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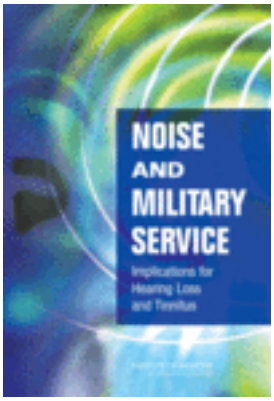

Noise and Military Service: Implications for Hearing Loss and Tinnitus

Larry E. Humes, Lois M. Joellenbeck, and Jane S. Durch, Editors, Committee on Noise-Induced Hearing Loss and Tinnitus Associated with Military Service from World War II to the Present

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The Institute of Medicine carried out a study mandated by Congress and sponsored by the Department of Veterans Affairs to provide an assessment of several issuesrelated to noise-induced hearing loss and tinnitus associated with service in theArmed Forces since World War II.The resulting book, Noise and Military Service: Implications for Hearing Loss andTinnitus, presents findings on the presence of hazardous noise in military settings,levels of noise exposure necessary to cause hearing loss or tinnitus, risk factors fornoise-induced hearing loss and tinnitus, the timing of the effects of noise exposureon hearing, and the adequacy of military hearing conservation programs and audiometrictesting. The book stresses the importance of conducting hearing tests (audiograms)at the beginning and end of military service for all military personnel andrecommends several steps aimed at improving the military services' prevention ofand surveillance for hearing loss and tinnitus. The book also identifies researchneeds, emphasizing topics specifically related to military service.

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Executive Summary

People serving in the military will, at some point, be exposed to high-intensity noise of various types. Some may develop hearing loss, especially for high-frequency sounds, or tinnitus ("ringing in the ears"), or both, as a result of their noise exposure. Hearing loss or tinnitus incurred or aggravated during military service may qualify veterans for services and financial compensation from the Department of Veterans Affairs (VA). Since World War II, the human and financial costs associated with hearing loss among military veterans have repeatedly drawn attention to noise, hearing loss, and the need for hearing conservation in military settings. In recent years, tinnitus has emerged as a significant concern as well.

VA reported that the 2.5 million veterans receiving disability compensation at the end of fiscal year 2003 had approximately 6.8 million separate disabilities related to their military service.[1] Disabilities of the auditory system, including tinnitus and hearing loss, were the third most common type, accounting for nearly 10 percent of the total number of disabilities among these veterans. For the roughly 158,000 veterans who began receiving compensation in 2003, auditory disabilities were the second most common type of disability. These veterans had approximately 75,300 disabilities of the auditory system out of a total of some 485,000 disabilities. At the

[1]Veterans may have hearing loss and other disabilities that have been determined to have been incurred during or aggravated by military service but that do not qualify for disability compensation payments (a "zero percent" service-connected disability). Veterans with service-connected hearing loss who do not qualify for any disability compensation payments are not included in the VA data on numbers of disabilities or numbers of veterans with disabilities. All veterans with service-connected tinnitus qualify for compensation payments.

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end of 2004, the monthly compensation payments to veterans with hearing loss as their major form of disability represented an annualized cost of some $660 million. The corresponding compensation payments to veterans with tinnitus as their major disability were close to $190 million on an annualized basis.

Determining whether hearing loss or tinnitus, evident at the time a claim is filed by a veteran, is attributable to prior military service can pose challenges for VA. After the fact, hearing loss or tinnitus incurred as a result of military service cannot be distinguished with certainty from subsequent noise-induced hearing loss or tinnitus resulting from work in a noisy industry or from participation in a variety of noisy recreational activities, such as hunting. Furthermore, high-frequency hearing losses are seen not only with noise exposure, but also at older ages (presbycusis), although the specific patterns of loss are generally distinguishable until 60–70 years of age (see Chapter 2). Tinnitus may also develop in response to factors other than noise exposure (e.g., head injury, brain tumors, middle ear diseases, certain medications) and can occur with or without hearing loss. If documentation of hearing thresholds or tinnitus during military service is not available, even a detailed case history from the veteran may leave considerable uncertainty about the association between a current hearing loss or tinnitus and prior military service.

