Tinnitus
An Epidemiologic Perspective

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KEYWORDS

• Tinnitus • Epidemiology • Risk factors • Prevalence • Ototoxicity • Noise • Hearing loss

KEY POINTS

- Tinnitus, often referred to as "ringing in the ears," is a health condition that is estimated to affect 10% to 15% of adults worldwide.
- Epidemiologic studies have attempted to describe tinnitus and its many facets, such as its psychoacoustic characteristics and functional effects.
- Data and findings cannot be compared between studies due to lack of standardization in tinnitus assessment.
- One of the goals of this article is to provide definitions and assessment tools that can promote standardization and data that are comparable between studies.
- The Noise Outcomes in Servicemembers Epidemiology study has a specific focus on tinnitus; this study can serve as a model for the capture of uniform and comparable measures.

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INTRODUCTION

Tinnitus is the perception of sound—in the head and/or ears—that does not have a source outside of the body. The 2 basic types of tinnitus are primary and secondary.[1] The sensation of primary tinnitus is entirely subjective, originating somewhere in the auditory system and confined to the auditory pathways. The American Academy of Otolaryngology–Head and Neck Surgery Foundation (AAO-HNSF) defines primary tinnitus as "idiopathic and may or may not be associated with sensorineural hearing loss."[1] Secondary tinnitus involves an underlying mechanical source within the head or neck that transmits an actual acoustic signal by bone conduction to the auditory end organ, where it is detected and processed as would be any external sound. This article focuses on the epidemiology of primary tinnitus, which is by far the most prevalent type.[1] Throughout the rest of this article, references to tinnitus indicate primary tinnitus unless otherwise specified. This article includes an overview of characteristics and epidemiologic findings from studies that have focused on tinnitus and describes pertinent results from the authors' own, ongoing epidemiology study.

Purpose

The overarching purpose of epidemiologic research is to develop knowledge of the distribution and determinants of health conditions across populations.[2] More specifically, the objective is to obtain data associated with a particular health condition or disease to improve the effectiveness of its prevention, management, or cure. Tinnitus is a health condition, not a disease. It is the symptom of pathologic neural activity that manifests as an unwanted phantom auditory sensation. To advance the development of methodologies that can restore normal neural function, research attempts to explain which mechanisms trigger tinnitus and sustain its underlying pathologic neural activity. This is difficult because tinnitus is associated most often with a permanently damaged auditory system. Thus, it may be necessary first to determine how damaged components of the auditory system can be restored. Epidemiologic research is 1 component of the larger effort to understand tinnitus etiology and to work toward a cure, or cures. Tinnitus-focused epidemiologic research examines risk factors to further inform determination of etiology and to advance prevention efforts. The integration of epidemiologic investigative methodologies and findings with those of other scientific endeavors can strengthen understanding of the causal mechanisms and drivers of tinnitus and allows elucidating populations at risk.

Because epidemiologic research requires precise definitions, the different parameters of tinnitus that must be defined are described first. These parameters include temporal characteristics, functional and emotional effects, and perceptual (including psychoacoustic) attributes.

Temporal Characteristics of Tinnitus

Temporal characteristics of tinnitus include how long the sensation lasts, how often it occurs, and for what length of time (duration) it has been experienced. Defining these characteristics is essential due to the many possible variations within these parameters. First, tinnitus must be distinguished from transient ear noise, which is the sudden unilateral sensation of a phantom tonal sound that decays within a minute or so. Transient ear noise, also referred to as spontaneous tinnitus,[3] often is described as a whistling sound and typically is accompanied by a sense of ear fullness and hearing loss. These symptoms decay simultaneously and the ear returns to normal function. Transient ear noise is experienced on an occasional basis by practically everyone and is not considered pathologic tinnitus.

