 – NOISE-INDUCED HEARING LOSS (NIHL)

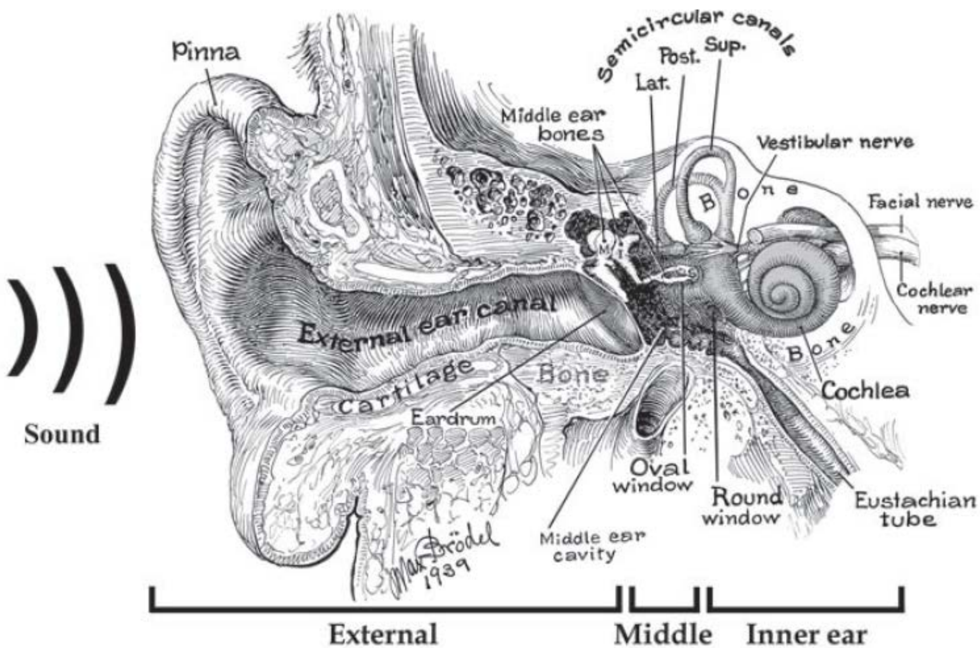


FIGURE 2-1 Semi-schematic drawing of the human ear. Sound waves enter the pinna, travel through the external ear canal, and strike the eardrum, setting it in motion. Motion of the eardrum sets the middle ear bones (malleus [M], incus [I], and stapes [S]) in motion and ultimately generates pressure waves in the fluids of the inner ear. Sensory cells in the hearing portion of the inner ear (i.e., cochlea) are then stimulated. When the fibers of the cochlear nerve are stimulated by the sensory cells, auditory information is transmitted to the brain.
SOURCE: Modified from Brödel (1946).

Figure on pg. 34 of complete report available from the National Academies Press: http://www.nap.edu/catalog/11443.html

2 – NOISE-INDUCED HEARING LOSS (NIHL)

TABLE 1-1 Categories of Hearing Loss and Corresponding Pure-Tone Thresholds for Adults

Category of Hearing Loss	Pure-Tone Threshold
Normal	< 25 dB HL
Mild	26–40 dB HL
Moderate	41–55 dB HL
Moderately severe	56–70 dB HL
Severe	71–90 dB HL
Profound	> 90 dB HL

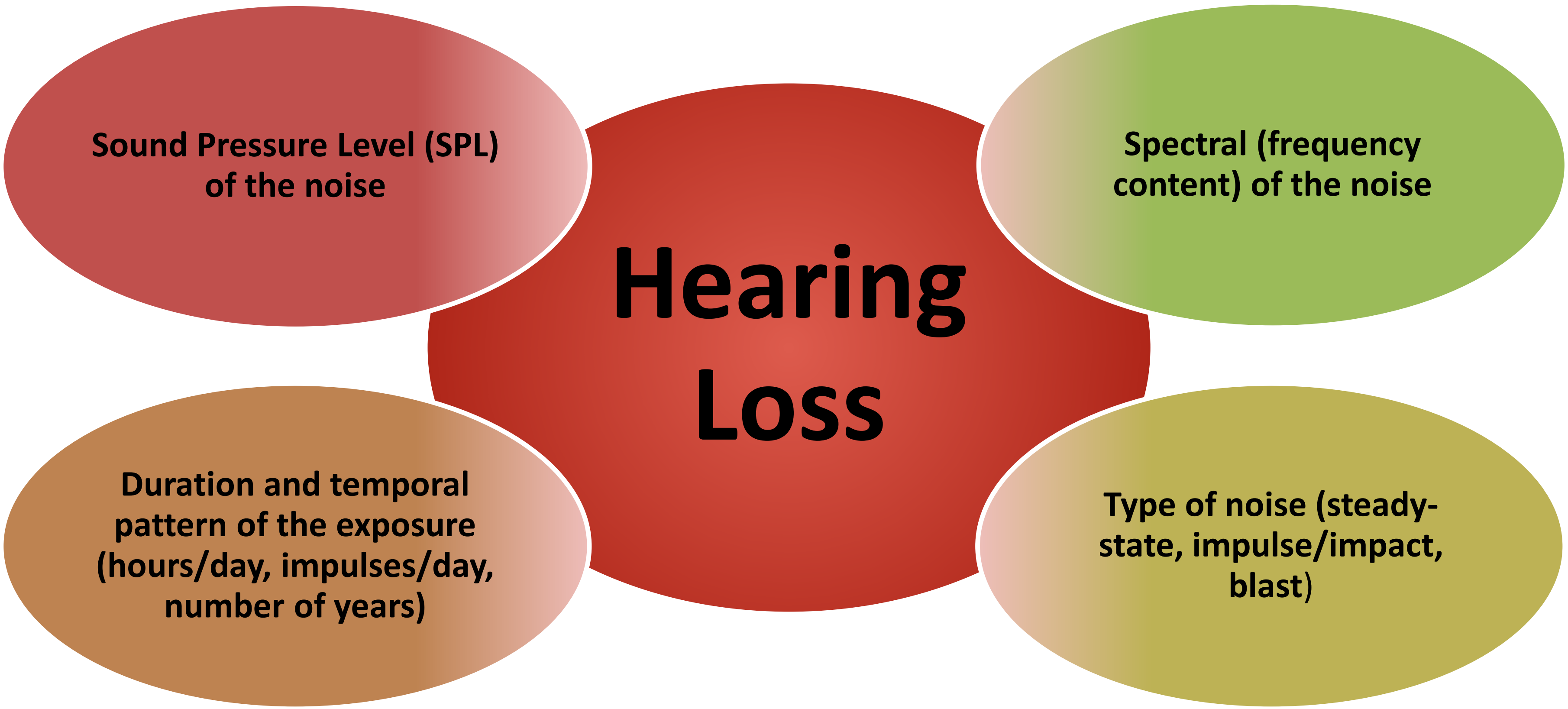
Table on pg. 21 of complete report available from the National Academies Press: http://www.nap.edu/catalog/11443.html

