J Am Acad Audiol 29:928–935 (2018)

A Large-Scale Examination of Veterans with Normal Pure-Tone Hearing Thresholds within the Department of Veterans Affairs

DOI: 10.3766/jaaa.17091

Curtis J. Billings*†
Lauren K. Dillard*‡
Zachary B. Hoskins*
Tina M. Penman*
Kelly M. Reavis*§

Abstract

Background: Department of Veterans Affairs (VA) audiologists have anecdotally reported examining numerous Veterans with normal pure-tone thresholds; however, the prevalence of these patients within the VA is unknown. The VA audiological data repository provides an ideal dataset to examine this group of Veterans. Knowing the prevalence of normal-hearing Veterans within the VA system is the first step to understanding the underlying referral patterns and clinical complaints of Veterans. Data repositories which capture data from both normal and impaired populations provide an indispensable view into hearing health care which can help to improve diagnosis and treatment of Veterans' hearing difficulties.

Purpose: Using the VA audiological data repository, this study aimed to (1) determine the prevalence of normal hearing thresholds among Veterans seeking hearing health care within the VA health care system and (2) determine the prevalence of abnormal clinical audiology test results among Veterans with normal hearing thresholds.

Research Design: This study was a large-scale retrospective, descriptive observational analysis of uploaded audiological records from the VA Denver Acquisition and Logistics Center audiological data repository encompassing visits that took place between April 1991 and June 2015.

Study Sample: At the time of data extraction, there were 3,641,326 audiological records in the repository, with 2,322,771 unique individual records. The study sample was further restricted to include only individuals with normal hearing (n = 235,091), which was defined as pure-tone thresholds better than, or equal to, 25 dB HL at octave frequencies from 250 to 8000 Hz, bilaterally. Patients ranged from 19 to 90+ years of age.

Data Collection and Analysis: We describe the data using frequencies and percentages for categorical variables and means and standard deviations for continuous variables. In addition to hearing thresholds, the occurrence of abnormal results on other tests in the audiological test battery is also reported. We estimate the prevalence of normal hearing among all Veterans with records in the VA audiological data repository.

Results: Veterans with normal hearing were on average 37 yr old. The prevalence of Veterans with normal hearing thresholds visiting VA audiology clinics in the current hearing repository dataset was 10.12%. Overall, 41% of Veterans with normal pure-tone thresholds had other clinically abnormal audiological test results; for example, contralateral acoustic reflex thresholds (31.7%) and tympanometry (21.5%) had the highest rate of abnormal test results.

*National Center for Rehabilitative Auditory Research, Veterans Affairs Portland Health Care System, Portland, OR; †Department of Otolaryngology, Oregon Health & Science University, Portland, OR; ‡Department of Communication Sciences and Disorders, University of Wisconsin-Madison, Madison, WI; §Epidemiology, OHSU-PSU School of Public Health, Oregon Health & Science University, Portland, OR

Corresponding author: Curtis J. Billings, National Center for Rehabilitative Auditory Research, Veterans Affairs Portland Health Care System, Portland, OR 97239; Email: curtis.billings2@va.gov

This study was supported by the U.S. Department of Veterans Affairs (RR&D-C8006W) and a U.S. National Institutes of Health T-35 grant (DC008764). The contents do not represent the views of the U.S. Department of Veterans Affairs or the U.S. government.

This work was presented, in part, at the 2017 American Auditory Society Annual Scientific and Technology Conference.

Conclusions: Approximately one in ten Veterans seeking care within the VA healthcare system, and reported to the VA audiological data repository, has normal pure-tone hearing thresholds. This may be an underestimate of the true underlying prevalence of normal-hearing Veterans seeking audiology services at the VA because records with normal results were not consistently submitted to the repository. In addition, 41% of Veterans with normal pure-tone thresholds nonetheless presented with other audiological abnormalities. This study suggests that future work directed toward understanding referral patterns and clinical complaints of individuals who present to VA audiology clinics with normal hearing thresholds may be fruitful in the cause of improving diagnosis and treatment of Veterans' hearing difficulties.

Key Words: abnormal test results, normal audiogram, prevalence, pure tone threshold, retrospective multi-site, Veteran

Abbreviations: ART = acoustic reflex threshold; ABG = air-bone gap; DALC = Denver Acquisition and Logistics Center; PTA = pure tone average; SD = standard deviation; VA = Veterans Affairs

INTRODUCTION

Audiology clinics within the Department of Veterans Affairs (VA) are among the busiest outpatient clinics in the VA health care system. Although audiologists primarily care for Veterans with auditory deficits, many clinicians report testing patients with normal pure-tone hearing thresholds; however, it is unknown exactly how frequently these patients present to audiology clinics. A subset of these patients is likely being referred to the audiology clinic with subjective complaints of difficulty hearing, such as understanding speech in background noise or other difficult listening situations. Little is known about the exact nature of their problems or what the most effective treatment options may be; best practice guidelines for such situations have yet to be formally established. An important first step to improving the diagnosis and treatment of these individuals with normal pure-tone thresholds is to determine the prevalence of these visits and to better characterize the results of other tests in the audiological test battery.

