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The Department of Defense Epidemiologic and Economic Burden of Hearing Loss Study

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Abstract

Although studies have examined the relation between military-related noise and hearing, comprehensive data to calculate rates of hearing loss across all Services and to determine economic impact are lacking. The goal of the multiphase Department of Defense (DoD) Epidemiologic and Economic Burden of Hearing Loss (DEEBoHL) project is to examine rates of hearing impairment and noise-induced hearing injury, relevant noise exposures, and to determine the economic burden of these outcomes to the DoD and Service Members. The DoD Hearing Center of Excellence is supporting the following Phase I specific aims, among active duty Service Members to (1) calculate rates of hearing impairment and noise-induced hearing injury, and (2) develop a framework for the DoD to conduct comprehensive economic burden studies for hearing impairment and noise-induced hearing injury. The study is led by a multidisciplinary team from The University of Texas School of Public Health, The University of Texas Health Science Center at San Antonio, and The Geneva Foundation, with guidance from experts who make up the study advisory board. In this article, we focus on an overview of the DEEBoHL study, the methods for the first aim of this effort, and describe future plans for the study.

INTRODUCTION

Recommendations from the 2005 Institute of Medicine report on noise and military service included a call for studies to estimate the incidence, prevalence, and severity of noise-induced hearing loss (NIHL) and tinnitus, and to use industrial hygiene (IH) methods to enhance noise and hazard surveillance.[1] Tinnitus and hearing loss combine to lead diagnoses among Service Members of Operations Enduring Freedom and Iraqi Freedom, and they are the top two Service-related disabilities among veterans who began receiving

disability compensation during 2012.[2] Despite the magnitude of veterans' compensation due to Service-related hearing disabilities of (1,883,919 cases in 2012, including 971,990 cases of tinnitus and 774,384 cases of NIHL)2 and the associated medical and disability-related costs, insufficient information presently exists to quantify the risk of noise on the auditory health of U.S. active duty Service Members, or the impact of hearing loss on Military readiness, population health, troop management or health utilization. Accurate assessment of hearing loss, as well as improved methods for exposure assessment of hazardous levels of noise, is critical. In audiologic research, U.S. military personnel offer a unique study population. Because they are exposed to noise levels and blast environments that are highly unusual in civilian work-settings, they experience military-specific injury risks, trends, and patterns, and serve as a model population for intervention and outcomes research specific to these conditions.

Hearing loss and tinnitus not only impact the health, well-being, and quality of life of Service Members but also create a significant economic burden for the Department of Defense (DoD) and the Department of Veterans Affairs (VA). This burden manifests in terms of primary medical and disability-related costs, and secondary costs due to personnel disqualification, retraining and replacement through expensive training, equipment loss, and tertiary loss due to underperformance and inefficiencies that are difficult to quantify.[3] There are additional economic burdens for the affected Service Members and their families (i.e., out-of-pocket expenses, Service potential, and overall financial future). Such effects may also be carried past discharge from the military in terms of ineligibility for intended post-Service occupation and security lines of work because of hearing loss and tinnitus; these conditions negatively impact communication, degrade quality of life and social interactions, and have been shown to be associated with secondary diagnoses, which potentially drive costs for medication and health care.[4,5]

The economic burden of Service-related hearing loss is immense for the VA, as evidenced by the significant cost due to compensation payments to over 1.8 million veterans in 2012.[2] Although well-characterized VA studies reveal the long-term consequence of hearing impairment and noise-induced hearing injury in veterans, an effort must also be undertaken to understand the burden of injury and expense that is largely overlooked in active duty populations. Bringing visibility to this invisible injury with its prevalence and cost may lead to earlier prevention and treatment strategies.

OBJECTIVES

The overarching goal of the DoD Epidemiologic and Economic Burden of Hearing Loss (DEEBoHL) project is to examine the rates of hearing impairment and noise-induced hearing injury, examine relevant noise exposures, and determine the cost burden of hearing impairment and noise-induced hearing injury to the DoD and to Service Members. These goals will be addressed as part of a multiyear effort, outlined in Figure 1. Specific aims of Phase I are to calculate cumulative incidence and prevalence rates of hearing impairment and noise-induced hearing injury (including tinnitus) among active duty Service Members, and to develop a framework for the DoD to conduct comprehensive economic burden studies for these outcomes among active duty Service Members. Further, we will complete gap

analyses of data sources for ascertaining hearing impairment and noise-induced hearing injury cases, and associated economic burden.