2 – NOISE-INDUCED HEARING LOSS (NIHL)

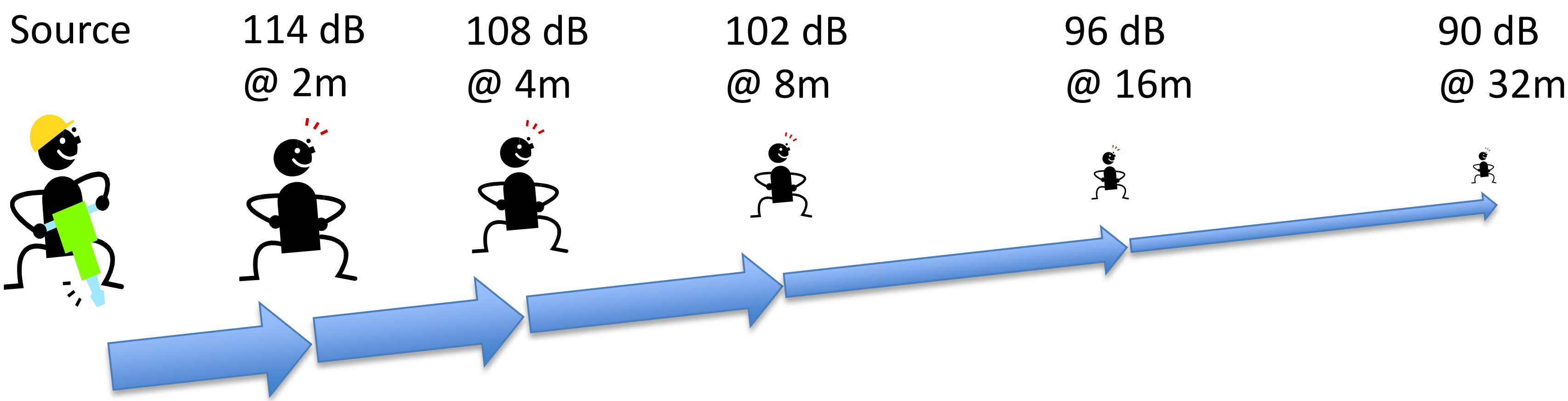
TERM	DEFINITION/NOTES
NIHL	"noise-induced hearing loss is confined primarily to frequencies at or above 2000 Hz" (pg. 22)
Noise-notch	"pattern of hearing loss across frequencies, together with supporting evidence from a detailed case history, that lead to the diagnosis of noise-induced hearing loss" (pg. 22) "hallmark of noise-induced hearing loss is a characteristic noise notch in the audiogram that typically occurs between 3000 and 6000 Hz" (Figure 2-3; pg. 38)
TTS	"Temporary threshold shift" is defined as hearing thresholds that have worsened from preexposure to postexposure. Specifically, postexposure measurements that reveal an eventual return to the preexposure hearing thresholds. (pg. 23)
PTS	"Permanent threshold shift" reflect postexposure measurements that do not return to the preexposure hearing thresholds. (pg. 22)
Acoustic trauma	Damage resulting from short-term, high-intensity noise exposure (pg. 37)

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Determinants of hearing loss



Refer to pg. 40 for details



There is a 6 dB decrease in Sound Pressure Level (SPL) for every *doubling* of the distance from the source.

IF Jackhammer is measured at 114 dB @2m,
THEN SPL would be expected to be:
-6 dB @4m, -12 dB @8m, -18 dB @16m, -24 dB @32m

Refer to "ACOUSTICS AND NOISE" on pg. 18 for more detailed review.

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Duration/Noise Dose

$$\% \text{Dose} = \left(\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n} \right) \times 100$$

- C = the actual time exposed at each dB level
- T = the time allowed to be exposed at each dB level

Acoustic parameters of noise (e.g., SPL, duration, type, and frequency content) can influence the hearing loss that is measured following noise exposure (pg. 19)

Noise dose captures the major influences of noise level and time of exposure (pg. 20)

- *8-hour, time-weighted average (TWA)*

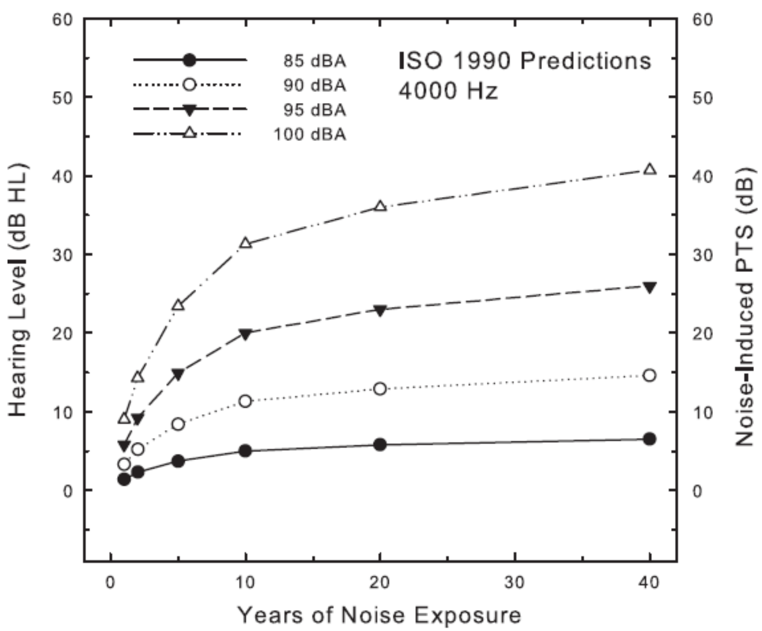
2 – NOISE-INDUCED HEARING LOSS (NIHL)