It is not surprising that abnormalities in the audiological test battery may be present even when pure-tone thresholds fall within the normal range. In fact, it is widely accepted that normal thresholds do not necessarily indicate a normal auditory system. Even among supposedly "normal-hearing" populations, there are individuals who experience an unexpectedly large decrease in speech understanding when listening in challenging listening environments (Gates et al, 1990; Jerger et al, 1990; Stach et al, 1990; Cooper and Gates, 1991). For example, normal-hearing individuals often struggle to understand speech in background noise or in situations with rapid, reverberant, or otherwise degraded speech (Middelweerd et al, 1990; AAA, 2010). Differences between auditory function near threshold and at suprathreshold levels have been an important distinction for many decades (Plomp, 1978). Plomp (1978) suggested that both attenuation (or reduced audibility due to hearing loss) and distortion (deterioration of the representation of a signal due to hearing loss) may play important roles in auditory perception. Attenuation can be resolved primarily by improving audibility, whereas distortion in the auditory system is more difficult to quantify and resolve. It may be that distortion within the auditory system, especially at suprathreshold levels is at the root of hearing difficulties experienced by those with normal pure-tone thresholds. Indeed, Martin et al. (1998) argued that pure-tone testing does not address distortion-related deficits. Patients with normal hearing thresholds who report having hearing difficulties have been studied for decades. Historically, these patients have been classified as having various conditions, including: auditory inferiority complex (Byrne and Kerr, 1987), auditory disability with normal hearing (Rendell and Stephens, 1988), selective dysacusis (Narula and Mason, 1988), obscure auditory dysfunction (Saunders and Haggard, 1989), King–Kopetzky syndrome (Kopetzky, 1948; King, 1954; Hinchcliffe, 1992) auditory dysacusis (Jayaram et al, 1992), and idiopathic discriminatory dysfunction (Rappaport et al, 1993). Although definitions and symptoms of these conditions vary, a common characteristic of these patients is their difficulty hearing even with normal pure-tone thresholds. Currently, clinicians may classify this group of patients as having an auditory processing disorder or deficit (Jerger et al, 1990; AAA, 2010). Reports from these patients show that a diagnosis of normal hearing combined with a lack of treatment recommendations may result in feelings of dismissal and confusion (Pryce and Wainwright, 2008).

Within the VA, clinicians report frustration with determining what to do for Veterans with subjective complaints of hearing difficulty in the context of normal pure-tone thresholds. An informal survey administered to VA audiologists by Saunders and Abrams (2009) estimated that 92% of responding audiologists reported encountering at least one Veteran per month with normal hearing who complained of hearing difficulties. The proportion of audiologists that reported encountering such a patient one to three times per month was 53% and 39% reported encountering four or more per month. Although 33% of these audiologists reported issuing a personal FM system and 26% reported recommending

auditory training, 30% reported being unsure of how to treat these patients. That is, a third of respondents did not know how to treat individuals with hearing difficulties and normal thresholds. This demonstrates a need to improve our understanding of the extent and nature of this clinical challenge. The Veteran population is unique in that individuals with normal hearing often present with comorbidities related to military service, such as blast exposure and traumatic brain injury (Gallun et al, 2012), tinnitus (Helfer et al, 2005), post-traumatic stress disorder (Gordon et al, 2017) or other mental health conditions (such as depression and anxiety), or auditory processing deficits (Saunders et al, 2015). Each of these factors may exacerbate hearing and processing difficulties.

The goals of this study were (a) to determine the prevalence of Veterans visiting VA audiology clinics who have normal pure-tone hearing thresholds and (b) to determine the prevalence of abnormal audiological measurements in these patients. This is the first large-scale report that characterizes Veterans with normal hearing thresholds.

METHODS

Data Source

This retrospective descriptive study was conducted on data collected within the VA health care system. We used data obtained from the U.S. Department of Veteran Affairs Office of Acquisition and Logistics. The Denver Acquisition and Logistics Center (DALC) supports the VA nationwide with acquisition and logistics services, including data storage and distribution of hearing aids, hearing aid accessories, and assistive listening devices. The DALC audiological repository data included in this study consisted of hearing assessments from 259 VA sites in the United States between 1991 and 2015. The repository is a useful dataset from which to establish the range of pure-tone thresholds among Veterans seeking care within outpatient audiology clinics. The repository contains more than three million audiograms from audiology visits by Veterans. To date, however, only a handful of peer-reviewed works have been published from this dataset and are primarily focused on hearing impairments including audiological notches (Wilson, 2011; Wilson and McArdle, 2013; 2014).