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.[2] The committee convened by the Institute of Medicine of the National Academies to conduct this study was charged with reviewing the following for the period from World War II to the present: (1) the available data on hearing loss that could be expected among members of the armed forces; (2) sources of hazardous noise exposure during military service; (3) the levels of noise exposure necessary to cause hearing loss or tinnitus; (4) the course of hearing loss following noise exposure, including whether onset can be delayed; (5) risk factors for noise-induced hearing loss and tinnitus; and (6) compliance by the military services with requirements for audiometric testing and the adequacy of the services' hearing conservation programs to protect the hearing of service members.

APPROACH TO THE STUDY

The committee's considerations included noise-induced hearing loss, which most commonly results from repeated exposures to hazardous noise

[2]The study was called for in Section 104 of the Veterans Benefits Act of 2002 (P.L. 107-330).

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for a period of several years, and the phenomenon of acoustic trauma, which is the sudden loss of hearing following a single exposure to very hazardous noise. Hearing loss was assessed primarily on the basis of data on hearing thresholds measured in humans by pure-tone audiometry. Noise-induced hearing loss is often characterized by a "notch" in the audiogram, reflecting worse hearing at frequencies between 3000 and 6000 Hz than at lower and higher frequencies. The specific pattern of changes in pure-tone thresholds can vary depending on the type of noise exposure. The committee focused most of its attention on permanent changes in those thresholds. In adults, hearing loss is typically considered to be present when pure-tone thresholds are worse than 25 dB HL at any frequency usually tested.[3]

The study also included consideration of noise-induced tinnitus. Tinnitus is the perception of sound (e.g., ringing, buzzing, whistling) that cannot be attributed to an external sound source and is perceivable only by the person who is experiencing it. This subjective phenomenon is distinct from perceived sound that can be generated by events in the head or neck and that may be perceptible by an observer. The presence of tinnitus is determined primarily by self-report, but perceptual attributes, such as its pitch and loudness, can be established reliably under controlled conditions (psychoacoustic testing). The mechanisms underlying tinnitus are not fully understood. Some people with tinnitus experience serious problems associated with emotional well-being, sleep, hearing, and concentration. No current treatment will eliminate tinnitus, but some treatments may reduce its adverse impact. Promising treatments may include counseling, counseling combined with sound therapies, medications, and electrical and magnetic stimulation.

The committee reviewed material from peer-reviewed journals, books, reports prepared by or for the military services, and documents and data provided by the military services at the committee's request. The committee's information gathering also included testimony and presentations from veterans and representatives of the military services. Published peer-reviewed reports generally carried the most weight. Ideally, the committee would like to have drawn on data from reports of longitudinal, population-based studies of noise-induced hearing loss and tinnitus in humans in military settings. There are few such studies, and therefore, the committee was compelled to turn to other sources of evidence to address its charge.

The committee's findings and conclusions concerning each element of its charge are summarized here. (See Box ES-1 for a complete listing of findings.) Also summarized are needs the committee identified for opera-

[3]A standardized value representing the average thresholds measured in a large group of young normal-hearing adults at a given frequency is said to be 0 dB "hearing level" or 0 dB HL. Hearing thresholds are commonly measured at the following frequencies: 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz.

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tional changes and further research. These proposals for operational changes and research are aimed at improving hearing protection, preventing hearing loss and noise-induced tinnitus during military service, and gaining a better understanding of noise hazards, noise-induced hearing loss, and tinnitus, especially among military personnel.

SOURCES OF NOISE DURING MILITARY SERVICE

Many sources of potentially damaging noise have long existed in military settings. For the period addressed by this report—World War II to the present—some of these sources include weapons systems (e.g., handguns, rifles, artillery pieces, rockets), wheeled and tracked vehicles, fixed- and rotary-wing aircraft, ships, and communications devices (Chapter 3). Service members may encounter these noise sources through training, standard military operations, and combat. Exposure to combat-related noise may be unpredictable in onset and duration. Service members may also be exposed to hazardous noise through activities that are not unique to the military environment, including various engineering, industrial, construction, or maintenance tasks.