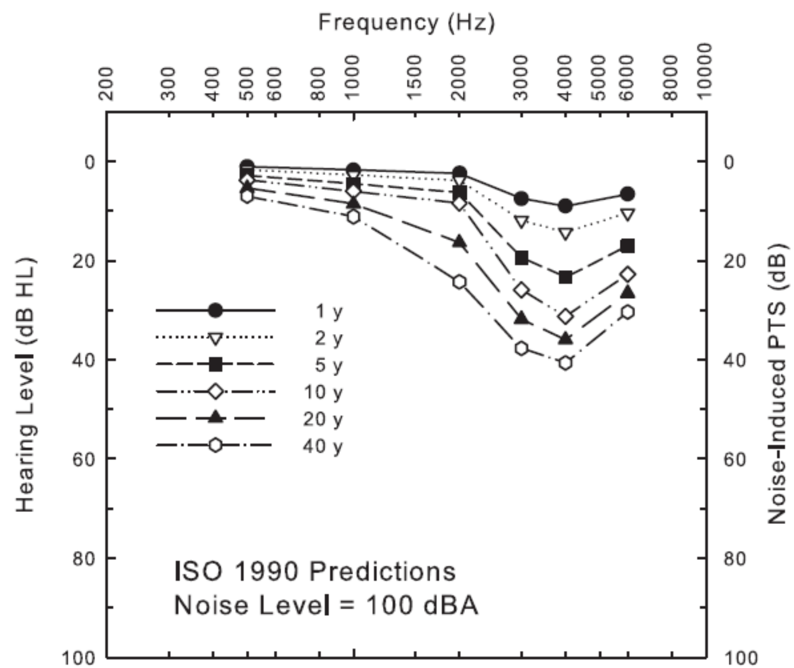
TYPE OF NOISE	DEFINITION/NOTES
Impulse/Impact Noise	"High-level, short-duration noise can arbitrarily be categorized as impulse noise, which is the product of explosive devices (e.g., gunfire), or impact noise, which is generated by the forceful meeting of two hard surfaces (e.g., a hammer to a nail, impact wrenches)." (pg. 36)
Steady-State Noise (Intermittent)	"Exposure to less intense noise (i.e., <90 dBA) for short durations (i.e., </= 24 hrs." (pg. 38)
Steady-State Noise (Continuous)	Exposure to less intense noise (i.e., <90 dBA) for longer durations (i.e., >24 hrs). (pg. 38)

"Generally…sounds in the frequency range 2000–5000 Hz tend to be more damaging to human hearing than sounds with energy at lower or higher frequencies." (pg. 19)

2 – NOISE-INDUCED HEARING LOSS (NIHL)

<u>Intermittent and Continuous Exposures to Steady-State Noise (pg. 56)</u>





2 – NOISE-INDUCED HEARING LOSS (NIHL)

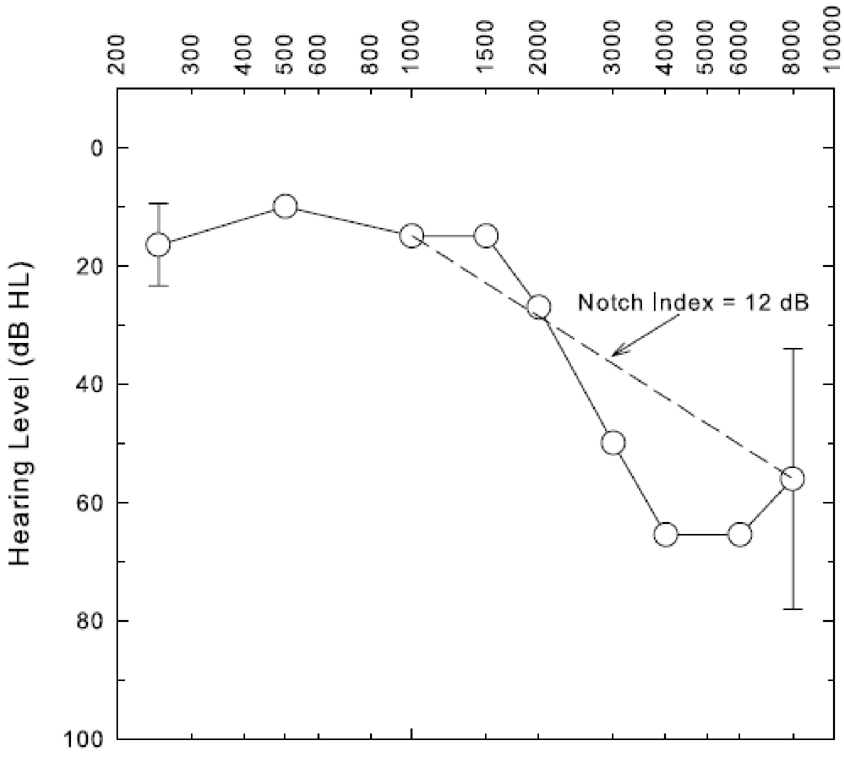


FIGURE 2-3 Illustration of a typical noise-notch audiogram. Average audiogram (n = 450 ears) from Cooper and Owen (1976) shown here. Error bars at 250 and 8000 Hz represent ±1 standard deviation and were the only standard deviations reported by the authors of this study for the average pure-tone thresholds at individual frequencies. The dashed line connecting thresholds at 1000 and 8000 Hz provides a visual representation of the Notch Index (NI) metric.