Phase II of the DEEBoHL project will build on the work completed during Phase I. First, we will expand the epidemiologic analyses by incorporating noise data. Specifically, qualitative and quantitative exposure data from the Defense Occupational and Environmental Health Readiness System (DOEHRS)-IH database will inform the creation of a job exposure matrix (JEM). Potential limitations of the DOEHRS-IH database will be overcome by refining the JEM as other sources of data become available. JEMs are used to assess potential exposures and provide a systematic method of translating work history data into a matrix of possible exposures. Exposure data derived from the JEM will be linked to individual Service Member records by military occupational code and may then be analyzed in relation to hearing impairment and noise-induced hearing injury. Also, during Phase II, specific cost-related variables identified as part of the economic burden framework will be accessed, cleaned, and analyzed. The framework will be implemented to calculate the costs of hearing impairment and noise-induced hearing injury borne by the DoD.

In addition, we expect to pursue a Phase III extension to further explore noise levels by occupational specialty using the JEM, describe hearing loss outcomes using sequential audiograms within a pilot sample of Service Members in the Hearing Conservation Program (HCP), apply the economic burden framework to evaluate the economic impact of potential hearing interventions, describe barriers to worker performance related to hearing outcomes among DoD veterans, and continue to improve upon the network between the DoD and VA established in Phase I.

The DEEBoHL project is consistent with and supportive of several national initiatives, including reviews by the Government Accountability Office,[6] the Institute of Medicine,[1] and the DoD HCE.[7] Specifically, this study is supportive of the HCE's goals to improve prevention and surveillance in hearing loss and auditory injury and to fill gaps in knowledge by engaging academic research partners.

In this article, we focus on the overarching goals and structure of the DEEBoHL study, including a discussion of the methods specific to the first aim of this effort (e.g., calculating rates of hearing impairment and noise-induced hearing injury) and future plans for this multiyear effort. Though we will briefly introduce the methods for the economic burden portion of the DEEBoHL study, a future article is planned to discuss these aims in more detail.

The DEEBoHL project is led by a multidisciplinary team with representation from the following disciplines: epidemiology, statistics, occupational and environmental medicine, computer science, and economics, from The University of Texas School of Public Health (UTSPH), The University of Texas Health Science Center at San Antonio, and The Geneva Foundation. Additionally, we have several consultants (an otolaryngologist, an audiologist, and a costing expert) who are intensely involved in this study.

A network of stakeholders, including otolaryngologists, audiologists, hearing loss researchers, program managers, policymakers, industrial hygienists, and other medical

representatives from the Army, Air Force, Navy, and VA, were brought together to form the study advisory board. The active engagement of each of the individuals on the advisory board and consulting team is essential to the successful completion of our study aims, as they each provide expertise and experience in areas of hearing loss and noise exposures, and will be vital to the appropriate interpretation of study findings. In April 2013, the advisory board, consultants, and the research team met for the first time as a group to review the study plan and methodology and make recommendations. A second advisory board meeting has since been conducted to review study progress, advise on data gaps, and discuss future research plans. The study team is also in constant contact with many of our advisory board members, who are consulted individually on an as-needed basis.

Institutional review board (IRB) approval has been obtained from The University of Texas School of Public Health, The University of Texas Health Science Center at San Antonio, and the U.S. Army Medical Research and Materiel Command. A data sharing agreement between the DoD HCE and Geneva Foundation, with UTSPH as a subcontractor, has been executed to allow the research team to access relevant data sources.