It is worth noting that although the repository dataset is quite expansive, it is not exhaustive or complete. Not all sites or audiologists within a site contributed records to the repository from every patient or every test during the date range queried for this study. An informal survey of VA audiologists we conducted demonstrated that there has been a wide range of compliance with requests for audiologists to submit records to the repository. Identification of patients' sex was not available in the repository, nor were there records of other health conditions, noise exposure history, or specifics regarding hearing difficulty.

Data Analysis

Data were summarized and examined using descriptive statistics including frequencies, percentages, means, and standard deviations (SD). All data were assessed using Excel and SPSS software. All patients aged 90 yr and older were aggregated into a single category in compliance with the Health Insurance Portability and Accountability Act Privacy Rule, which classifies ages over 89 yr as identifiable data. Abnormal results were determined by comparing with commonly accepted standards (shown in Table 1). The normative values listed in Table 1 come from common and well-supported definitions of normal status that are applicable to this study population. Normal hearing was defined as pure-tone thresholds ≤25 dB HL at each octave frequency from 250 to 8000 Hz.

RESULTS

At the time the data were obtained, the total number of records in the DALC audiological data repository was 3,641,326. Figure 1 depicts the study population and how the analytic sample was determined. For patients with more than one audiological evaluation on file, only the entry that included the best audiogram was used for analysis, resulting in 2,322,771 unique patient records. For these purposes, the "best" audiogram was defined as the one with the lowest binaural average of air-conduction thresholds at 250, 500, and 1000 Hz.

Table 1. Commonly Accepted Definitions of Abnormal Test Results for Adult Populations

Test	Definition of abnormal	Reference
Acoustic reflex threshold (ART) at 1000 Hz	Threshold > 95 dB HL	Gelfand et al (1990)
Tympanometry	Ear canal volume <0.63, >2.0 cm^3 Admittance <0.2, >1.5 mmho	Wiley et al (1996) and Margolis and Heller (1987)
Maximum word recognition score (WRS)	Score < 92%	Thornton and Raffin (1978)
Air bone gap (ABG) at 1000 Hz	AC-BC ≥ 15 dB HL	Wilson and McArdle (2013)
Audiometric notch	Differences ≥10 dB between center and adjacent frequencies	Wilson and McArdle (2013)

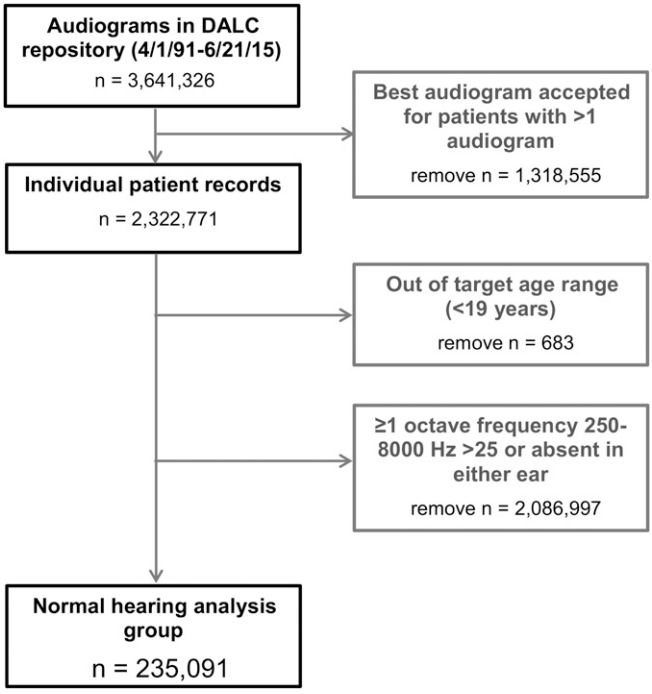

Figure 1. Epidemiological decision tree for DALC audiological data repository audiograms. Final analysis was performed on 235,091 audiograms with normal pure-tone thresholds within the target age and date ranges.

Data included records for patients that were seen between April 1, 1991 and June 21, 2015, who were ≥19 yr of age. Those younger than 19 were excluded in compliance with the approved institutional review board protocol. Subsequently, only records with present and normal pure-tone thresholds (≤25 dB HL) at all octave frequencies (250, 500, 1000, 2000, 4000, 8000 Hz) in both ears were retained. The final analysis group was composed of 235,091 patients with normal hearing thresholds. Most of these 235,091 patients also had pure-tone thresholds reported at 3000 and/or 6000 Hz (n = 229,270), which were used to perform analyses related to audiological notches at these frequencies but were not used to define exclusion criteria. Patients with pure-tone thresholds above 25 dB HL at 3000 and 6000 Hz were still considered to have normal hearing thresholds for the purposes of this study.