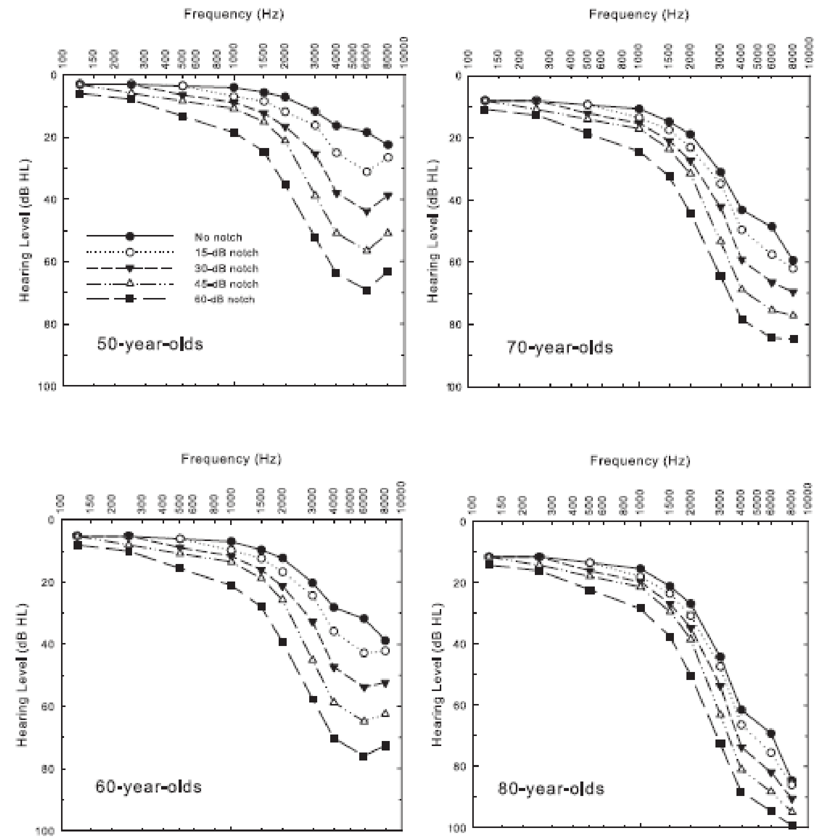


FIGURE 2-7 Illustrations of the combined effects of aging (top panel from Figure 2-6) and noise exposure (bottom panel from Figure 2-6) using the ISO-1999/ANSI S3.44 model for additivity. Each panel depicts the combined hearing loss for a separate decade (50-, 60-, 70-, or 80-year-old men).

Figures on pg. 39 & 63 of complete report available from the National Academies Press: http://www.nap.edu/catalog/11443.html

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Acoustic Trauma (pg. 40-41)

Acoustic Trauma = Intense Noise (Blast) > 150 dBA

Potential for damage at levels approaching/exceeding 180 dB SPL:
• Hemorrhage in eardrum
• Perforation of eardrum
• Fracture of malleus
• Organ of Corti may rupture off basilar membrane

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Committee-adopted Scale for Evaluating Strength of Evidence in Research (pg. 30):

Sufficient evidence that NO association exists	Not sufficient evidence to determine whether an association exists	Limited or suggestive evidence (of an association)	Sufficient evidence (of an association)	Sufficient evidence of a causal relationship
Several strong studies that find ***no*** association	***Few or no*** studies of sufficient quality	No evidence from strong studies, but ***some*** evidence from other studies of sufficient quality	Evidence from ***several*** strong longitudinal or cross-sectional studies	Consistent evidence from ***many*** strong longitudinal studies

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Research Summary Scale

Sufficient evidence that no association exists	Not sufficient evidence to determine whether an association exists	Limited or suggestive evidence (of an association)	Sufficient evidence (of an association)	Sufficient evidence of a causal relationship
• Several strong studies that find *no* association	• *Few or no* studies of sufficient quality	• No evidence from strong studies, but some evidence from other studies of sufficient quality	• Evidence from *several* strong longitudinal or cross-sectional studies	• Consistent evidence from *many* strong longitudinal studies

NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Findings (Laboratory Studies in Animals and Humans):	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Most pronounced effects of a given noise exposure on pure-tone thresholds are measurable immediately following the exposure. (pg. 44)			X
The length of recovery of hearing thresholds (partial or complete) related to the level, duration, and type of noise exposure. (pg. 44)			X
Most recovery to stable hearing thresholds occurs within 30 days. (pg. 44)			X
Permanent NIHL can develop much later in one's lifetime, long after the cessation of that noise exposure based on longitudinal studies. (pg. 44)	X		
Based on…data available on the recovery process following noise exposure, it is unlikely that such delayed effects occur. (pg. 44)		X	

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Findings (Exogenous Risk Factors):	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Carbon Disulfide (pg. 48)	X		
Organic Solvents (Toluene/Ototoxins) (pg. 49)	X		
Chemical asphyxiants (hydrogen cyanide, carbon monoxide, noise) (pg. 50)	X		
Jet fuel (pg. 49)		X	
Cigarette smoke (possible) (pg. 50)	X		
Whole-body vibration (increases TTS when noise present and body temperature elevated) (pg. 50)		X	
Body temp elevation (pg. 50)	X		
Electromagnetic fields (Magnetic Resonance Imaging) (implicated) (pg. 51)		X	

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Findings (Endogenous Risk Factors):	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Age (pg. 52)	X		
Race (pg. 52)	X		
Gender (pg. 51)	X		
Eye color (pg. 54)	X		
Prior hearing loss/noise exposure (pg. 54)	X		

2 – NOISE-INDUCED HEARING LOSS (NIHL)

Findings (General):	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Daily time-weighted average noise exposures greater than approximately 85 dBA for 8 hour periods for many years pose a hazard to human hearing and that hazard increases as the time-weighted average exposure exceeds this value. (pg. 64)			X
Ability to determine probability of acquiring a noise-induced hearing loss, or to estimate the magnitude of NIHL that an individual is likely to experience from a given noise exposure (pg. 64)	X		

3 – NOISE AND NIHL IN THE MILITARY

- The focus of this chapter is on noise and noise induced hearing loss in the U.S. military. (pg. 72)
  - The first part of the chapter briefly reviews the services' policies and programs to collect data on noise levels generated by equipment used by military personnel and the noise doses received by military personnel working in certain settings.
  - The remainder of the chapter focuses on the committee's assessment of data on hearing thresholds and hearing loss among military service members since World War II.

3 – NOISE AND NIHL IN THE MILITARY

- The assessment noted limitations in data collection efforts, such as:
  - Incomplete noise exposure data (SPL and dosimetry data) as well as insufficient measurements of pure-tone hearing thresholds among military personnel result in inability to provide comprehensive review (pg. 77, 82, 84-85)
  - Few studies available are not generalizable to "broader populations of military service members or veterans…" (pg. 111)

- Examples:
  - No systematic data on acoustic trauma injuries (pg. 89)
  - Noise notch data collected after 1970s excludes 8000 Hz test frequency and is often only for "worse ear." (pg. 90-91)
  - Unreliable data from large-scale studies due to changing measurement procedures and conditions (pg. 91)

3 – NOISE AND NIHL IN THE MILITARY

Findings:	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Hazardous noise levels are and have been present in many military settings. (pg. 82)			X
(Available data provides)…basis for estimating cumulative noise exposures over the course of military service for individuals or for subgroups. (pg. 82)	X		
Conclusion(s) regarding the number or proportion of service members, overall or in specific occupational groups or eras since World War II, who have experienced noise-induced hearing loss while in the military. (pg. 111)	X		
Certain military personnel from World War II to the present have exhibited hearing thresholds while in the military that are typical of noise-induced hearing loss. (pg. 111)			X
The probability of acquiring noise-induced hearing loss associated with service in the military, or in specific branches of the military, for a given individual. (pg. 111)	X		
In the absence of audiograms obtained at the beginning and end of military service, **it is difficult or impossible to determine with certainty how much of a specific individual's hearing loss was acquired during military service**. (pg. 111)			X