Aim 1. Calculate Cumulative Incidence and Prevalence Rates of Hearing Impairment and Noise-Induced Hearing Injury Among Active Duty Service Members

Methods—Table I lists the DoD data sources that we will initially target. With appropriate data sharing agreements in place, we will access clinical encounter data from the Military Health System (MHS) Data Repository (MDR)/MHS Mart (M2) to identify subjects with hearing impairment and noise-induced hearing injury from January 1, 2007, when coding standards for the use of International Statistical Classification of Diseases, 9th Revision (ICD-9) codes to identify hearing conditions improved, to January 1, 2013. The MDR is a consolidated data repository under the TRICARE Management Activities umbrella that maintains a centralized repository of clinical data from over 260 DoD health data network systems. The MHS M2 is a data query tool that allows researchers to obtain summary and detailed analyses of billing, cost, and clinical personnel data.[8] Because of physical examination requirements for active duty Service Members, the study data based on clinical encounters from the M2/MDR data resource will cover the vast majority of active duty Service Members each year (including inpatient, outpatient, and paid provider encounters), estimated to be greater than 95% by comparing the number of unique patients to publicly available active duty force size (personal communication, DoD Hearing Center of Excellence).

Our hearing-related outcome will be “hearing impairment and noise-induced hearing injury” based on our review of the peer-reviewed literature and Congressionally Mandated Reports.[9] This grouping includes both acute acoustic trauma that occurs due to a single exposure involving a sudden eruption of sound as well as more insidious onset of hearing loss from continuous or intermittent noise exposure that often develops slowly over time.[10] Military audiologists developed a preliminary list of 26 ICD-9 codes that are used for surveillance of active duty Service Members seeking inpatient or outpatient services, and the list will be expanded as necessary. They defined noise-induced hearing injury as “acoustic overstimulation of the sensory organ of hearing (cochlea) and associated acoustic energy

conduction structures such as the eardrum and middle ear bones (ossicles).”[9] Hearing impairment and noise-induced hearing injury will be identified by the initial list of ICD-9 codes in Table II as recorded in M2/MDR, including tinnitus, which is self-reported to the provider. The subcategories of this case definition will vary in our ability to determine time of onset, and whether the case is, for example, an incident or prevalent case. We will expand these lists as necessary to ensure the most complete ascertainment of cases as possible, including middle ear injuries and temporal bone fractures.[9,11]

We will evaluate several coding-based case definitions of hearing impairment and noise-induced hearing injury with input from medical and audiology experts on our advisory board and published articles. We also plan to conduct a series of sensitivity analyses to explore how varying definitions may influence cumulative incidence or prevalence estimates. To the extent possible, rates will be calculated by Service, military occupational specialty (MOS or corresponding Service designation), rank and grade, age group, race/ethnicity, gender, and calendar year. Since the MDR/M2 provides information on other injuries and medical conditions incurred by a Service Member with one of the specified hearing-related ICD-9 codes, we may also conduct a series of descriptive analyses to examine the correlation between hearing impairment and noise-induced hearing injury with these other conditions, such as post-traumatic stress disorder and traumatic brain injury, as noted by Heifer et al.[12]

Additionally, we will obtain data from the DOEHRS — Hearing Conservation database (DOEHRS-HC), which maintains hearing conservation and audiometric data across the DoD.[1,13] In addition to calculating rates of hearing impairment and noise-induced hearing injury based on ICD-9 codes, we will, in Phase II, conduct analyses incorporating audiometric data collected from active duty personnel enrolled in HCPs and captured in the DOEHRS-HC system from January 01, 1998 to January 01, 2013.

Although the target population of this study is all U.S. active duty military personnel, the accessible study population comprised U.S. active duty military personnel with at least one reported medical encounter reflected in MDR/M2, or with data captured in DOEHRS-HC, which reflects military personnel in HCPs.

Data Gaps and Limitations—There is not a single accepted term to cover the wide range of ICD-9-definied outcomes such as hearing loss, acoustic trauma, and tinnitus. Therefore, we decided to use the term that is most often used in the literature for military surveillance of these hearing-related outcomes. Although some may not consider tinnitus as a hearing disorder, most tinnitus is caused by hearing loss of peripheral (ear) origin, and for the puiposes of the study, we combined tinnitus with other types of injury to the ear. Further, without serial audiogram data and noise exposure history, NIHL cannot be accurately diagnosed, and the case definition here relies solely on physician diagnosis and subsequent assignment of ICD-9 codes to a clinical encounter, based on information available at the time of the visit, and accuracy of the coding. This study will not be able to validate the accuracy of these diagnoses.