If a phantom auditory sensation lasts at least 5 minutes; this normally distinguishes it from transient ear noise.[4] If tinnitus lasting at least 5 minutes is experienced infrequently, however, it is considered as a different category of tinnitus than tinnitus experienced on a regular basis. This distinction is somewhat arbitrary, but, for the epidemiology study the authors have undertaken, *regular* is defined tinnitus as tinnitus that occurs at least weekly.[5] Regular tinnitus can further be classified as *intermittent* (occurring on a daily or weekly basis) or *constant* (always present), either of which indicates a pathologic condition necessitating assessment. Ideally, assessment is performed by both an otolaryngologist and an audiologist due to the high likelihood of comorbid hearing loss.[6]

The duration of a person's tinnitus (how long it has been experienced) can vary from 1 day to many decades. The dividing point between acute tinnitus and chronic tinnitus (referred to, respectively, by the AAO-HNSF as recent-onset and persistent) usually is considered 6 months.[1] To reasonably ensure that tinnitus is chronic, a great majority of tinnitus clinical trials require their research participants to have experienced tinnitus for at least 6 months. Tinnitus of less than 6 months duration is considered more labile. The typical natural history of tinnitus is to habituate to both awareness of, and reactions to, the auditory sensation within 1 year to 2 years.[3] The AAO-HNSF guideline makes the point that a person whose tinnitus is bothersome after 6 months is more likely in need of management than if the tinnitus has been bothersome for less than 6 months.

Functional and Emotional Effects of Tinnitus

Although primary tinnitus mainly involves the auditory pathways, its sensation can cause disturbing effects of activation in the limbic and autonomic nervous systems.[7] Such tinnitus may be considered "bothersome" because it is reported to be for approximatively 20% of people who experience chronic tinnitus.[1,8] Tinnitus can be mildly, moderately, or severely bothersome.[3] For some individuals, tinnitus is considered debilitating. When tinnitus becomes bothersome, it most broadly affects sleep, concentration, and emotional stability. Sleep disturbance is the most common effect of bothersome tinnitus.[9,10] Tinnitus also can affect tasks adversely that involve concentration, such as reading and writing. Finally, there is ample evidence that tinnitus may be associated with mental distress, namely depression and anxiety.[11] Tinnitus does not reduce hearing sensitivity but it can distract from listening, which may exacerbate the perception of a hearing problem.

Perceptual Attributes of Tinnitus

The perception of tinnitus can be described with respect to its loudness, pitch, spectral quality, number of sounds perceived, and lateralization. None of these parameters can be evaluated or quantified objectively, so their study relies on patient self-report.

It seems that the loudness of tinnitus might be its most significant source of distress. Loudness of tinnitus can be reported on a numeric 0 to 10 scale, with 10 representing the "loudest sound imaginable." High ratings of tinnitus loudness tend to be associated with high index scores on tinnitus outcome questionnaires; hence, self-rated loudness and tinnitus functional and emotional effects are strongly correlated.[12] Tinnitus loudness can also be assessed by asking tinnitus patients to match the level of an external tone or noise to the loudness of their tinnitus. Because tinnitus cannot be objectively observed, however, this approach cannot be proved accurate or reliable. Likewise, it is not possible to validate that post-treatment changes in tinnitus loudness matches represent meaningful and reliable changes or even that post-treatment changes are related specifically to treatment.[13] To evaluate whether a treatment

can effectively suppress the tinnitus percept, it is helpful to be able to objectively quantify tinnitus loudness before and after treatment.

Pitch matching is a common clinical procedure but cannot be objectively validated and has not been proved to have clinical relevance. Pitch matching is done using various methods with the common objective to match the frequency of a tone to the perceived pitch of the tinnitus. It is known that repeated pitch matches tend to be variable, often spanning a range of 2 to 3 octaves.[13] This high variability calls into question the validity of sound therapies that rely on pitch matching to establish acoustic parameters with respect to the perceived pitch of tinnitus. It seems likely that tinnitus often is not perceived as a pure tone but rather as a sound spectrum, which could explain why repeated pitch matches can vary so much within a given frequency range. Any tone within the range of an individual's tinnitus spectrum might be judged to match the tinnitus percept.[14] The perceived tinnitus pitch usually is within the frequency range of hearing loss,[15–17] and patients typically match their tinnitus to a tone greater than 3 kHz.[9]

