Epidemiology of Hearing Impairment and Noise-Induced Hearing Injury Among U.S. Military Personnel, 2003–2005

Thomas M. Helfer, PhD, MA, Michelle Canham-Chervak, PhD, MPH, Sara Canada, MPH, Timothy A. Mitchener, DMD, MPH

Introduction: Rates of noise-induced hearing injury (NIHI) among U.S. active duty military have not been previously described using available military medical surveillance data.

Methods: NIHI were identified in the Defense Medical Surveillance System (DMSS) using a list of ICD-9-CM diagnosis codes selected in collaboration with military audiologists. To provide a more comprehensive view of the NIHI problem, NIHI-related ICD-9 codes beyond the traditional 388 noise injury–code set were included. Visit rates by gender and age group are reported by quarter, 2003–2005. Overall frequencies and rates by occupational specialty, 2003–2005, are also described.

Results: From 2003 to 2005, rates for men were significantly higher than rates for women, with rate ratios (RR) ranging from 1.15 (95% CI =1.07, 1.23) to 1.78 (95% CI= 1.62, 1.93). Rates among women ranged from 2.9 to 6.2 per 1000 person-years; rates among men ranged from 4.5 to 6.7 per 1000 person-years. NIHI rates were highest among those aged ≥40 years and lowest among those aged 17–19 years, with RRs ranging from 3.06 (95% CI=2.77, 3.40) to 5.51 (95% CI=4.88, 6.30) during this time period. Among occupational groups, general officers/executives had the highest NIHI rate over this time period (29.5/1000 person-years), followed by enlisted personnel in training (14.3/1000 person-years) and scientists and professionals (12.8/1000 person-years).

Conclusions: While data on outpatient injury causes and use of hearing protection are also needed to guide the future design and/or modification of interventions, existing military medical surveillance provides essential information for tracking NIHI and monitoring NIHI intervention effects.

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Introduction

The National Institute of Occupational Safety and Health estimates that approximately 30 million workers in the U.S. are exposed to hazardous noise, with an economic impact of an estimated $242.4 million per year in disability.[1] According to Veterans Affairs (VA), noise-induced hearing injuries (NIHI) are costly and are very much a public health problem for former and current armed forces service members. Veterans Affairs NIHI disability compensation rates are currently over $1 billion per year.[2]

Generally, studies of nonmilitary populations have evaluated NIHI in select cohorts of subjects in various industries or in select population centers.[3,4] Military studies have tended to look at larger populations. For example, in 1975, Walden looked at hearing loss prevalence rates among soldiers in combat arms units and found that 30% of combat arms soldiers had mild hearing loss or worse (moderate to severe hearing loss).[5,6] A CDC study compared hearing loss in Vietnam veterans to nondeployed veterans and found that the Vietnam service cohort was 40% more likely to have high-frequency hearing loss than the nondeployed service cohort.[7] The most definitive reference on NIHI in the military after 1945 was published by the IOM in 2006.[8] Data were furnished for this report from audiometric records in the Defense Occupational Environmental Health Readiness System—

From the U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, Maryland

Address correspondence and reprint requests to: Thomas M. Helfer, PhD, MA, Army Hearing Program, U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground MD 21010. E-mail: Thomas.Helfer@us.army.mil.

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Hearing Conservation (DOEHRS-HC) database of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). The report revealed that by 1999, 18% of military personnel in this Department of Defense (DoD) hearing conservation database showed significant threshold shifts or changes in hearing for the worse.[9] In 2004 and 2005, Helfer reported a 21% prevalence rate of noise-induced hearing loss and a 28% prevalence rate of tinnitus in postdeployment records during the first 16 months of Operation Iraqi Freedom (OIF) and for the period April 1, 2003 through March 31, 2004.[10,11]

Table 1. Hearing impairment and noise-induced hearing injury visits by ICD-9-CM code, 2003–2005