When data are received, data limitations (i.e., under-reporting, exclusions, or lack of specific denominator data) will be described and gaps will be reported (i.e., data may

not exist, be accessible, be complete, or be evaluated and studied adequately). Although the source data systems already have extensive data quality controls applied during audit processes, after we received the de-identified data, we will further assess data quality by investigating duplicates, out-of-range values, and missing data. We have already identified several potential limitations of the data based on reviews of data dictionaries, relevant literature, and expert consultations. For example, because we will not have access to personnel records, we must rely on aggregate numbers of individuals "at auditory risk" among those with clinical encounters to define the denominator for rate calculations (ideally, stratified by relevant demographic variables such as age, gender, race/ethnicity, etc.). These numbers will be obtained from the MDR/M2 Defense Manpower Data Center persons table (representing all active duty Service Members with any type of clinical encounter during the specified period) and therefore represent an estimate of the true denominator (all active duty Service Members during the specified period, regardless of clinical encounters). The MDR/M2 database captures only those Service Members referred to and treated at a DoD military treatment facility (MTF), resulting in a potential underestimation of cases of hearing impairment and noise-induced hearing injury because Service Members (including the Reserves and National Guard) treated elsewhere or in-theater will not be included. DoD civilian employees and contractors will not be represented in these analyses. As recommended by our advisory board, in the future, we will request DoD personnel data (from the Defense Manpower Data Center) to better refine at-risk denominators, and Theater Medical Data Store data (in-theater clinical encounter data) to fill the noted gap. Further, we will not be able to assess nonoccupational exposures that may impact the overall risk for hearing impairment and noise-induced hearing injury in this population.

Aim 2. Develop a Framework for the DoD to Conduct Comprehensive Economic Burden Studies for Hearing Impairment and Noise-Induced Hearing Injury Among Active Duty Service Members

Though we will briefly introduce the methods for the economic burden aspect of the DEEBoFIL study here, a future article is planned which will discuss these aims in more detail.

Methods—Several steps are involved in the development of the economic burden framework (Fig. 2). First, we identified relevant cost items based on comprehensive review of published and unpublished literature. Additional input was solicited from consultants and members of the advisory board with expertise in DoD noise control programs, health care service provisions and delivery in the MHS, health care costing and accounting in the MHS, military personnel training costs, and MHS medical supply purchasing and inventory. Identified costs were grouped into standard categories used in cost-of-illness studies. The economic burden framework was implemented by developing a computer-based simulation model that projects the total costs associated with hearing impairment and noise-induced hearing injury in the target population. The model assumes an ideal situation, in which a comprehensive range of cost items are incorporated regardless of data availability. As a next step, we will identify relevant data sources for each key cost item and estimated resource utilization (in terms of the number of units purchased or used) and unit costs based on the identified data. We plan to use these data and estimates to develop the necessary formulas

for cost calculation and to populate the model. Uncertainty surrounding data is inevitable in this type of analysis, and the implementation of the economic burden framework will be further limited by incomplete access to available data. To explore uncertainty about the model outcomes and address these limitations, we plan to conduct comprehensive sensitivity analyses or scenario analyses. We believe that this framework will provide stakeholders with useful information about the economic burden of hearing impairment and noise-induced hearing injury borne by the DoD.

Based on literature review and expert consultations, we have created and categorized a comprehensive listing of hearing impairment and noise-induced hearing injury-related costs to the DoD (Fig. 3). Each of the identified costs was categorized as a medical, nonmedical, or structural cost (Fig. 3). A schematic representation of DoD costs throughout the Service Member's career is presently under development. We will apply health economic modeling to estimate the economic impact of hearing impairment and noise-induced hearing injury. A Markov model will be built to simulate and fit the economic burden.[14,15] The M2/MDR database will be the primary source of costing data for the medical encounter costs.

Data Gaps and Limitations—To date, we have not identified appropriate data sources to quantify nonfiscal cost items such as Service Member counseling, vocational rehabilitation for those Service Members having to reclassify into another job category, and reduced unit readiness. The economic framework for the Phase I of this study will focus solely on active duty Service Members with hearing impairment and noise-induced hearing injury, although we recognize that the DoD does incur some costs related to hearing impairment and noise-induced hearing injury among DoD civilians, contractors, and retired military personnel who receive their healthcare at military treatment facilities; however, medical services provided to these groups of individuals will be difficult to quantify. During Phase I, we will not quantify costs incurred directly by the Service Members (e.g., out-of-pocket costs), nor are we planning to estimate quality of life outcome measures for Service Members. However, we do have plans to include these costs and outcomes in the future. Additional detail regarding the cost categories and items our team intends to capture will be further described in a future article, which focuses on the economic burden of hearing impairment and noise-induced hearing injury. Costs related to military discharge, job change, impact on military and post-military career, retraining costs, and time away from the job for medical appointments are among the cost items we intend to capture.