Throughout the period since World War II, the military services have collected data on noise levels associated with various kinds of equipment and activities, but a complete catalog of noise sources and the noise levels they produce is not feasible. The committee compiled an illustrative listing of documents reporting on sound levels in military settings (see Chapter 3 and Appendix F).

HAZARDOUS NOISE LEVELS

The specific noise levels that cause noise-induced hearing loss vary with the duration of the exposure, the type of noise, and the frequency content of the noise, as well as the susceptibility of the exposed individual (Chapters 1 and 2). Time-weighted average noise exposures of approximately 85 dBA for 8 hours per day for a 40-hour work week, or the equivalent, are considered to be hazardous, but a person must be so exposed for a number of years before developing noise-induced hearing loss. On the other hand, impulse noise with peak levels exceeding approximately 140 dB SPL may be hazardous even for a single exposure. With regard to noise-induced tinnitus, specific parameters of hazardous noise exposure have not been defined, but noise levels associated with hearing loss are also likely to be associated with tinnitus (Chapter 4).

HEARING LOSS AND TINNITUS AMONG MILITARY PERSONNEL

In the more than 60 years since the U.S. entrance into World War II, over 25 million people have served in the U.S. armed forces. Their experiences, in

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five different services and at least five major conflicts, as well as peacetime eras, have exposed many to loud noise. The total number who experienced noise-induced hearing loss or tinnitus by the time their military service ended may be substantial, but the available data provide no basis for a valid estimate of the number (Chapters 3 and 4). The abundant clinical evidence that noise exposure can result in hearing loss or tinnitus is not sufficient to determine in a particular group of people the extent to which such conditions have actually occurred or to establish that exposure to noise during military service was the cause of observed hearing losses or tinnitus.

Over the decades since World War II, noise exposures are likely to have varied widely, even within similar occupational specialties and eras. Data and analyses to document and quantify noise exposures of military personnel during this period, as well as to document and quantify their hearing thresholds and permanent changes in those thresholds over the course of military service, are rarely available. The committee found only a limited number of studies of hearing loss on which to base its findings, and those studies were primarily for the period since 1970. Among these were cross-sectional studies showing patterns of hearing loss consistent with noise exposure, but no longitudinal studies that could provide reliable data on changes in individuals' hearing thresholds over the course of military service (Chapters 1 and 3). The available studies were not designed to be representative of a service as a whole and only rarely of a particular military occupational group. Furthermore, the variability of individual responses to noise exposure precludes using the average hearing thresholds reported in many studies to estimate the hearing loss of individuals.

No epidemiological studies of tinnitus among U.S. military personnel were identified, and the services' hearing conservation programs do not include surveillance for tinnitus. Limited tinnitus surveillance was introduced in 2003 with post-deployment health assessment questionnaires.

Together, these factors made it impossible to generalize findings from the available studies to broader populations of military service members or veterans. In particular, it was not possible to estimate the proportion of a given military population that developed noise-induced hearing loss or tinnitus during military service, the amount of hearing loss incurred, or the relative risk of noise-induced hearing loss or tinnitus for a given individual, based on his or her branch of military service, occupational speciality, or service era.

ONSET AND COURSE OF HEARING LOSS

There is little evidence available to address whether noise-induced hearing loss or tinnitus progresses after noise exposure ends or whether noise-induced hearing loss can develop several months or years after the noise

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exposure has ended (Chapters 2 and 4). No longitudinal studies have examined patterns of hearing loss in noise-exposed humans or laboratory animals who did not develop hearing loss at the time of noise exposure. The committee's understanding of the mechanisms and processes involved in the recovery from noise exposure suggests, however, that a prolonged delay in the onset of noise-induced hearing loss is unlikely.