People with tinnitus often report that they hear multiple sounds.[9] They can distinguish and describe each sound and how the different sounds relate to each other with respect to their loudness and pitch. For example, a tinnitus sufferer might hear a high-pitched sound along with a low-pitched hum. The high-pitched sound might be noticeable in most situations if it is above the frequency range of typical ambient sound. By contrast, the hum might be easily masked by ambient sound and, therefore, be noticeable only in very quiet environments.

Finally, tinnitus can be perceived as occurring in various locations with respect to the head and ears. The tinnitus may be heard as unilateral, bilateral, as symmetric, as asymmetric, in the head, in the ears, and/or outside of the head.[9] The localization or lateralization of tinnitus might yield clues as to its underlying mechanism. For example, it can be postulated that tinnitus that is heard in both ears might originate in 2 different locations distal (peripheral) to the medial superior olive where sounds have not binaurally converged below this level of the brainstem.[18,19] In contrast, tinnitus that is perceived as a fused binaural percept might originate somewhere proximal (central) to the medial superior olive. This example illustrates how precise definitions for tinnitus parameters of interest can inform understanding of its distribution and determinants in various populations.

EPIDEMIOLOGIC STUDIES: PREVALENCE OF AND RISK FACTORS FOR TINNITUS

This overview of findings from tinnitus epidemiologic studies is limited to a few population-based studies that the authors selected as representative of the field. Hoffman and Reed[8] conducted a survey of epidemiologic studies relating to tinnitus prior to the year 2000. Their review was thorough, and interested readers are advised to refer to their publication for more detailed analysis. Their main findings were as follows: (1) factors highly associated with the presence and severity of tinnitus include degree of hearing loss, exposure to high levels of both occupational and nonoccupational noise, and overall general health; (2) additional factors associated with tinnitus include cardiovascular and cerebrovascular disease, pharmaceutical medications, ear infections and inflammation, head or neck trauma including traumatic brain injury, hyperthyroidism and hypothyroidism, Meniere's disease, otosclerosis, sudden deafness, and vestibular schwannoma; (3) genetic factors may be associated with tinnitus; (4) once hearing loss is taken into account, age may have no association with tinnitus; (5) chronic tinnitus has a 10% to 15% prevalence in the adult population; and (6)

military veterans (vs nonveterans) are at significantly greater risk for developing chronic tinnitus.

Baguley and colleagues[20] searched for relevant tinnitus studies published between 1987 and 2012, with a focus on studies published within the previous 5 years. Consistent with Hoffman and Reed,[8] they found that a majority of studies reported 10% to 15% prevalence of tinnitus in adults. They found the main risk factor for tinnitus to be hearing loss but pointed out that people with hearing loss may not report tinnitus and that people with bothersome tinnitus may have hearing sensitivity within audiometrically normal limits. Another identified major risk factor was noise due to occupational or recreational exposure. Additional risk factors included various prescription and nonprescription drugs, otosclerosis, Meniere's disease, vestibular schwannoma, head injuries, smoking, alcohol consumption, arthritis, obesity, and hypertension. Baguley and colleagues[20] listed comorbidities, including depression, anxiety, temporomandibular joint disorder, and hyperacusis. Among studies that reported the localization of tinnitus, most found that for approximately half of tinnitus patients, tinnitus was perceived in the middle of the head or in both ears. For all others, tinnitus was perceived as predominantly left-sided. Some patients perceived their tinnitus to come from outside of the head. The authors found only 1 longitudinal study that reported incidence data.[21] In that study, which included a cohort between 48 years and 92 years of age, baseline prevalence was approximately 8%. Incidence of new tinnitus was approximately 6% and 13% for 5 years and 10 years in duration, respectively. Baguley and colleagues[20] highlighted the fact that epidemiologic studies use inconsistent definitions of tinnitus and different questions, resulting in heterogeneous data.