RELEVANCE OF THE STUDY

As Service Members return from deployment, the need to better understand the magnitude and impact of hearing impairment and noise-induced hearing injury is paramount. Further, the potential economic burden of Service-connected hearing impairment and noise-induced hearing injury is immense, as evidenced by the significant cost of disability compensation to 1.8 million Veterans in 2012.[2] Given the importance of hearing impairment and noise-induced hearing injury to the DoD, we anticipate that the DEEBoHL project will lay the groundwork for comprehensive epidemiologic studies of these hearing outcomes among U.S. military personnel. Additionally, results from this research project will draw much-needed attention to this critical issue, encouraging initiatives to improve the auditory health

and well-being of Service Members and aiding in the development and implementation of prevention measures. Given the current economic challenges and imperative to contain costs, economic burden data could also help inform policymakers on prioritizing strategies to reduce the enormous costs associated with hearing loss to both the DoD and the VA.

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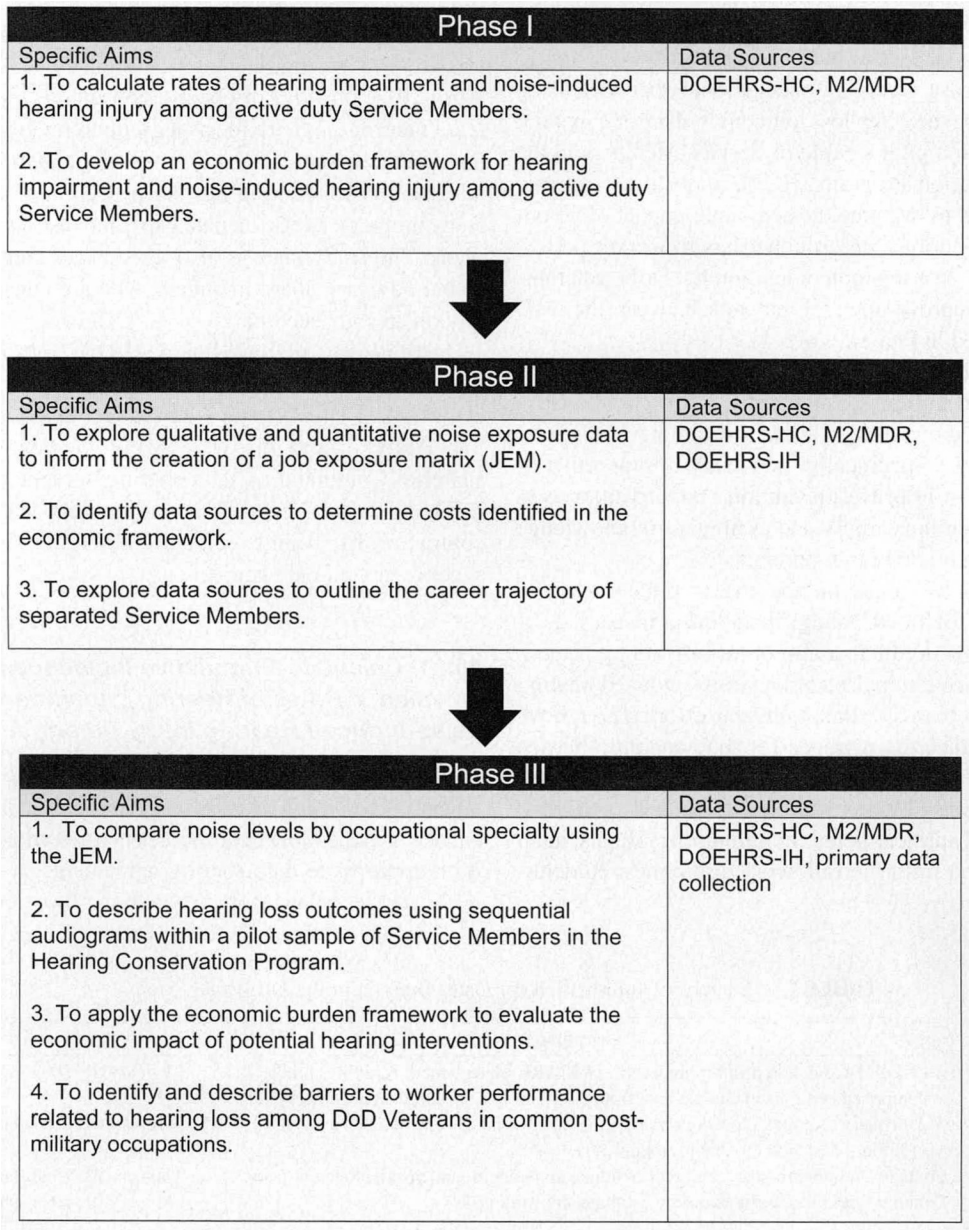