Figure 2 shows a scatterplot of high-frequency pure tone averages (PTAs) for each record plotted as a function of age. The mean age of participants was 37.14 yr (SD = 11.7 yr; range = 19–90+ yr). The mean bilateral high-frequency PTA (average of 1.0, 2.0, and 4.0 kHz values) was 10.59 dB HL (SD = 5.0; range = −10 to 25 dB HL). Figure 2 excludes participants 90 yr of age or older (n = 12) and participants with no age listed (n = 77), and includes a linear trendline (R^2 = 0.0758) that illustrates a limited relationship. It should be noted that this value will not represent the general relationship between age and hearing loss because thresholds were limited to 25 dB HL.

Prevalence of Normal Pure-Tone Thresholds

Of the 2,322,088 unique patients, 235,091 (10.12%) were determined to have normal hearing, with pure-tone thresholds ≤25 dB HL at all octave frequencies. The number of normal-hearing patients by age decade is displayed in Table 2, and mean thresholds for different decade groups are shown in Figure 3. Thresholds

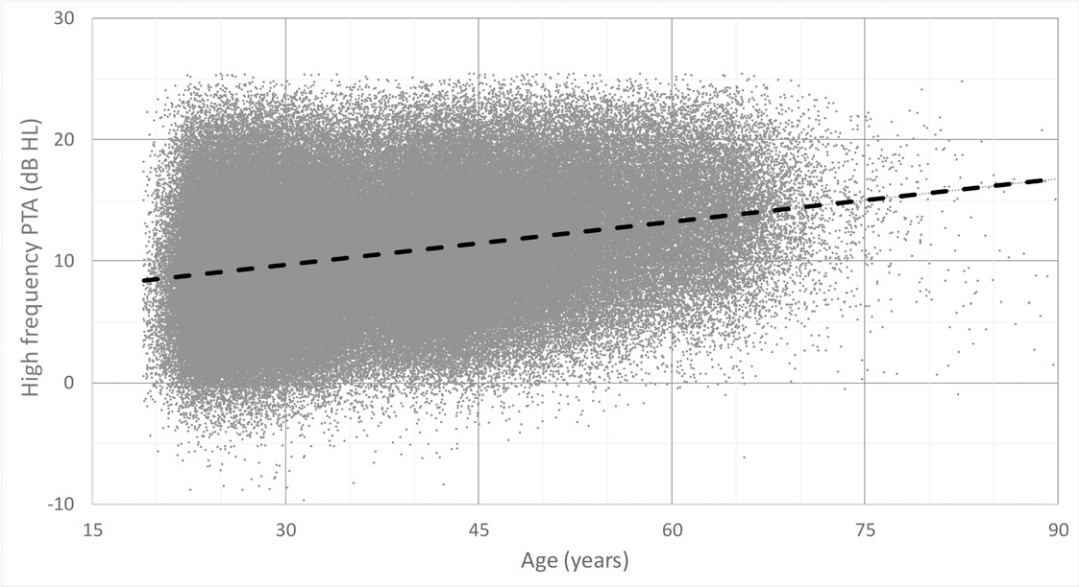

Figure 2. Scatterplot of all audiograms. The PTA (1.0, 2.0, and 4.0 kHz) of each record is shown as a function of age and demonstrates the large number of normal audiological records that made up this dataset (n = 235,091). *Y*-axis values were jittered to display individual data points. Older Veterans exhibit higher PTAs on average even within bounds of normal hearing, as seen by the dashed linear trendline.

Table 2. Breakdown of Included Records by Decade of Life

Age	Number	Percent
19–29	81,662	34.75
30–39	59,902	25.49
40–49	54,604	23.23
50–59	27,602	11.74
60–69	10,416	4.43
70–79	743	0.32
80 and older	85	0.04
Sub-total	235,014	100
No age available	77	—
Total	235,091	—

generally increase with age, especially at high frequencies (4000 and 8000 Hz), meaning that on average patients are less likely to have normal hearing as they get older. The majority (141,564 or 60.2%) of individuals fell between 19 and 39 yr of age.

Other Abnormal Audiological Test Results

Figure 4 shows how many of the 235,091 normal-hearing patient records contained results for each of several other audiological test measures. The most commonly recorded test measure was word recognition (n = 217,396), followed by tympanometry (n = 156,078), bone-conduction audiometry (n = 123,658), ipsilateral acoustic reflexes (n = 97,966), and contralateral acoustic reflexes (n = 71,936). Abnormal results were determined by comparing with commonly accepted standards (shown in Table 1). Contralateral acoustic reflex threshold (ART) tests had