4 - TINNITUS

- "This chapter first provides a brief overview of the features of tinnitus, its impact on individuals with the condition, and approaches to its clinical assessment and treatment. Some of the issues that arise in studying tinnitus are noted, and basic data on its occurrence in the general population are presented. The major portion of the chapter focuses on a review of epidemiological data on the relationship between tinnitus and noise exposure, hearing loss, and other risk factors." (pg. 116)

- Tinnitus is variously characterized as (pg. 117):
  - Buzzing
  - Whistling
  - High-pitched (with noise exposure)
  - Transient or persistent
  - Gradual or sudden onset
  - Hissing
  - Humming
  - Low-pitched (Meniere's disease)
  - Occasional or consistent
  - Associated with many conditions, including noise exposure and NIHL

4 - TINNITUS

<u>Impacts (pg. 119):</u>

Impaired psychological well-being	Increased fear
Impaired emotional health	Increased frustration
Impaired hearing	Increased anger
Impaired sleep	Increased irritability
Impaired concentration	Increased anxiety
Impaired ability to function in social and professional settings	Increased suicide risk potential
Depression	

4 - TINNITUS

TABLE 4-2 Percentage of U.S. Military Personnel Completing Post-Deployment Health Assessment Questionnaires Who Reported Tinnitus, by Reported Exposure to Loud Noise During Deployment, 2003–2004

		Exposure to Loud Noise During Deployment		
Reports on Ringing in Ears	Total (n = 440,451)	No (n = 159,725)	Sometimes (n = 120,928)	Often (n = 159,798)
No ringing	89	97	91	78
Ringing in ears				
Developed during deployment	8	2	6	15
Now*	2	1	2	4
During deployment and now	1	0	1	3
Total	100%	100%	100%	100%

* "Now" refers to the time at which the questionnaire was completed (within 30 days before or after the end of deployment).
SOURCE: AMSA (2004).

pg. 129

4 - TINNITUS

Findings:	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Noise doses associated with hearing loss are likely to be associated with tinnitus. (pg. 132)			X
Reach conclusions regarding the specific number or proportion of service members, overall or in specific branches or occupational groups, who report that tinnitus began or was exacerbated by noise exposure during military service. (pg. 132)	X		
Exposure to impulse noise is associated with a greater likelihood of having tinnitus compared with exposure to steady-state noise (pg. 133)		X	
Hearing loss (hearing thresholds greater than 25dB HL at one or more frequencies between 250 and 8000Hz) is associated with higher prevalence of tinnitus. (pg. 135)			X
Determine precisely the magnitude of the risk of tinnitus associated with hearing loss. (pg. 135)	X		

"Despite the fact that tinnitus is compensable, the committee found little indication that the services monitor the presence or absence of tinnitus among military personnel during active duty…" (pg. 138)

"…Perhaps the only current source of limited but explicit documentation of tinnitus is the post-deployment health assessment questionnaire (DD Form 2796)." (pg. 139)

5 – RESPONDING TO NOISE RISKS

- This chapter describes key aspects of hearing conservation programs and reviews the development and adequacy of programs in the military. Current hearing conservation programs do not include monitoring or prevention of tinnitus. As described in Chapter 4, the relationship between noise exposure and tinnitus is not yet well understood. However, the committee makes the presumption that measures taken to protect against noise-induced hearing loss are likely to help in the prevention of tinnitus. Thus, many of the elements of a hearing conservation program could be applied to prevention of tinnitus as well as hearing loss. (pg. 146)

- The chapter includes:
  – Historical background on military hearing conservation programming (pg. 146-159)
  – Assessments of hearing conservation program adequacy for the various branches, since World War II (pg. 159-180)

Timeline of Military Hearing Conservation Efforts (pg. 72-77, 87-88, 149)

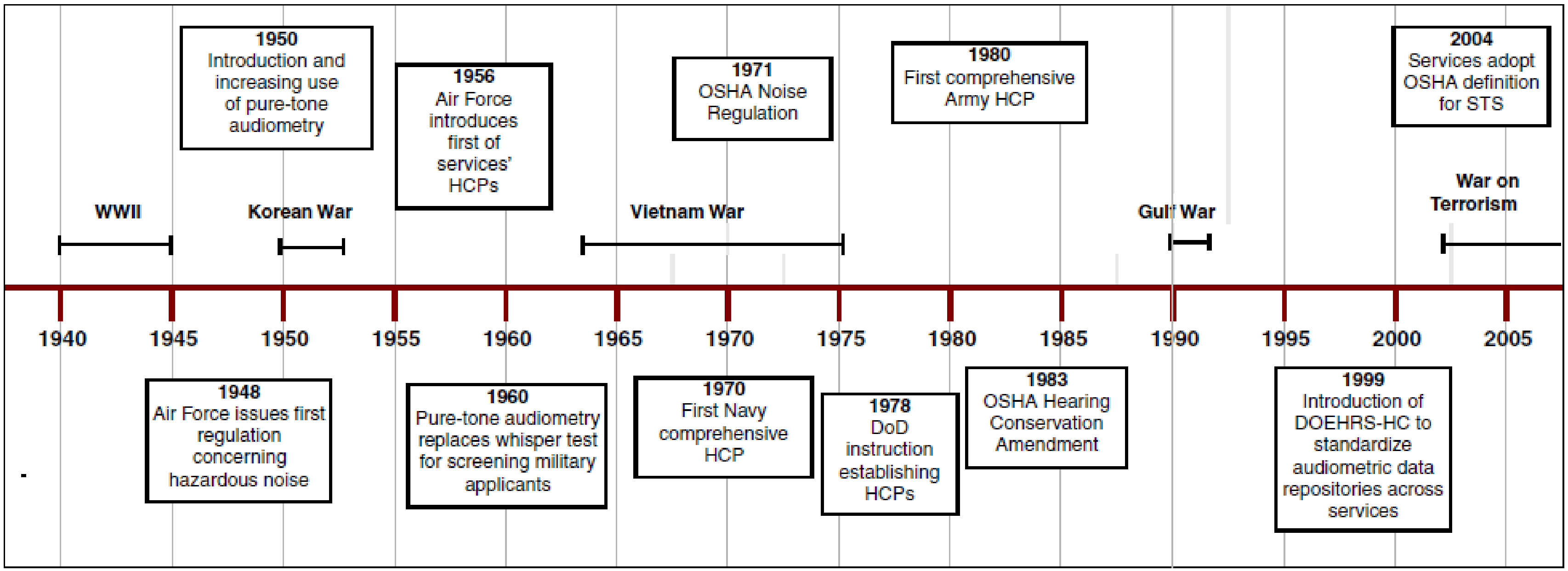


FIGURE 5-1 Time line of major conflicts and milestones in hearing conservation programs.
NOTES: DoD, Department of Defense; DOEHRS-HC, Defense Occupational and Environmental Health Readiness System–Hearing Conservation; HCP, hearing conservation program; OSHA, Occupational Safety and Health Administration; STS, significant threshold shift.
SOURCES: Gasaway (1988); Nixon (1998); Department of Veterans Affairs (2005); Ohlin (2005b).