Phase I

Specific Aims	Data Sources
1. To calculate rates of hearing impairment and noise-induced hearing injury among active duty Service Members. 2. To develop an economic burden framework for hearing impairment and noise-induced hearing injury among active duty Service Members.	DOEHRS-HC, M2/MDR

Phase II

Specific Aims	Data Sources
1. To explore qualitative and quantitative noise exposure data to inform the creation of a job exposure matrix (JEM). 2. To identify data sources to determine costs identified in the economic framework. 3. To explore data sources to outline the career trajectory of separated Service Members.	DOEHRS-HC, M2/MDR, DOEHRS-IH

Phase III

Specific Aims	Data Sources
1. To compare noise levels by occupational specialty using the JEM. 2. To describe hearing loss outcomes using sequential audiograms within a pilot sample of Service Members in the Hearing Conservation Program. 3. To apply the economic burden framework to evaluate the economic impact of potential hearing interventions. 4. To identify and describe barriers to worker performance related to hearing loss among DoD Veterans in common post-military occupations.	DOEHRS-HC, M2/MDR, DOEHRS-IH, primary data collection

FIGURE 1.
DEEBoHL study project phases, aims, and data sources.

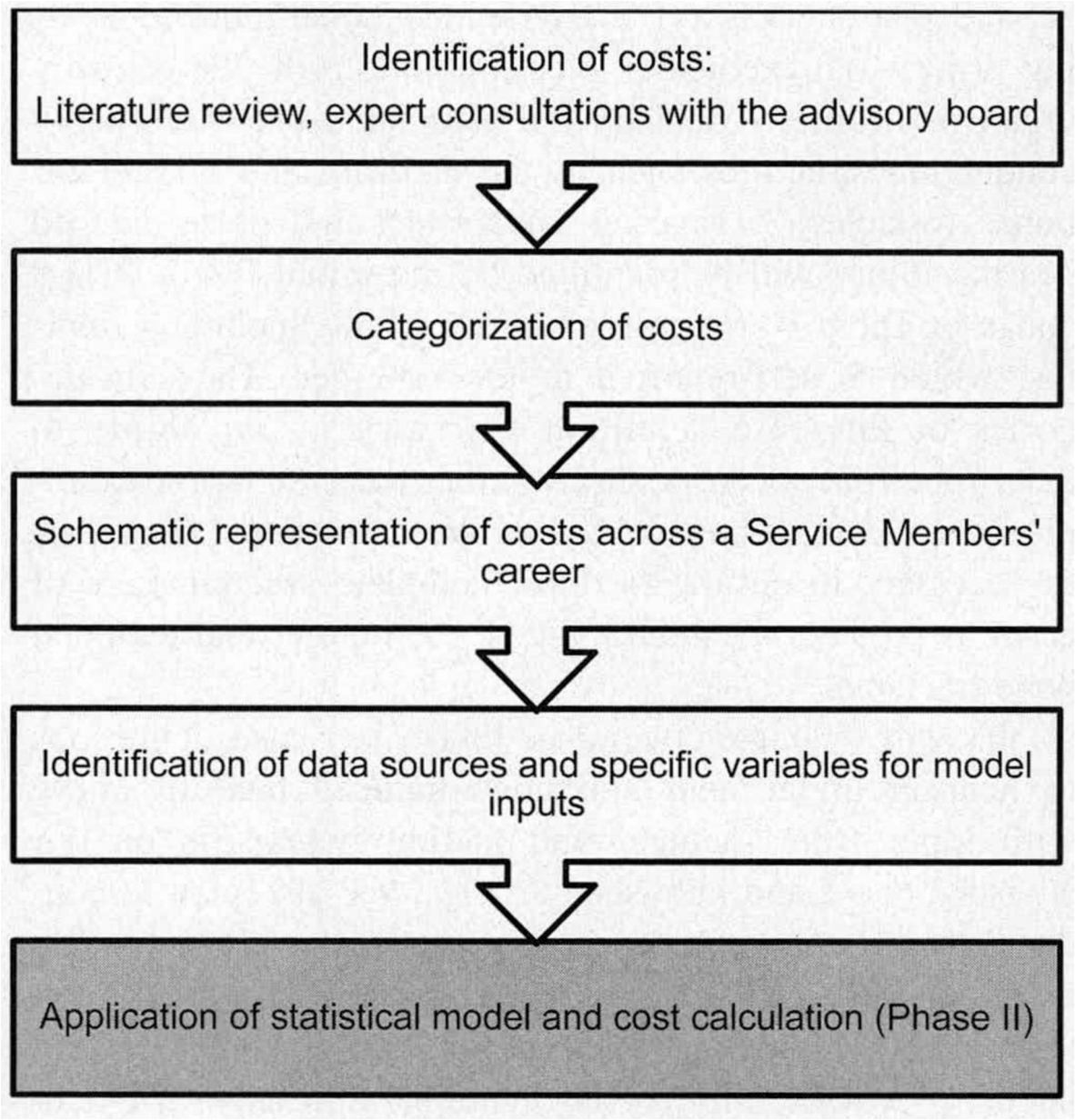

FIGURE 2.
Creating and implementing the economic burden framework.