ICD-9-CM code	Diagnosis description	Total visits, 2003–2005 (% total)
389.9[a]	Unspecified hearing loss	37,161 (42.1)
388.30	Tinnitus, unspecified	18,073 (20.5)
388.12	Noise-induced hearing loss	12,298 (13.9)
388.31	Subjective tinnitus	7,572 (8.6)
384.20	Perforation of tympanic membrane, unspecified	5,326 (6.0)
389.8[a]	Specified forms of hearing loss, not elsewhere classified	4,249 (4.8)
384.21	Central perforation of tympanic membrane	1,014 (1.1)
388.11	Acoustic trauma (explosive) to ear	882 (1.0)
384.23	Other marginal perforation of tympanic membrane	572 (0.6)
384.25	Total perforation of tympanic membrane	292 (0.3)
388.32	Objective tinnitus	220 (0.2)
384.81	Atrophic flaccid tympanic membrane	209 (0.2)
384.22	Attic perforation of tympanic membrane	147 (0.2)
388.43	Impairment of auditory discrimination	140 (0.2)
385.23	Discontinuity or dislocation of ear ossicles	88 (0.1)
384.24	Multiple perforations of tympanic membrane	42 (0.1)
	Total	88,285 (100.0)

[a]Used by military audiologists to document medical encounters for severe hearing loss (H-3 and H-4 hearing loss profiles)

For the U.S. Army, since September 2006, DOEHRS-HC monitoring of audiometry outcomes (i.e., rates of significant threshold shifts, hearing loss profiles) has been tied to combat readiness of soldiers through the Medical Protection System (MEDPROS) Hearing Readiness Module (HRM). Analysis of data from this system suggests that army audiometry compliance rates are improving. However, since the HRM implementation started in September 2006, it is too early to tell the effect of the process in terms of reducing the prevalence of NIHI for the army.

The purpose of this paper is to report ICD-9-CM–based NIHI data from a second surveillance source, the Defense Medical Surveillance System (DMSS). Specifically, this paper is intended to provide a baseline description and overview of frequencies and rates of NIHI-related medical encounters among U.S. active duty military personnel. This analysis was originally completed for and submitted to the Defense Safety Oversight Council (DSOC).

Methods

For this study, the term "noise-induced hearing injury" referred to the result of acoustic overstimulation of the sensory end organ of hearing (cochlea) and associated acoustic energy conduction structures such as the eardrum and middle ear bones (ossicles). Active duty U.S military personnel who sought inpatient or outpatient treatment for NIHI, 2003–2005, were identified in the DMSS using ICD-9-CM diagnosis codes selected by a group of experienced military audiologists (Table 1). Military audiologists developed the initial NIHI ICD-9-CM code list between 1999 and 2003 to capture the medical encounters that could be used to routinely monitor NIHI clinical outcomes.[12] Analysts at USACHPPM used the list to perform prevalence studies of NIHI and comorbidities using medical encounters related to deployed cohorts.[10,11,13] The authors performed the current study using the same code list as described by Jordan,[13] with the exception of the exclusion of codes for dizziness and imbalance. DMSS data were provided by the Armed Forces Health Surveillance Center (formerly, U.S. Army Medical Surveillance Activity). The data included medical encounters obtained at fixed military medical treatment facilities (overseas and in the U.S.) or civilian medical facilities (i.e., care outside the military health system for which the military paid); visits occurring in battalion aid stations or deployment settings were not included.

Multiple visits for the same diagnosis within 60 days of the initial visit were excluded to reduce the effect of follow-up visits and resultant potential overestimation of rates. To capture all NIHI visits and not just those for which the NIHI was the primary reason for the visit, both primary and nonprimary NIHI diagnoses were obtained. If there were two or more NIHI codes per visit, the visit was counted only once (not multiple times). Quarterly NIHI visit rates were calculated by dividing the number of injury visits by the person-time for nondeployed active duty personnel at risk during each quarter. Deployed personnel did not contribute to these data, as their medical encounters were not captured by this surveillance system. However, recently redeployed personnel were included in the study, and were known to have higher rates of NIHI.[10,11,13]

Frequencies of NIHI visits by individual ICD-9-CM code are presented for the full period, 2003–2005 combined. Visit rates over time are presented by gender and age. Risk ratios (RR) and 95% CIs are reported when describing statistical differences between rates by gender and age group. Linear regression *p*-values are reported when describing trends of gender and age group rates over time. To gain a better sense of subpopulations affected, frequencies and rates by DoD occupational group for 2003–2005 are also presented.