When hearing loss is known to have occurred as a result of a noise exposure, it has generally been thought that hearing loss for pure tones does not worsen following the cessation of a given noise exposure. However, there are no longitudinal data from humans who developed noise-induced hearing loss in early adulthood and were followed into their 60s, 70s, or 80s. Data from a few longitudinal studies of older adults, which differed in the way prior noise exposure was documented, have not produced conclusive results.

RISK FACTORS FOR NOISE-INDUCED HEARING LOSS AND TINNITUS

It is well established that individuals vary in their responses to noise exposure, but the factors that account for this variability are still poorly understood. Evidence from studies in humans was not sufficient to determine whether noise exposure combined with specific endogenous or exogenous factors was associated with additional risk for noise-induced hearing loss or tinnitus (Chapters 2 and 4). Studies of several endogenous factors—older age, gender, race, eye color, and prior hearing loss—have shown little association with noise-induced hearing loss. Conclusive results have not emerged from investigations of the effects of noise exposure in combination with the following exogenous risk factors: aminoglycoside antibiotics, cisplatin, diuretics, salicylates, solvents, carbon disulfide, carbon monoxide, cigarette smoking, whole-body vibration, body temperature, exercise, or electromagnetic fields. Some of these medications and chemicals are recognized ototoxins that may induce hearing loss unrelated to noise exposure.

The committee identified only one study in humans that had investigated the association between tinnitus and combined exposures to noise and other factors. Tinnitus risk factors, independent of noise exposure, include hearing loss, head injury, middle ear disease, and certain medications (e.g., salicylates, aminoglycoside antibiotics).

MILITARY HEARING CONSERVATION PROGRAMS

Data analyzed by the committee led to the conclusion that military hearing conservation programs, dating from the late 1970s, were not adequate to protect the hearing of service members. The committee concluded

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that hearing conservation activities from World War II through the 1970s would have been even less adequate to protect the hearing of service members than the programs in place since the late 1970s, because only early hearing protection devices of limited effectiveness were available and mandatory hearing conservation measures were in place only in the Air Force (Chapter 5).

Given that engineering measures to reduce noise levels and administrative measures to reduce noise exposures may not be compatible with requirements for military operations, use of hearing protection devices is often the primary defense against noise-induced hearing loss for military personnel. The effectiveness of these devices depends, in large measure, on how well and how often they are used. Data on the use of hearing protection by military personnel are limited, but a handful of reports over the past 30 years suggests that in some settings, only about half of those who should have been using hearing protection devices were doing so.

The services' hearing conservation programs require annual audiometric testing for personnel enrolled in the program. The percentage of service members tested each year who have a significant shift in hearing thresholds currently ranges from about 10 percent to 18 percent, which is two to five times higher than rates considered appropriate in industrial hearing conservation programs. Testing will not prevent noise-induced hearing loss, but it may serve to limit the loss if the detection of temporary hearing losses or small permanent losses results in increased use of hearing protection or the reassignment of individuals to lower noise environments. Available data showed, however, that some personnel may not be receiving the required tests, and discussions with personnel from the hearing conservation programs suggest that some test results may not be reaching the central hearing conservation registry system.

DOCUMENTATION OF AUDIOMETRIC TESTING DURING MILITARY SERVICE

A review of service medical records for veterans who left military service during the period from World War II to 2002 suggests that documented audiometric testing at entrance into and separation from service has not been adequate, throughout the period, to evaluate changes in hearing associated with military service for the majority of service members (Chapter 6). As argued repeatedly in this report, it is critical to obtain an audiogram at entry into and exit from military service to clearly establish whether noise-induced hearing loss developed during military service. The service medical records audited revealed that about 30 percent of personnel who left the Navy and Marine Corps during the period from the early 1980s to 2002 had both an entry and separation audiogram

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within ±60 days of entry or separation, whereas the percentages were even lower, typically less than 12 percent, for personnel who had served in either the Army or the Air Force. As expected, the percentage of service medical records containing audiograms of any type was lowest for the period before 1950, except for the Air Force, an early leader in requiring the collection of audiograms.