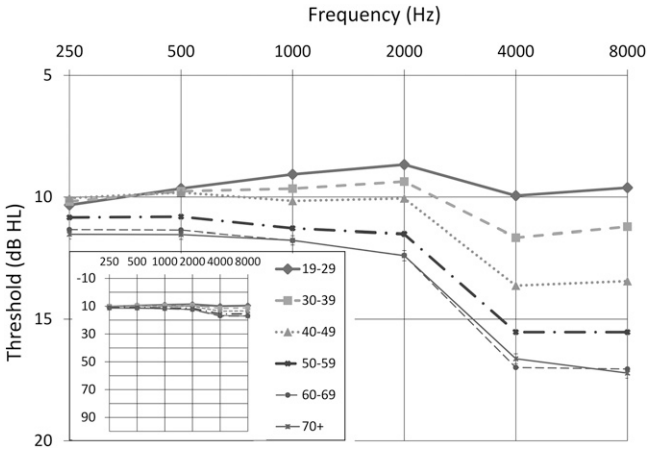

Figure 3. Mean pure-tone air-conduction thresholds for each ten-year age group. Veterans 70 yr and older were grouped together because of the comparatively small number of normal audiograms available. Age groups show differences in high-frequency hearing, and there is a visible elevation of hearing thresholds with increasing age, even within this population of ostensibly normal-hearing individuals. Error bars display the standard error of the mean, although they may be difficult to see because the large size of the dataset produces very small standard error estimates.

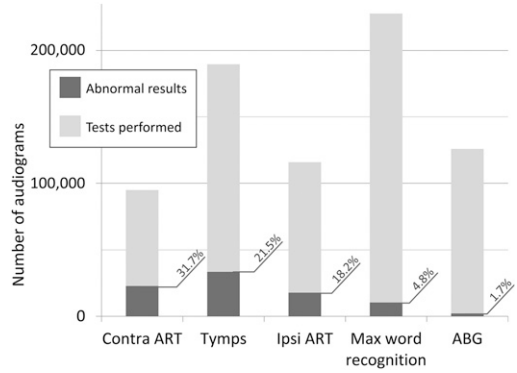

Figure 4. Number of normal-hearing VA patient records containing each of five different audiological tests. Not all tests were completed for the full sample; gray bars represent the total number of records where results for the given test were available. Black bars represent the number of abnormal results for each test. The proportion of abnormal tests to total tests performed is expressed next to each bar as a percentage.

the highest prevalence of abnormal results compared with the number of individuals tested (31.7%). Air-bone gaps (ABG) had the lowest prevalence at 1.74% abnormal results of tests performed. The overall prevalence of any abnormality in either ear for this normal-hearing population was 41.10%. An abnormality was defined as an audiological notch at 3000, 4000, or 6000 Hz, or an abnormal test result in any of the tests listed in Table 1.

Table 3 shows the mean depth and prevalence of unilateral and bilateral notches for 3000, 4000, and 6000 Hz notches. Notch depth was defined as the difference between the threshold at the notch frequency and the average of the thresholds at its two adjacent octave frequencies. Left-ear notches were found to be more prevalent than right-ear notches at all frequencies. Notches were also deeper in the left ear than in the right ear for all notch frequencies, although no statistical analysis was performed to determine significance because of the descriptive nature of the study. Bilateral notches were the least common, consistently appearing less than half as often as right-ear notches. Average thresholds for 3000 and 6000 Hz notches are shown in Figure 5. Most of the 235,091 records contained pure-tone thresholds at 3000 and/or 6000 Hz resulting in a total of 229,270 records used for notch analysis. Notches at 6000 Hz were deeper on average than 3000 Hz, but 6000 Hz was tested less frequently (211,536 audiograms compared with 228,161). Notches at 4000 Hz may be shallower in this dataset because the threshold at the notch center frequency was always ≤25 dB HL because of the inclusion criteria.

DISCUSSION

An important premise of this paper is the definition of "normal hearing" as it pertains to pure-tone

Table 3. Depth and Prevalence of Unilateral and Bilateral Notches

Notch Frequency (Edge Frequency)	Right-Ear Notch Depth (Standard Deviation)	Left-Ear Notch Depth (Standard Deviation)	Right-Ear Notch Prevalence (%)	Left-Ear Notch Prevalence (%)	Prevalence of Bilateral Notch (%)
4 (2, 8)	12.728 (2.94)	13.29 (3.20)	4.79	6.66	2.18
3 (2, 4)	12.69 (4.01)	13.34 (4.62)	2.22	2.54	0.46
6 (4, 8)	14.13 (5.04)	14.40 (5.36)	5.85	6.41	2.21

thresholds, which varies across clinical settings and publications. The American National Standards Institute standards define audiological zero (0 dB HL) for each frequency as the average threshold level at that frequency for normal-hearing young adults. For frequencies measured in a typical audiological evaluation (octave intervals 250–8000 Hz), the SD from the mean (i.e., 0 dB HL) is 3–5 dB, depending on the frequency (Wilber et al, 1988; ANSI, 2010). Although early descriptions defined the normal range as 3 SDs from audiological zero, today many clinicians and researchers do not use this definition. It is common for contemporary definitions to be based on a three-frequency (500, 1000, 2000) or four-frequency (500, 1000, 2000, 4000) PTA. A PTA, even if it is calculated from thresholds at each octave test frequency from 250 to 8000 Hz, allows for normal-hearing individuals to have some elevated thresholds. More stringent definitions of normal hearing place an upper limit on thresholds at each frequency. An upper limit (applied to each octave frequency) of 25 dB HL was chosen for this study because it is common in clinical protocols, which ensures that results are applicable to clinical settings (Glorig et al, 1956; Goodman, 1965; Glorig, 1966). It should be noted that an upper limit of 25 dB HL to define normal hearing allows for a large range of "normal" variation that may be problematic when considering functional deficits and hearing difficulty complaints in patients seen in the clinic.