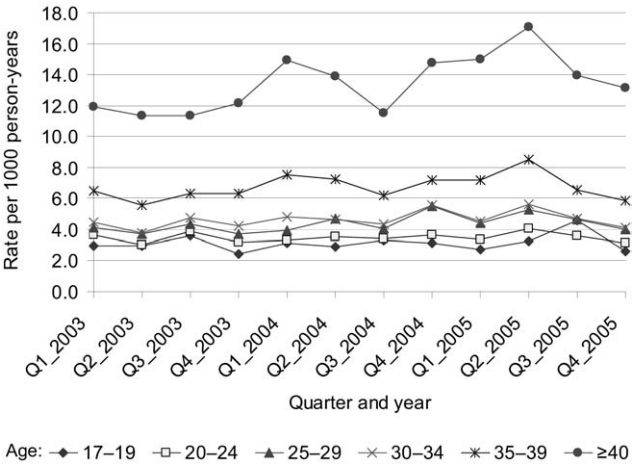

Figure 2. Visit rates of noise-induced hearing injury by age, DoD active duty, CY2003–2005[a]
[a]Assumes stable population in each quarter
Inpatient and outpatient visits; primary and nonprimary diagnoses; considered a follow-up visit if same diagnoses seen within 60 days
Source: Defense Medical Surveillance System, Army Medical Surveillance Activity, 2006
CY, calendar year; DoD, Department of Defense

Results

There were a total of 88,285 hearing impairment and NIHI-related visits for active duty service members between 2003 and 2005, for an annual incidence rate of 19.3 to 22.2 per 1000 personnel during this time period. Men accounted for 88% (n=77,938) of the NIHI visits, while women represented 12% (n=10,347). Figure 1 shows the quarterly rates of NIHI visits by gender. During this time period, rates ranged from 4.5 to 6.7 per 1000 for men and from 2.9 to 6.2 per 1000 for women. NIHI visit rates among men were 15% to 78% higher than those among women, with rate ratios (RR) for each quarter (Q) ranging from 1.15 (95% CI=1.07, 1.23) to 1.78 (95% CI=1.62, 1.93), with one exception ($RR_{Q4\ 2004}$ 0.95, 95% CI=0.89, 1.01). Rates among women followed a similar trend as those among men, except for an increase in NIHI visit rates among women during the fourth quarter of 2004. This higher rate resulted from a known artifact, a predeployment record screening for audiograms that was mandated by Army G-1 in September 2004.[13] With the exception of this anomaly, rates for both men and women did not increase or decrease significantly from 2003 to 2005 (p>0.05).

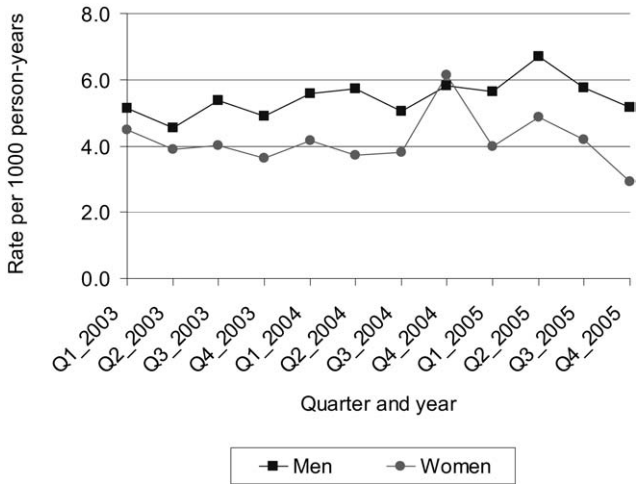

Figure 1. Visit rates of noise-induced hearing injury by gender, DoD active duty, CY2003–2005[a]
[a]Assumes stable population in each quarter
Inpatient and outpatient visits; primary and nonprimary diagnoses; considered a follow-up visit if same diagnoses seen within 60 days
Source: Defense Medical Surveillance System, Army Medical Surveillance Activity, 2006
CY, calendar year; DoD, Department of Defense

Figure 2 shows the quarterly rates for NIHI visits by age group. Consistently, the older the age group, the higher the NIHI visit rate. In the last quarter observed (Q4 2005), NIHI visit rates among active duty service members aged ≥40 years were over twice as high as those for the next age group, active duty service members aged 35–39 years ($RR_{Q4\ 2005}$ 2.24, 95% CI=2.08, 2.24). Rates for those aged ≥40 years were significantly greater than rates among those aged 17–19 years, with RRs ranging from 3.06 (95% CI=2.77, 3.40) to 5.51 (95% CI=4.88, 6.30) during this time period. The rate for service members aged ≥40 years

peaked at nearly 17.0 (NIHI visits) per 1000 person-years in the second quarter of calendar year (CY) 2005. As a comparison, the rate for those aged 35–39 years peaked also in the second quarter of CY 2005 at a rate of 8.5 per 1000 person-years.