OPERATIONAL NEEDS SUGGESTED BY THE REPORT

The current irreversibility of noise-induced hearing loss and tinnitus means that preventing these problems, or limiting their progression, is especially important. From the review of information on noise exposure in military settings, hearing loss and tinnitus experienced by some service members, and the hearing conservation activities of the military services, the committee identified several steps that may enhance hearing protection for service members and improve the effectiveness of the services' hearing conservation programs. Although this report was prepared for the Department of Veterans Affairs, it is the Department of Defense and the individual military services that can take these important steps to minimize the adverse effects of noise exposure on military personnel and better document hearing loss or tinnitus when either occurs during military service. The committee strongly recommends that the following practices be implemented:

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.
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.

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6. Enforce hearing conservation requirements for annual monitoring audiograms, as well as for follow-up audiograms if a 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.

RESEARCH NEEDS SUGGESTED BY THE REPORT

The committee also saw areas where further research would be valuable for improving understanding of broad scientific questions concerning the relationship between noise exposure and hearing loss and tinnitus. Research could also address more targeted questions concerning noise exposure, hearing loss, tinnitus, and hearing conservation measures related to military service.

Two broad scientific areas were 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 mechanisms, natural history, epidemiology, measurement, and treatment of noise-induced hearing loss and tinnitus.

Several avenues of research specifically related to military settings and military personnel could be considered. Many are offered as a means to fill the void for prospective, longitudinal, epidemiological data on noise-induced hearing loss and tinnitus in military 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

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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 on 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.

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.

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BOX ES-1
Compilation of Report Findings

Chapter 2: Noise-Induced Hearing Loss

- The evidence from laboratory studies in humans and animals is sufficient to conclude that the most pronounced effects of a given noise exposure on pure-tone thresholds are measurable immediately following the exposure, with the length of recovery, whether partial or complete, related to the level, duration, and type of noise exposure. Most recovery to stable hearing thresholds occurs within 30 days.
- There is not sufficient evidence from longitudinal studies in laboratory animals or humans to determine whether permanent noise-induced hearing loss can develop much later in one's lifetime, long after the cessation of that noise exposure. Although the definitive studies to address this issue have not been performed, based on the anatomical and physiological data available on the recovery process following noise exposure, it is unlikely that such delayed effects occur.
- Nonacoustic factors may interact with the effects of noise to increase the measured noise-induced hearing loss. For many exogenous factors, evidence in animal models reveals that the effects of drugs or chemical agents may combine in an additive or synergistic manner with the effects of noise to increase noise-induced hearing loss. In particular, aminoglycosides, cisplatin, and solvents (toluene and styrene) interact in laboratory animals with noise presented simultaneously or sequentially to increase the amount of noise-induced hearing loss. However, there is not sufficient evidence to confirm this finding in humans. In particular, the evidence is not conclusive in humans with regard to additive or synergistic effects of noise and the following exogenous factors on hearing: aminoglycosides, cisplatin, diuretics, salicylates, solvents, carbon disulfide, carbon monoxide, cigarette smoking, whole-body vibration, body temperature, exercise, and electromagnetic fields.
- Several endogenous factors have been examined, including (old) age, gender, race, eye color, and prior hearing loss, but there is not sufficient evidence in humans to conclude that any of these factors predicts susceptibility to noise-induced hearing loss.
- The evidence from cross-sectional studies of noise-induced hearing loss in humans is sufficient to conclude that daily time-weighted average noise exposures greater than approximately 85 dBA for 8 hours for periods of many years pose a hazard to human hearing and that the hazard increases as the time-weighted average exposure exceeds this value.
- The evidence is not sufficient to determine the probability of acquiring a noise-induced hearing loss, or to estimate the magnitude of the noise-induced hearing loss, that a specific *individual* is likely to experience from a given noise exposure.