The prevalence of Veterans with normal hearing thresholds visiting VA audiology clinics in the DALC audiological data repository was 10.12%. Other studies have reported a prevalence of around 5% normal-hearing individuals (excluding middle ear pathologies) in civilian clinical populations (Saunders and Haggard, 1989; Higson et al, 1994). We suspect that the prevalence reported herein may underestimate patient visits within the VA system. Requirements for entry of information into the repository vary both by clinic site and clinician as some enter all data into the DALC repository, whereas others only use it to track hearing aid orders. In an informal survey of VA audiologists that we conducted, it was reported that when hearing aids were not ordered, the test results were not consistently entered into the repository at every site or by every audiologist. The magnitude of this effect is unknown, but would result in an underestimation of the prevalence of normal audiograms (i.e., fewer normal records would be entered than records that reflect hearing loss). Furthermore, the ratio of reported data included in this analysis has changed over the years depending on the clinic and clinician.

It is not known what portion of these normal-hearing individuals report hearing difficulty. Future studies could examine visit notes or diagnosis/treatment codes to determine the reason for visits as well as noise exposure history and other comorbid conditions. Medication effects may also be important to consider. Medications might be prescribed for Veterans with various comorbid conditions (e.g., post-traumatic stress disorder) who may also report hearing difficulties. It has been noted that

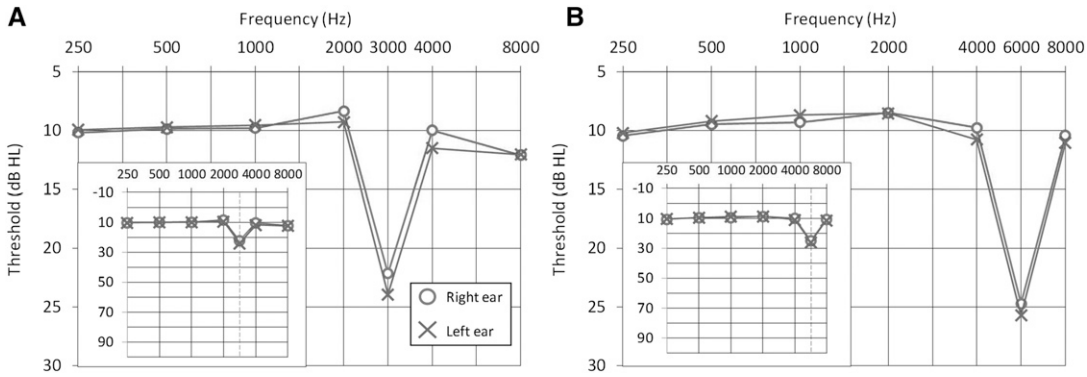

Figure 5. (A) Right-ear and left-ear notches at 3000 Hz. On average, left-ear notches are deeper than right-ear notches in this population. (B) The 6000-Hz notches show a similar pattern, but have a greater average depth (see Table 3). Error bars display standard errors of the mean, but may be difficult to see because of the large sample size and the resulting small standard errors.

these medications should be used with caution for some patients as it may cause confusion and deterioration of cognitive performance (VA/DoD, 2010). A deterioration of cognitive performance may exacerbate existing difficulties with hearing, especially in the presence of background noise. All of these factors are important considering that Veterans come to the clinic with different medical histories than the average civilian.