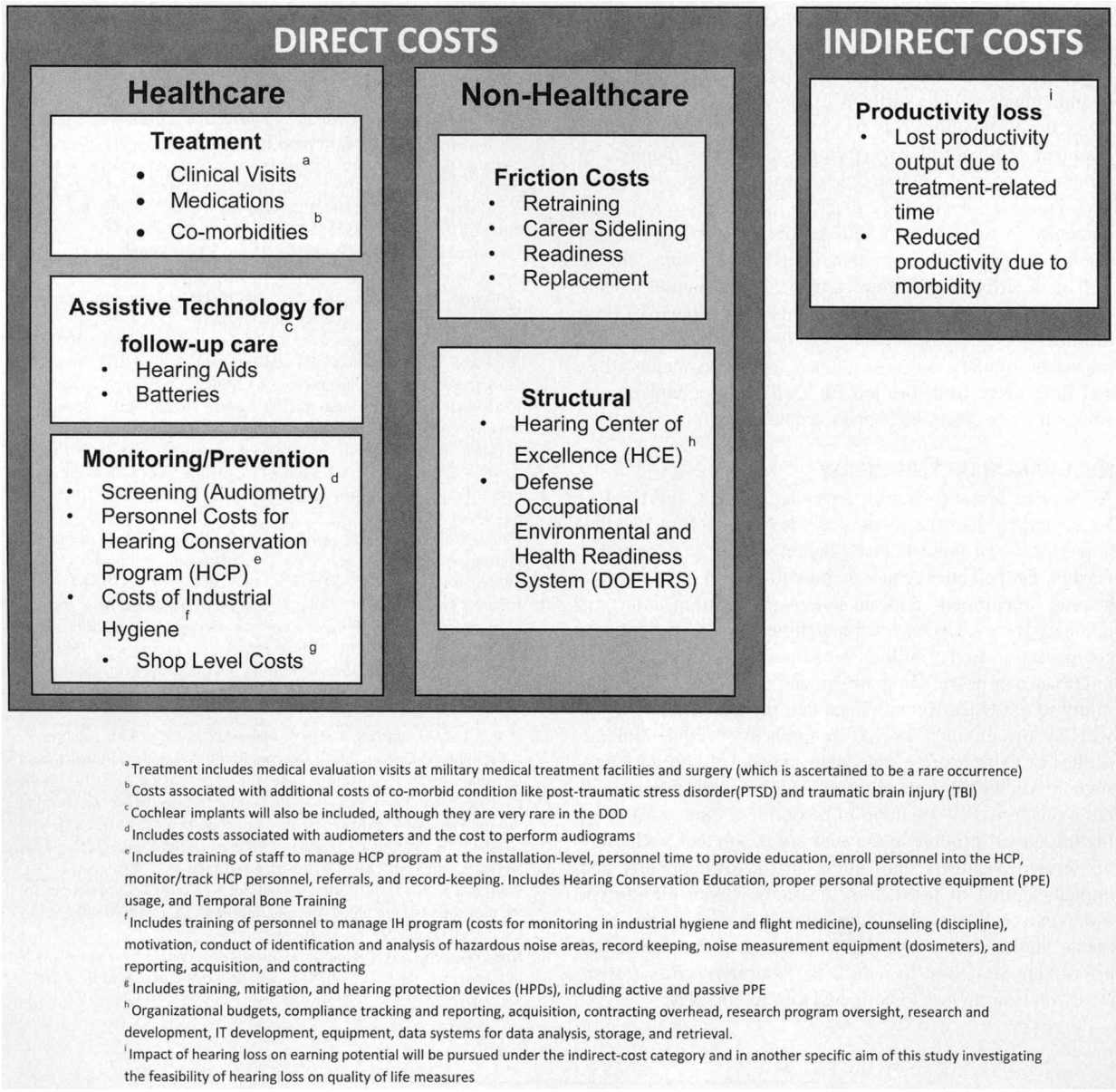

FIGURE 3.
Categorized costs for the economic burden framework.

TABLE I.

Sources of Information for Data Analysis in the DEEBoHL Study

Database	Description	Time Period Analyzed
MDR	A consolidated data repository under the TRICARE Management Activities umbrella; comprised centralized clinical data from over 260 DoD health data network systems	January 01, 2007-January 01, 2013
M2	A data query tool that allows researchers to obtain summary and detailed analyses of billing, cost, and clinical personnel data	January 01, 2007-January 01, 2013
DOEHRS-HC	Contains audiometric test results for baseline, annual, pre- and postdeployment tests	January 01, 1998-January 01, 2013
DOEHRS-IH[a]	Contains workplace noise exposure estimates by work task	January 01, 1998-January 01, 2013

[a]Phase II.

TABLE II.

ICD-9 Codes Used to Identify Cases of Hearing Impairment and Noise-Induced Hearing Injury[11,12] in the DEEBoHL Study

Code	Code Description
384.81	Atrophic Flaccid Tympanic Membrane
384.9	Unspecified Disorder of Tympanic Membrane
388.1	Noise Effects on Inner Ear, Unspecified