5 – RESPONDING TO NOISE RISKS

TABLE 5-2 Available Hearing Protection from World War II to the Present

Time Frame	Typical Devices	Comments
World War II	Cotton	Minor amounts of noise reduction
	Fingers	Effective but inconvenient; used by artillery crews to some extent
	Nothing	The standard of the day
1945–late 1950s	Vaseline-impregnated cotton	Messy, modestly effective, better for water protection than noise protection
	V-51R earplug	Initially produced in three sizes; developed just at the end of World War II
	Hard custom earmolds	Easily lost seal, not widely used
	Early circumaural earmuff designs	Initial designs had inadequate cushions and modest attenuation (around 20 dB or less) up to 1000 Hz
	Navy "cranial earmuffs" introduced in mid-1950s and still in use today (circa 2005)	Plastic earmuff cups held in place by fabric head cap with a plastic shell covering the fabric but not enclosing the earmuff cups; inadequate fitting and modest protection
1960s	V-51R earplug	An extra-small and extra-large size added to fit a wider range of ear canals
	Triple-flange earplug	Alternative easier-to-fit design introduced as a two-sized version
	Canal caps (pods on light-weight band)	Modest protection for intermittent environments
	Malleable putty earplug	Not widely used, and ergonomic problems due to required kneading and messiness
	Improved earmuffs	Higher attenuating designs introduced with better cushions and headbands
1970s	Conventional plugs and muffs same as 1960s	Technology essentially mature by this time, but some material improvements such as newer three-sized silicone version of triple-flange plug. Also, color-coded sizing introduced.
	Roll-down slow-recovery foam earplugs	New-concept earplug that provided better protection and comfort, but limited use in military initially
	Tanker helmets and aircraft flight helmets with internal earcups for noise attenuation	Helmets began to provide not only impact protection, but acoustical protection too. Low-frequency attenuation not as good as conventional earmuffs.

pg. 166-167

5 – RESPONDING TO NOISE RISKS

1980s	Conventional plugs and muffs same as 1960s and 1970s	No technology advances
	Tanker helmets began to appear with ANR included	ANR in this environment improved communication and protection
1990s	Same as prior decades	Minor technology advancements especially in cosmetics, but performance essentially unchanged
	Widespread use of roll-down slow-recovery foam ear plugs	Most commonly used hearing protection device
	Communication earplugs	Use of earphone in foam earplugs for use in tanker and helicopter applications for enhanced communication under helmet and increased protection
	Widespread use of ANR for tanker helmets and limited application of ANR for aircraft flight helmets	The advantages of ANR began to appear in aircraft applications too
2000–present	Same as prior decades	As before, except that V-51R plug dropped from inventory
	Level-dependent "combat arms" earplugs	New technology provides the ability to protect against weapons and blast noise, but still allow communication and signal detection of lower-level sounds when the impacts are not present

NOTE: ANR = active noise reduction.
SOURCES: Shaw and Veneklasen (1945); Department of the Air Force (1949); Blackstock and Von Gierke (1956); Guild (1966); Gardner and Berger (1994); Mozo and Murphy (1998); Ohlin (2005c); Schulz (2005a); Personal communication, D. Gauger, Bose Corporation, April 2005; personal communication, D. Ohlin, USACHPPM, April 2005.

pg. 166-167

TABLE 5-3 Representative Minimum and Maximum Mean Attenuation Values of Well-Fitted Hearing Protectors Under Laboratory Conditions, in dB

	Octave-Band Center Frequency (Hz)						
Type of Hearing Protector	125	250	500	1000	2000	4000	8000
Inserted Hearing Protectors							
Foam earplugs (attenuation varies with depth of insertion)	20–40	20–40	25–45	25–45	30–40	40–45	35–45
Premolded earplugs	20–30	20–30	20–30	20–35	25–35	30–45	30–45
Formable (fiberglass/mineral wool)	20–30	20–30	20–30	25–30	25–30	35–40	35–40
Formable (wax-impregnated cotton or silicone)	20–25	20–25	20–25	25–30	30–35	40–45	40–45
Custom-molded earplugs	15–35	15–35	15–35	20–35	30–40	35–45	30–45
Semi-insert earplugs	15–30	15–30	10–30	15–30	25–35	25–45	30–45
Circumaural, Helmet, and Combined							
Earmuffs (with or without communications components)	5–20	10–25	15–40	25–45	30–40	30–40	25–40
Military helmets	0–15	5–15	15–25	15–30	25–40	30–50	20–50
Dual protection (earplugs + earmuffs)	20–40	25–45	25–50	30–50	35–45	40–50	40–50
Active noise reduction (closed-cup systems; identical to conventional muffs above 1 kHz)	15–25	15–30	20–45	25–40	30–40	30–40	25–40
Other Types							
Cotton balls	0–5	0–10	5–10	5–10	10–15	10–20	10–20
Motorcycle helmets	0–5	0–5	0–10	0–15	5–20	10–30	15–35
Air-fed shotblasting helmets	0–5	0–5	0–5	0–15	15–25	15–30	15–25
Finger tips in ear canals	25–30	25–30	25–30	25–30	25–30	30–35	30–35

NOTE: Data are intended to account for brand and testing variability; however, not all manufacturers' reported data or values referenced in the literature will necessarily fall within the ranges cited. All data are from E·A·RCAL Laboratory as reported by Berger (2000a), except for the shotblasting helmets (Price and Whitaker, 1986) and fingers (Holland, 1967).