Table 1 presents frequencies of individual NIHI ICD-9-CM codes for 2003–2005 combined. "Unspecified hearing loss (389.9)" was the leading NIHI diagnosis during this time period (n=37,161 visits). The second leading NIHI diagnosis was "Tinnitus, unspecified" (n=18,073), followed by "Noise-induced hearing loss" (n=12,298). These top three diagnoses accounted for over 75% of all NIHI visits during this time period.

Table 2 shows the frequency of NIHI by DoD occupational group over the period covered, along with rates. Occupational groups such as combat arms (infantry/gun crews) and electrical mechanical equipment repairers had the highest frequencies of NIHI. However, their corresponding rates were lower than those of other occupational groups. General officers and executives, enlisted trainees, and scientists and professionals had the highest NIHI rates in 2003–2005.

Table 2. Frequency and rate of noise-induced hearing loss by DoD occupational group, 2003–2005[a]

DoD occupational group (code)	Frequency of noise-induced hearing injury visits	Rate per 1000 personnel
General officers and executives, not elsewhere classified (21)	225	29.5
Enlisted in training (19)	2,645	14.3
Scientists and professionals (25)	491	12.8
Engineering and maintenance officers (24)	1,169	11.9
Intelligence officers (23)	427	11.8
Crafts workers (17)	1,630	11.5
Administrators (27)	540	11.5
Infantry, gun crews, and seamanship specialists (10)	7,101	11.2
Healthcare officers (26)	1,198	11.2
Other technical and allied specialists (14)	1,202	11.1
Tactical operations officers (22)	2,574	10.6
Supply, procurement, and allied officers (28)	602	10.2
Electrical/mechanical equipment repairers (16)	6,958	9.3
Healthcare specialists (13)	2,194	9.0
Service and supply handlers (18)	2,825	8.7
Functional support and administration (15)	4,753	8.2
Communications and intelligence specialists (12)	2,782	7.9
Electronic equipment repairers (11)	2,551	7.9
Officers in training (29)	203	4.9
Total	42,070	9.9

[a]Inpatient and outpatient visits for 2003–2005 combined. Includes primary and nonprimary NIHI diagnoses. Follow-up visits for same diagnosis within 60 days were excluded.
Source: Defense Medical Surveillance System, Armed Forces Health Surveillance Center, 2007

Discussion

The risky exposures to steady state noise that lead to NIHI are well known and predictable for both military and civilian populations. Military exposures include military vehicles and aircraft, military equipment, and tools common to both military and civilian industrial environments. Noise-level information on common army equipment is available on the USACHPPM website.[14] In addition, recreational noise exposures (e.g., motorcycles, sport shooting, snowmobiles, power tools) are common to both military and civilian populations.

Impulse noise damage risks are also present, but are less predictable. Military members have more of these kinds of exposures in training, and now in combat operations, due to weapons firing. Exposures to noise from explosives due to combat operations introduce complications such as traumatic brain injury (TBI), dizziness/imbalance outcomes, and other multimodal sensory and sensory–motor central nervous system disorders, along with auditory nervous system disorders associated with TBI. Jordan reported that 12.5% of redeploying army soldiers having combat exposures during OIF had NIHI.[15]

Work-related hearing loss incidence rates among military personnel have been reported to be higher than rates in other occupations. Meyer et al.[16] reported an annual incidence of work-related noise-induced hearing loss among British military of 28.3 per 100,000 personnel, while rates among the British working population were 1.94 and 1.23 per 100,000 workers, depending on the data source used. Leigh et al.[17] reported a worldwide occupational noise-induced hearing loss annual incidence rate of 17.7 per 100,000 among men/boys aged 15–44 years. In this analysis, the visit rate of NIHI among U.S. military personnel from 2003 to 2005 averaged 9.6 per 1000 personnel (men and women combined), or 960 per 100,000 personnel. Rates observed in the current analysis were higher than rates reported in other populations, possibly due in part to the comprehensive capture of NIHI visits in the surveillance system used and a broader range of NIHI-related ICD-9 codes used. This code set is consistent, however, with what has been recommended by U.S. military audiologists for hearing conservation program outcomes analyses.[12]

The effect of gender seen in this analysis was consistent with other studies,[3,18] in that men showed a higher prevalence of NIHI than women. Some military occupations with high levels of noise exposure may have a higher preponderance of men than women; this may explain the higher rates of NIHI in men. The effects of age were also consistent with what was expected, in that older age was associated with a higher incidence of NIHI.