388.12	Noise-Induced Hearing Loss
388.43	Impairment of Auditory Discrimination
389.02	Conductive Hearing Loss, Tympanic Membrane
389.1	Sensorineural Hearing Loss, Unspecified
389.11	Sensory Hearing Loss, Bilateral
389.15	Sensorineural Hearing Loss, Unilateral
389.16	Sensorineural Hearing Loss, Asymmetrical
389.17	Sensory Hearing Loss, Unilateral
389.18	Sensorineural Hearing Loss, Bilateral
389.8	Other Specified Forms Of Hearing Loss
389.9	Unspecified Hearing Loss
794.15	Nonspecific Abnormal Auditory Function Studies
384.2	Perforation of Tympanic Membrane, Unspecified
384.21	Central Perforation of Tympanic Membrane
384.22	Attic Perforation of Tympanic Membrane
384.23	Other Marginal Perforation of Tympanic Membrane
384.24	Multiple Perforations of Tympanic Membrane
384.25	Total Perforation of Tympanic Membrane
385.23	Discontinuity or Dislocation of Ear Ossicles
388.11	Acoustic Trauma (Explosive) to Ear
388.3	Tinnitus, Unspecified
388.31	Subjective Tinnitus
388.32	Objective Tinnitus

This list will be expanded as necessary based on updated literature reviews and expert opinion.