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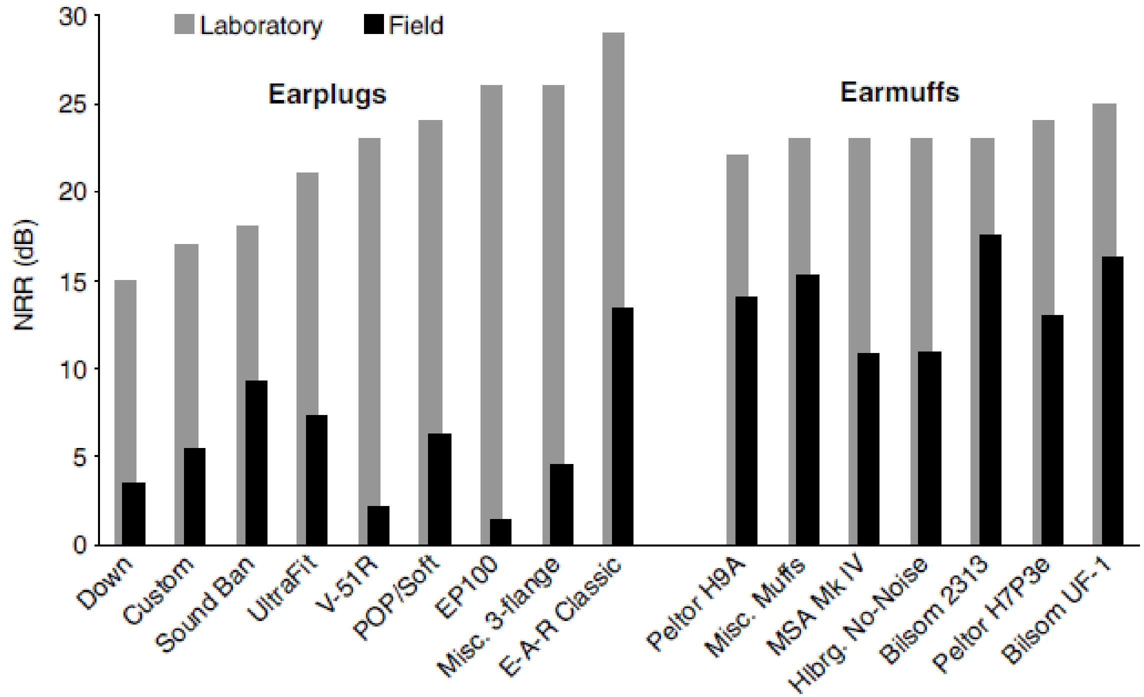

FIGURE 5-2 Comparison of Noise Reduction Ratings published in North America (labeled values based on laboratory tests) to real-world attenuation results derived from 22 studies.
SOURCE: Berger (2000b). Reprinted, with permission, from Berger (1993). Copyright 2000 by E•A•R Company.

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5 – RESPONDING TO NOISE RISKS

Findings:	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Use of hearing protection devices and the level of real-world hearing protection these devices provide have been and remain ***not adequate*** in military hearing conservation programs…consistent with studies from other settings… (pg. 170)		X	
Incomplete reporting, lack of compliance with requirements for annual audiograms, or both, severely limit the usefulness of the centralized database and the conclusions that can be drawn from it regarding hearing conservation program effectiveness. (pg. 174)			X
Hearing conservation programs in the military are currently ***not adequate*** to protect the hearing of military service members, and have not bee adequate for the period since World War II. (pg. 180)			X

"The effectiveness of the military hearing conservation programs is difficult to evaluate because of the disjointed and limited information available. The military services must contend with substantial challenges beyond their control, including the mobility and high turnover of their workforce and most significantly, the extreme and frequently unpredictable exposure to hazardous noise in combat." (pg. 180)

6 – REPORTS OF AUDIOMETRIC TESTING OF VETERANS

- "This chapter describes and presents results from the study to evaluate service medical records for the presence of audiograms performed when service members entered and left active duty (referred to here as entrance and separation audiograms). The Army, Navy, and Marine Corps have required such testing for all service members since at least the early 1980s, but some audiometric testing was being done in all of the services as early as the 1940s." (pg. 190)
- Two problems:
  - Army, Navy, and Marine Corps did not have mandatory testing until the late 1970s and 1980. As a result there is no basis for "compliance" with testing requirements for the period from World War II through the 1970s. (pg. 190)
  - The services do not have central registries of personnel enrolled in their hearing conservation programs. (pg. 190)
- Result:
  - Study was conducted "based on data from service medical records of individuals who had served in the military without regard to their enrollment in hearing conservation programs. "(pg. 191)

6 – REPORTS OF AUDIOMETRIC TESTING OF VETERANS

TABLE 6-2 Percentages of Service Medical Records (95% Confidence Intervals) with Reports Containing Any Numeric Data from an Audiogram (n = 3,570)

Branch	Before 1950	1950–1969	1970–Regulation Date	Regulation Date–1993	1994–2002
Army	8 (4–12)	32 (25–39)	99 (97–100)	98 (96–100)	99 (97–100)
Air Force	81 (71–92)	77 (67–86)	100 (98–100)	100 (99–100)	100 (99–100)
Marine Corps	9 (3–14)	53 (43–63)	99 (97–100)	100	100
Navy	9 (4–14)	34 (25–44)	93 (90–97)	100	100

NOTE: The time periods reflect the era of the service member's release from active duty.

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6 – REPORTS OF AUDIOMETRIC TESTING OF VETERANS

TABLE 6-3 Percentages of Service Medical Records (95% Confidence Intervals) with Reports of Audiometric Examinations Within 60 Days of Entry into Active Duty (n = 3,212)

Branch	Before 1950	1950–1969	1970–Regulation Date	Regulation Date–1993	1994–2002
Army	1 (0–2)	7 (3–11)	36 (30–43)	26 (20–32)	30 (24–35)
Air Force	*	17 (9–26)	30 (23–37)	25 (19–31)	20 (15–25)
Marine Corps	0	13 (4–23)	37 (30–44)	51 (44–59)	69 (63–74)
Navy	0	6 (1–11)	35 (28–41)	56 (49–63)	70 (64–75)

*Fewer than 40 records in the denominator.

NOTE: The time periods reflect the era of the service member's release from active duty.

Note: An arbitrary window of +/- 60 days of service member's entry into active duty was used as evidence of an entrance audiogram having been administered. (pg. 195)

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6 – REPORTS OF AUDIOMETRIC TESTING OF VETERANS

TABLE 6-4 Percentages of Service Medical Records (95% Confidence Intervals) with Reports of Audiometric Examinations Within 60 Days of Release from Active Duty ($n = 3,226$)

Branch	Before 1950	1950–1969	1970–Regulation Date	Regulation Date–1993	1994–2002
Army	1 (0–3)	12 (7–17)	27 (21–33)	29 (23–35)	14 (9–18)
Air Force	*	30 (20–40)	25 (19–31)	23 (17–28)	7 (4–10)
Marine Corps	0	2 (0–6)	49 (42–57)	53 (46–61)	36 (30–42)
Navy	0	11 (5–17)	54 (47–61)	54 (48–61)	44 (39–50)

*Fewer than 40 records in the denominator.