Chapter 3: Noise and Noise-Induced Hearing Loss in the Military

- The evidence is sufficient to conclude that hazardous noise levels are and have been present in many military settings.
- Extensive collections of data on sound pressure levels produced by equipment and activities in military settings are available from World War II to the present. Many estimates of noise exposures (doses) from specific activities also

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are available from more restricted time periods. However, because of the changing nature of assignments in the military, the unpredictable aspects of military training and combat, the intermittent nature of many military noise exposures, and the sporadic use of hearing protection while in the military, these data do not provide a sufficient basis for estimating cumulative noise exposures over the course of military service for individuals or for subgroups (e.g., occupational specialties, branches, or eras).

- The evidence is sufficient to conclude that 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.
- The evidence is not sufficient to reach conclusions 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.
- The evidence is not sufficient to determine 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. The probability of acquiring noise-induced hearing loss can only be determined precisely with well-controlled, longitudinal epidemiological studies.
- The evidence is sufficient to conclude that, 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.

Chapter 4: Tinnitus

- The evidence is sufficient to conclude that noise doses associated with hearing loss are likely to be associated with tinnitus.
- The evidence was not sufficient to 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.
- There is limited or suggestive evidence that exposure to impulse noise is associated with a greater likelihood of having tinnitus compared with exposure to steady-state noise.
- The evidence is sufficient to conclude that hearing loss (hearing thresholds greater than 25 dB HL at one or more audiometric frequencies between 250 and 8000 Hz) is associated with a higher prevalence of tinnitus.
- The evidence is not sufficient to determine precisely the magnitude of the risk of tinnitus associated with hearing loss.

Chapter 5: Responding to Noise Risks: Hearing Conservation Programs in the Military

- Compliance with requirements for use of hearing protection devices is crucial for an effective hearing conservation program. There is limited or suggestive evidence to conclude that 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. However, the studies conducted in U.S. military personnel are generally consistent with studies from other settings

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that provide additional evidence that the use and real-world protection of hearing protection devices are not adequate.

- Results of annual audiograms are available for approximately half of military service members in hearing conservation programs reporting compliance with testing requirements during the period 1988–2003. 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.
- The evidence reviewed by the committee—including information on the effectiveness of available hearing protection devices and indicators regarding use of hearing protection, the completeness of audiometric monitoring, and compliance with requirements for entrance and separation audiograms—was sufficient to conclude that hearing conservation programs in the military are currently not adequate to protect the hearing of military service members, and have not been adequate for the period since World War II. This has important human health, personnel readiness, and financial implications.

Chapter 6: Reports of Audiometric Testing in Service Medical Records of Military Veterans

- 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.
- 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.
- 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.

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NOISE AND MILITARY SERVICE

Implications for Hearing Loss and Tinnitus

Committee on Noise-Induced Hearing Loss and Tinnitus Associated with Military Service from World War II to the Present

Medical Follow-up Agency

Larry E. Humes, Lois M. Joellenbeck, and Jane S. Durch, *Editors*

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"Knowing is not enough; we must apply.
Willing is not enough; we must do."
—Goethe

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Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Bobby R. Alford, Department of Otolaryngology–Head and Neck Surgery, Baylor College of Medicine
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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Hyla Napadensky, Napadensky Energetics Inc. (retired), and Linda D. Cowan, Health Sciences Center, University of Oklahoma. Appointed by the National Research Council and Institute of Medicine, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Preface

This report represents the collective efforts of many people over a period of approximately 15 months. First and foremost are the committee members, who devoted countless hours of volunteer service to address the committee's charge. The numerous discussions held, both face to face and via conference calls, were thorough and, when opinions differed, were always conducted with respect for divergent views. The report reflects the broad input and consensus of all committee members and is much stronger as a result. Clearly, the charge could not be addressed without a panel having sufficiently broad areas of expertise, but also a willingness to listen to sometimes differing perspectives with an open mind before moving to consensus. I truly appreciate not only the amount of expertise available through the committee, but the manner in which each member shared that expertise and worked together to meet our collective responsibilities.