The spike in NIHI visit rates among women during the fourth quarter of 2004 observed in these data was also seen in an analysis of army data for the same period.[13] The ICD-9 codes used in the military health system to capture severe hearing loss affecting readiness (H-3 and H-4 hearing loss profiles) were the most likely source of this anomaly, which has been attributed to the establishment of required predeployment record screening and referrals for audiometry.[13]

Table 1 presents some of the more interesting findings of the study. NIHI-specific diagnoses (ICD-9-CM codes 388.11 and 388.12) represented 14% of all visits over this time period. As shown in Table 1, other conditions (e.g., tinnitus, eardrum perforations, discontinuity of ossicles, impairment of auditory discrimination) were also included in the definition of NIHI used in this study, consistent with prior army NIHI investigations.[11,13] These conditions were included because they are likely due to noise/blast exposure, particularly in military occupational environments. In particular, while there are few data on causes of tinnitus, Luxon indicates that, in her expert opinion, a sizable portion of tinnitus is due to noise-induced hearing loss from sources like gunfire, leisure activities, industrial exposure, and blast injury.[19] These are essentially the exposures seen in U.S. armed forces at war in the Central Command Area of Responsibility (CENTCOM-AOR: Afghanistan and Iraq). Eardrum perforations were included based on findings from two previously published postdeployment NIHI studies[11,13] and medical evacuation data from CENTCOM-AOR (Hauret K, USACHPPM, unpublished observations, September 10, 2009).

Infantry/gun crews (combat arms) and electrical mechanical equipment repairers had higher NIHI frequencies than other DoD occupational groups, but their rates of NIHI were lower than expected. These occupations were expected to have higher rates of NIHI due to job duties frequently exposing them to weapons fire, operation of noisy equipment, aircraft, and vehicle noise. Based on past experience, rates in these high-risk professions were lower than expected.[5] This finding may indicate under-reporting of NIHI among combat arms and equipment repair occupations.

Regarding prevention, there are a number of best practices suggested by the DoD Hearing Conservation Program (HCP), which are as follows: (1) identification of noise hazards; (2) engineering controls where applicable; (3) hearing protectors; (4) health-threat briefing/education; (5) audiometric testing; and (6) command enforcement of safety procedures and use of personal protective equipment.[20] The 2006 IOM report[8] points out, however, that "military hearing conservation programs, dating from the late 1970s, cannot be considered adequate to protect the hearing of service members." This criticism was partially based on the historically low level of compliance with monitoring audiometry in the military. Criticism of the effectiveness of HCPs has also been commented on in the civilian sector. Daniell et al.[21] reviewed civilian industries' hearing loss–prevention efforts. Their findings showed serious concerns about the adequacy of prevention, regulation, and enforcement strategies among civilian industries in the U.S., essentially the same conclusions as the IOM report stated with regard to the military HCPs.[8]

Surveillance can also play a key role in prevention. Monitoring audiometry results, available through the DOEHRS-HC database, can be used to evaluate HCP effectiveness through analysis of significant threshold shift (STS) rates in relation to monitoring audiometry compliance.[20] Medical encounters (ICD-9 coded diagnoses) resulting from NIHI can also be monitored using available military medical surveillance data, as demonstrated in this paper. Active surveillance gives preventive medicine better visibility of military personnel hearing protection use and provides information on risk factors for noise exposure and hearing loss that can be incorporated into existing health threat briefings. Analyses of

medical surveillance data have also been used to assess postdeployment audiology services requirements,[11,13] and can provide additional, much-needed information on comorbidities associated with NIHI.