Note: Separation audiograms were defined as audiograms recorded within 60 days of a service member's release from active duty. (pg. 196)

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TABLE 6-5 Percentages of Service Medical Records (95% Confidence Intervals) with Reports of Audiometric Examinations Within 60 Days of Entrance into and Release from Active Duty (n = 3,210)

Branch	Before 1950	1950–1969	1970–Regulation Date	Regulation Date–1993	1994–2002
Army	0	4 (1–7)	13 (8–17)	12 (7–16)	5 (2–7)
Air Force	*	10 (3–16)	12 (7–17)	5 (2–9)	1 (0–3)
Marine Corps	0	0	25 (19–32)	29 (22–35)	31 (25–37)
Navy	0	1 (0–3)	24 (18–30)	33 (27–40)	34 (28–39)

*Fewer than 40 records in the denominator.
NOTE: The time periods reflect the era of the service member's release from active duty.

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6 – REPORTS OF AUDIOMETRIC TESTING OF VETERANS

Findings:	NOT Sufficient evidence	Limited/Suggestive	Sufficient evidence
Review of a sample of service medical records of military veterans indicates that compliance with requirements for audiometric testing at entrance into service has been limited, even in the most recent eras, and did not exceed 70 percent in any branch or era when using a ±60-day window for analysis. (pg. 199)	X		
Review of a sample of service medical records of military veterans indicates that audiometric testing at separation from service has been limited, even in the most recent eras, and did not exceed 54 percent in any branch or era when using a ±60-day window for analysis. (pg. 199)	X		
Review of a sample of service medical records of military veterans indicates that audiometric testing at both entrance into and separation from service has been extremely limited, even in the most recent eras, and did not exceed 34 percent in any branch or era when using a ±60-day window for analysis. (pg. 200)	X		

7 – CONCLUSIONS AND COMMENTS

Operational Needs Suggested by the Report (pg. 206-207)
1. Work to achieve more extensive and consistent use of hearing protection by military personnel.
2. Include questions about the presence and severity of tinnitus in each ear on all audiometric records obtained from enlistment through the end of military service. (In the remaining suggestions, audiograms and audiometric records are assumed to include responses to questions about the presence and severity of tinnitus.)
3. Enforce requirements for audiograms prior to noise exposure for all new military service members at *all* basic training sites.
4. Enforce, and establish where they do not presently exist, requirements for audiograms at the completion of military service to ensure that any hearing loss or tinnitus arising during military service is adequately documented. The Department of Defense and the Department of Veterans Affairs should explore whether resources are available within the VA system to aid the military services in conducting audiometric tests and tinnitus assessments for personnel completing their military service.

7 – CONCLUSIONS AND COMMENTS

Operational Needs Suggested by the Report (continued) (pg. 206-207)
5. Given the likely occurrence of maximum noise-induced hearing loss at 6000 Hz, include the measurement of hearing thresholds at 8000 Hz in all audiograms to allow for detection of the noise-notch pattern of hearing loss associated with noise exposure.
6. Enforce hearing conservation requirements for annual monitoring audiograms, as well as for follow-up audiograms if significant threshold shift is detected in annual monitoring audiograms.
7. Continue to develop the Defense Occupational and Environmental Health Readiness System (DOEHRS) to improve its reporting capabilities to match and exceed those available with the services' previous systems. Further development of this system should include modification of the hearing conservation component (DOEHRS-HC) to track reports of tinnitus. It should also include implementation of the industrial hygiene component (DOEHRS-IH) to provide information on exposures to hazardous noise and other chemical, physical, biological, and ergonomic hazards.
8. Develop mechanisms to provide VA personnel access to records from DOEHRS-HC for review of disability claims for hearing loss or tinnitus that are not otherwise supported by audiometric records in the service medical record.

7 – CONCLUSIONS AND COMMENTS

Research Needs Suggested by the Report (pg. 208)
Two broad scientific areas of interest to the committee:
1. Further investigate, both in laboratory animals and humans, exposures to fluctuating noise, impulse/impact noise, and combinations of noise, as well as intermittent exposures to steady-state noise, to determine the acoustic parameters associated with noise-induced hearing loss and tinnitus.
2. Further investigate the mechanism, natural history, epidemiology, measurement, and treatment of noise-induced hearing loss and tinnitus.

7 – CONCLUSIONS AND COMMENTS

Research Needs Suggested by the Report (continued) (pg. 207)
Avenues of research specific to military settings and personnel:
1. Obtain valid estimates of the incidence, prevalence, and severity of noise-induced hearing loss and tinnitus among military personnel, including gender-specific estimates. If the reporting ability and completeness of existing databases, such as DOEHRS-HC, improve, greater use might be made of their data for analyses for personnel enrolled in hearing conservation programs.
2. Establish cohorts of military veterans with various documented noise exposures, immediately upon discharge, and survey them periodically for ototoxic exposures, subsequent nonmilitary noise exposures, and hearing function, as well as presence and severity of tinnitus, in order to determine whether there is a delay in the effects of military noise exposure. These cohorts will need to be followed through the remainder of members' lifetimes, but this longitudinal study will reveal elements of the natural history of noise-induced hearing loss and tinnitus that otherwise will not be determined. The Millennium Cohort Study, which is designed to evaluate the long-term health of people who have served in the military, might provide a mechanism for conducting a longitudinal investigation of hearing health.

7 – CONCLUSIONS AND COMMENTS

Research Needs Suggested by the Report (continued) (pg. 207)
Avenues of research specific to military settings and personnel:
3. Conduct randomized trials of interventions within each military branch to determine with greater certainty which approaches to hearing conservation—including efforts to increase the use and effectiveness of hearing protection devices, compliance with requirements for audiometric testing, and the use of otoprotective medications—lead to lower incidence of noise-induced hearing loss and tinnitus.
4. On a sample basis, determine noise levels for modern military activities and also determine, with standard industrial hygiene methods, the noise dose experienced by individual military personnel where dosimetry has not been done.
5. Conduct real-world studies in military settings, including field and garrison conditions, to assess the noise attenuation and utilization rates of hearing protection devices, including the recently introduced earplugs that provide level-dependent sound attenuation.