Although Veterans with normal hearing visit audiology clinics for a variety of reasons, including referral from case manager, compensation and pension evaluation, employment screenings, and problems with tinnitus or balance (rather than sensitivity or clarity of hearing), we assume that some of them are seeking care for hearing and listening difficulties. It is unknown what the exact causes of hearing problems are among individuals with normal hearing thresholds. In an attempt to begin to understand this issue, the second goal of this study was to report abnormalities found among the results from other audiological tests often included in a comprehensive testing battery. Among Veterans with normal pure-tone thresholds, the 41.10% prevalence of abnormal test results illustrates the importance of considering the complete battery of audiological tests. It is known that normal hearing thresholds do not necessarily indicate a normal auditory system, nor do they necessarily predict how an individual will perform in challenging listening situations. The high rate of abnormal test results among these individuals presents an argument for more rigorous testing, even for individuals who present with normal hearing. This is especially true if Veterans come complaining of hearing difficulty and that difficulty is not adequately captured by their audiogram. For example, abnormal physiological test results may be related to middle-ear or reflex-arc problems that disrupt the normal encoding of information, abnormal speech-testing results may indicate distortion in auditory processing, and the presence of elevated thresholds and notches, even within the normal range, may decrease speech-in-noise understanding. The greater depth and prevalence of left-ear notches are difficult to explain without information about noise exposure. Given the nature of the Veteran patient population, it is conceivable that these notches are a result of firearm use or blast exposure. The notch prevalence and depth results from this study are consistent with previous findings (Wilson, 2011; Wilson and McArdle, 2013). The nontrivial number of 3000 and 6000 Hz notches found in this population whose octave thresholds all fall within normal limits speaks to the necessity of testing interoctave frequencies because these are potential abnormalities that might otherwise be hidden in an audiogram that only examines octave frequencies. Although more comprehensive testing can provide additional clarity, it must be noted that 58.9% of the patients with normal audiograms also had normal results on all other audiological tests we examined despite the likelihood that some of them came into the clinic with hearing complaints. For these Veterans, conventional diagnostic methods and treatments do not provide adequate solutions.

In addition to diagnostic considerations, it is challenging for audiologists to develop treatment plans for these normal-hearing individuals who present with complaints of hearing difficulty. These challenges present themselves regardless of whether other audiological test results are abnormal. The presence of a normal audiogram does not necessarily mean there is no damage to the auditory system. The audiogram, on which we often base our judgment of a normal or nonnormal auditory system, only represents near-threshold testing. The existence of many diverse etiologies that may result in hearing difficulties further contributes to the lack of consensus regarding treatment for these patients. The utilization of the three treatment options for these patients (low- to mild-gain amplification, FM systems, and auditory training) may or may not be appropriate depending on each Veteran's specific needs. It is noteworthy that normal pure-tone threshold prevalence in the Veteran population was twice that found in the civilian population.

CONCLUSIONS

This large-sample retrospective analysis of Veterans establishes an estimate of the prevalence of Veterans visiting VA audiology clinics with normal pure-tone thresholds at 10%; in addition, estimates of the audiological abnormalities on other tests (tympanometry, acoustic reflexes, word recognition, and bone conduction) in this population are detailed. These findings may inform future studies that investigate why people with normal pure-tone thresholds sometimes report difficulties hearing, and they suggest that clinicians should think beyond the audiogram when considering what constitutes "normal hearing."

Acknowledgments. The authors would like to acknowledge the efforts and support of Angela Eilbes and Rachel Stanziola.

REFERENCES

American Academy of Audiology (AAA). (2010) Guidelines for the diagnosis, treatment, and management of children and adults with central auditory processing disorder. https://audiology.org/publications-resources/document-library/central-auditory-processing-disorder

American National Standards Institute (ANSI). (2010) *American National Standard Specification for Audiometers. Acoustical Society of America* (ANSI S3.6-2010). New York, NY: ANSI.

Byrne JET, Kerr AG. (1987) Deafness with normal pure tone audiometry. In: Kerr AG, Groves J, Booth JB, eds. *Scott Brown's Otolaryngology*. Great Britain, UK: Butterworth and Co, 383–384.

Cooper JC Jr, Gates GA. (1991) Hearing in the elderly—the Framingham cohort, 1983–1985: part II. Prevalence of central auditory processing disorders. *Ear Hear* 12(5):304–311.

Gallun FJ, Lewis MS, Folmer RL, Diedesch AC, Kubli LR, McDermott DJ, Walden TC, Fausti SA, Lew HL, Leek MR. (2012) Implications of blast exposure for central auditory function: a review. *J Rehabil Res Dev* 49(7):1059–1074.

Gates GA, Cooper JC Jr, Kannel WB, Miller NJ. (1990) Hearing in the elderly: the Framingham cohort, 1983–1985. Part I. Basic audiometric test results. *Ear Hear* 11(4):247–256.

Gelfand SA, Schwander T, Silman S. (1990) Acoustic reflex thresholds in normal and cochlear-impaired ears: effects of no-response rates on 90th percentiles in a large sample. *J Speech Hear Disord* 55(2):198–205.

Glorig A. (1966) Audiometric references levels. *Laryngoscope* 76(5): 842–849.

Glorig A, Quiggle R, Wheeler DE, Grings W. (1956) Determination of the normal hearing reference zero. *J Acoust Soc Am* 28: 1110–1113.

Goodman A. (1965) Reference zero levels for pure-tone audiometer. *ASHA* 7(Suppl):262–263.