As with any surveillance effort, data quality is always a concern. Within the military audiology community, ICD-9-CM coding guidelines for audiology outcomes related to NIHI have been available to military audiologists since 2001. By early 2003, standard coding guidelines were more readily available for inputting NIHI codes into military medical administrative and surveillance systems.[22,23] At the time of this study, military audiologists were required to use rule-governed coding guidelines established by the Military Health System (MHS)'s coding standards organization, the Unified Biostatistical Utility working group,[24] who worked in collaboration with military audiologists since 1999 to set these standards. These coding standards are enforced by patient administration coders at the military medical treatment facilities who refer to the MHS coding standards manual for coding guidance.[24]

The strengths of this analysis were the following: (1) the data received from DMSS consisted of all medical encounters of active duty U.S. military personnel occurring in fixed (i.e., not temporary) military and civilian medical treatment facilities; (2) all medical encounters were subject to standardized and routine recordkeeping and coding; (3) the data collected came from a large patient population (approximately 1.3 million active duty personnel have access to MHS care); and (4) the data captured care received both within and outside the MHS (purchased care).

The limitations of the study included: (1) data on the troops deployed and receiving care in the theater of operations were not available in DMSS; (2) National Guard and Reserve troop data are not included in the present analysis, so incidence of NIHI in these populations is unknown and the cost and reduced readiness burdens of NIHI in the National Guard and Reserve are likewise unknown; (3) inability to assess exact causes of NIHI using medical data (i.e., higher rates among service members aged ≥40 years may be partially due to more years of exposure than that of junior service members, as well as presbycusis involvement in the older cohort; exposure information is not available, and cause coding is not required in the medical data); (4) where the diagnoses were correct, the person entering the ICD-9-CM code(s) may have not entered the most specific or accurate code (two of the commonly used ICD-9-CM codes, 389.8 and 389.9, are nonspecific diagnoses); (5) the aggregation of NIHI across all U.S. military services probably affects the rates reported, particularly if the rates among the services are varied due to different exposures among the individual services; and (6) the aggregation of NIHI ICD-9-CM codes blurs the distinction of different clinical outcomes tied to different exposures (e.g., steady noise versus impulse noise of weapons firing or exposure to explosives during war operations).

Conclusion and Recommendations

This analysis provides baseline NIHI visit rates among U.S. active duty military personnel. Key findings included: (1) overall NIHI rates ranged from 19 to 23 per 1000 person-years between 2003 and 2005; (2) rates were 15%–78% greater among men compared to women; (3) rates were three to five times greater among service members aged ≥40 years compared to rates among service members aged 17–19 years; and (4) crude NIHI rates were highest among general officers and executives.

There are many recommendations for improving NIHI surveillance in the U.S. DoD military services: (1) emphasize improved reporting of NIHI by encouraging precision coding of the ICD-9-CM data into healthcare databases and encouraging better annotation of hearing profiles in medical records; (2) use DMSS as the primary data source for monitoring NIHI in order to compare with other injury types (ICD-9-CM codes) in the DoD-level reports; (3) instruct public health analysts to make denominator adjustments to "person-year" to exclude time lost to follow up (either from deployment, separation from service, retirement, demobilization, or death), thereby increase the accuracy of reporting; (4) perform separate surveillance processes for active duty and National Guard/Reserve service members; (5) report NIHI by calendar year for better comparison with DMSS data for other injuries; (6) report injury rates stratified and/or adjusted by gender and age, allowing health promotion and education efforts to target specific age/gender groups; (7) report injury rates stratified by occupation types, thereby helping to develop health promotion and education materials that target specific occupational groups; (8) conduct postdeployment analyses and reporting separately from general DoD NIHI visit rates; (9) conduct postdeployment analyses and reporting for individual services based on different combat exposures; (10) conduct postdeployment analyses from accurate personnel data as to deployment status; and (11) report different categories or symptoms of NIHI (e.g., tinnitus, acoustic trauma, sensory hearing loss due to steady noise exposure) individually rather than aggregated for DoD reports.

For the period of this report, U.S. Armed Forces were at war. Some wartime exposures are so extreme as to overcome the best preventive measures. That being said, various measures have been put into place since the pe-

riod reported in this paper. However, paradoxically the rates of NIHI in redeploying Army personnel have increased dramatically. This is most likely due to improved compliance with postdeployment monitoring audiometry since September 2006, as well as improvement in adherence to MHS NIHI coding guidelines.

In summary, this analysis represents the first step in the public health process,[25,26] in which data, in particular surveillance data, are used to describe and understand a health problem. This paper provides a methodology (i.e., suggested ICD-9-CM codes) and broad data overview on which future surveillance efforts and analyses can build. Additional and more detailed analyses of data available in the Defense Medical Surveillance System (e.g., age-adjusted and service-specific rates, multivariate analyses) are needed to further understanding of the rates, trends, and leading risk factors for NIHI in the U.S. military population.

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