Another group central to the committee's work included the staff members from the Institute of Medicine (IOM) and National Research Council (NRC) who supported our efforts. Lois Joellenbeck, who served as study director, and Jane Durch were the committee's principal guides. We were ably aided as well by research assistant Kristen Gilbertson, whose contributions included not only research and administrative tasks, but also participating in the collection and entry of data from veterans' medical records. Program assistant Allison Berger managed the logistics of many of the committee's earlier meetings. Karen Kazmerzak helped initiate our research efforts during the first 3 months of the committee's work. Susan Van Hemel, a senior program officer with the NRC, contributed advice throughout the study.

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This study included the collection and analysis of data from the service medical records of some 3,500 veterans by members of the staff of the Medical Follow-up Agency of the IOM. The large data collection and data management task was overseen by Harriet Crawford, with the work of data collection and entry performed by Noreen Stevenson, John Larson, and Al Mattei. The data analysis was performed by William Page, a biostatistician with the Medical Follow-up Agency. Identifying and obtaining these records required the assistance of personnel from the Department of Veterans Affairs, the Department of Defense, and the National Archives and Records Administration. On behalf of the committee and staff, I want to thank the many individuals from those agencies for their assistance, and to offer special thanks to Lynda Russell, Yvonne Hamilton, and James White from the Department of Veterans Affairs.

The work of the committee was also supported by other staff members from the Medical Follow-up Agency, particularly the director, Rick Erdtmann, and the administrative assistant, Pamela Ramey-McCray. In addition, on behalf of the committee and staff, I wish to thank Liesl Peters, Clyde Behney, Janice Mehler, Jennifer Bitticks, Jennifer Otten, and Andrea Cohen from the IOM and NRC staffs, who participated in the report review, preproduction, dissemination, and financial management.

I would like to acknowledge the assistance of Lauren Strauser in the preparation and analyses of the data from the many cross-sectional studies of noise-induced hearing loss in military personnel that are the basis for Figures 3-3 through 3-6. In addition, the time needed for these analyses, as well as for my writing and editorial duties, would not have been available were it not for a generous release from teaching responsibilities granted to me by Indiana University for the spring 2005 semester.

Finally, on behalf of the committee, I wish to express our gratitude to the individuals who made presentations to the committee at its three information-gathering meetings: Mary Schoelen from the Senate Committee on Veterans' Affairs; COL David Chandler and Douglas Ohlin from the U.S. Army; John Page and Kurt Yankaskas from the U.S. Navy; Maj. Joseph Narrigan and Maj. Robert Pluta from the U.S. Air Force; Al Lillibridge from the U.S. Marine Corps; CDR Wade McConnell from the U.S. Coast Guard; Michael Hodgson, Kyle Dennis, Judy Schafer, and Bradley Flohr from the Department of Veterans Affairs; and veterans Arnold Mathias, Ansell (Mac) MacMillan, Carroll Williams, John Warwick, Rick Weidman, and David Kayal. Our project officer from the Department of Veterans Affairs, Michael Hodgson, provided valuable guidance on the scope of the study as the committee began its work. Also at the Department of Veterans Affairs, Michael Wells responded to several requests for data on veterans receiving disability compensation. Throughout the study, representatives of the military services provided ongoing assistance by responding to numerous requests for infor-

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mation. In particular, we want to acknowledge the assistance of the following individuals in this regard: COL David Chandler, Douglas Ohlin, Kevin Wisniewski, Felix Sachs, and COL Mark Rubertone from the U.S. Army; John Page, Leslie Crowder, Kurt Yankaskas, and Valerie Bjorn from the U.S. Navy; Maj. Robert Pluta and Lt. Col. Wade Weisman from the U.S. Air Force; and CDR Wade McConnell from the U.S. Coast Guard.

Larry E. Humes
Committee Chair

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FIGURES

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BOXES

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