Gordon JS, Griest SE, Thielman EJ, Carlson KF, Helt WJ, Lewis MS, Blankenship C, Austin D, Theodoroff SM, Henry JA. (2017) Audiologic characteristics in a sample of recently-separated military veterans: the Noise Outcomes in Servicemembers Epidemiology Study (NOISE Study). *Hear Res* 349:21–30.

Helfer TM, Jordan NN, Lee RB. (2005) Postdeployment hearing loss in U.S. army soldiers seen at audiology clinics from April 1, 2003, through March 31, 2004. *Am J Audiol* 14(2):161–168.

Higson JM, Haggard MP, Field DL. (1994) Validation of parameters for assessing obscure auditory dysfunction—robustness of determinants of OAD status across samples and test methods. *Br J Audiol* 28(1):27–39.

Hinchcliffe R. (1992) King-Kopetzky syndrome: an auditory stress disorder. *J Audiol Med* 1:89–98.

Jayaram M, Baguley DM, Moffat DA. (1992) Speech in noise: a practical test procedure. *J Laryngol Otol* 106(2):105–110.

Jerger J, Oliver TA, Pirozzolo F. (1990) Impact of central auditory processing disorder and cognitive deficit on the self-assessment of hearing handicap in the elderly. *J Am Acad Audiol* 1(2):75–80.

King PF. (1954) Psychogenic deafness. *J Laryngol Otol* 68(9): 623–635.

Kopetzky SJ. (1948) *Deafness, Tinnitus, and Vertigo*. New York, NY: Thomas Nelson & Sons.

Margolis RH, Heller JW. (1987) Screening tympanometry: criteria for medical referral. *Audiology* 26(4):197–208.

Martin FN, Champlin CA, Chambers JA. (1998) Seventh survey of audiometric practices in the United States. *J Am Acad Audiol* 9(2): 95–104.

Middelweerd MJ, Festen JM, Plomp R. (1990) Difficulties with speech intelligibility in noise in spite of a normal pure-tone audiogram. *Audiology* 29(1):1–7.

Narula AA, Mason SM. (1988) Selective dysacusis—a preliminary report. *J R Soc Med* 81(6):338–340.

Plomp R. (1978) Auditory handicap of hearing impairment and the limited benefit of hearing aids. *J Acoust Soc Am* 63(2):533–549.

Pryce H, Wainwright D. (2008) Help-seeking for medically unexplained hearing difficulties: a qualitative study. *Int J Ther Rehabil* 15:343–349.

Rappaport JM, Phillips DP, Gulliver JM. (1993) Disturbed speech intelligibility in noise despite a normal audiogram: a defect in temporal resolution? *J Otolaryngol* 22(6):447–453.

Rendell RJ, Stephens SDG. (1988) Auditory disability with normal hearing. *Br J Audiol* 22:233–234.

Saunders G, Abrams H. (2009) Evaluation of Approaches to Auditory Rehabilitation of mTBI. NCRAR Pre-conference Workshop: Current Directions and Interdisciplinary Approaches to mTBI, October 7, Portland, OR

Saunders GH, Frederick MT, Arnold M, Silverman S, Chisolm TH, Myers P. (2015) Auditory difficulties in blast-exposed eterans with clinically normal hearing. *J Rehabil Res Dev* 52(3):343–360.

Saunders GH, Haggard MP. (1989) The clinical assessment of obscure auditory dysfunction—1. Auditory and psychological factors. *Ear Hear* 10(3):200–208.

Stach BA, Spretnjak ML, Jerger J. (1990) The prevalence of central presbyacusis in a clinical population. *J Am Acad Audiol* 1(2): 109–115.

Thornton AR, Raffin MJ. (1978) Speech-discrimination scores modeled as a binomial variable. *J Speech Hear Res* 21(3): 507–518.

Department of Veterans Affairs and Department of Defense (VA/DoD). (2010) VA/DoD clinical practice guidelines for management of post-traumatic stress. https://www.healthquality.va.gov/guidelines/MH/ptsd/cpgPTSDFULL201011612c.pdf

Wilber LA, Kruger B, Killion MC. (1988) Reference thresholds for the ER-3A insert earphone. *J Acoust Soc Am* 83(2):669–676.

Wiley TL, Cruickshanks KJ, Nondahl DM, Tweed TS, Klein R, Klein BEK. (1996) Tympanometric measures in older adults. *J Am Acad Audiol* 7(4):260–268.

Wilson RH. (2011) Some observations on the nature of the audiometric 4000 Hz notch: data from 3430 veterans. *J Am Acad Audiol* 22(1):23–33.

Wilson RH, McArdle R. (2013) Characteristics of the audiometric 4,000 Hz notch (744,553 veterans) and the 3,000, 4,000, and 6,000 Hz notches (539,932 veterans). *J Rehabil Res Dev* 50(1):111–132.

Wilson RH, McArdle R. (2014) A treatise on the thresholds of interoctave frequencies: 1500, 3000, and 6000 Hz. *J Am Acad Audiol* 25(2):171–186.