McCormack and colleagues[4] conducted a systematic review of all studies between 1980 and 2015 that reported the prevalence of tinnitus in adults; 39 studies, representing 16 countries, met their criteria for data extraction. Approximately 3 of every 5 studies were conducted in Europe, and approximately half of the studies had been conducted since 2010. Across all the studies, reported prevalence of tinnitus was 5% to 43%. Only 12 of these studies used a consistent definition of tinnitus, and their prevalence levels ranged between 12% and 30%. Otherwise, there were 8 different definitions used for tinnitus; approximately one-third (34%) of the studies defined tinnitus as "lasting for more than 5 minutes at a time." The investigators pointed out the widespread inconsistency in how tinnitus is defined and reported, which may account for the extreme variability among prevalence estimates. Furthermore, heterogeneity of the data prevented pooling data across studies to perform meta-analyses. The studies used different tinnitus diagnostic criteria, considered different age groups, and analyzed and reported their data differently. It, therefore, was not possible to estimate a global prevalence of tinnitus. The authors concluded that epidemiologic studies of tinnitus should utilize standardized questions for measuring, reporting, and defining tinnitus.

DATA FROM THE NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY

Table 1 shows 2009 to 2012 data from the population-based National Health and Nutrition Examination Survey (NHANES) study, which reviews commonly examined demographic associations as an up-to-date presentation of the state of US community dwelling adults (20 years and older) with tinnitus.[11] In this study, participants were asked, "In the past 12 months, have you been bothered by ringing, roaring, or buzzing in your ears or head that lasts for 5 minutes or more?" Those who responded affirmatively then were asked, "How long have you been bothered by this ringing,

Table 1
Characteristics of US adults ages 20 and older by tinnitus status, National Health and Nutrition Examination Survey, 2009-2012. Prevalence is shown as percentages and 95% confidence intervals. All results are weighted using NHANES 2009-2012 examination weights. Row percentages are shown.

Characteristic	Sample Size (n = 5550)	Tinnitus (%)	No Tinnitus (%)
Sex			
Male	2732	19 (16–22)	81 (78–84)
Female	2818	16 (14–18)	84 (82–86)
Missing	0	—	—
Age			
20–39 y	1876	9 (7–11)	91 (89–93)
40–59 y	1754	21 (17–24)	79 (76–83)
60–79 y	1525	25 (21–28)	75 (72–79)
80+ y	395	24 (19–30)	76 (70–82)
Missing	0	—	—
Race/ethnicity			
Non-Hispanic white	2184	20 (17–22)	80 (78–83)
Non-Hispanic black	1387	13 (11–15)	87 (85–89)
Mexican American	588	13 (10–16)	87 (84–90)
Other Hispanic	524	12 (9–15)	88 (85–91)
Other	867	13 (8–18)	87 (82–92)
Missing	0	—	—
Education			
<High school	1338	21 (16–26)	79 (74–84)
High school graduate	1164	20 (15–24)	80 (76–85)
>High school	3045	16 (14–17)	84 (83–86)
Missing	3	—	—
Income (federal poverty level)			
≤100%	1696	16 (14–18)	84 (82–86)
101%–200%	1324	23 (18–27)	77 (73–82)
>200%	2530	16 (15–18)	84 (82–85)
Missing	0	—	—
Marital status			
Married	2712	17 (15–19)	83 (81–85)
Widowed/divorced/separated	1273	26 (21–31)	74 (69–79)
Never married	1143	13 (10–15)	87 (85–90)
Living with partner	420	13 (8–18)	87 (82–92)
Missing	2	—	—
Veteran status			
Veteran	625	27 (20–33)	73 (8–10)
Nonveteran	4925	16 (15–18)	84 (82–85)
Missing	0	—	—

(*continued on next page*)

Table 1
(*continued*)

Characteristic	Sample Size (n = 5550)	Tinnitus (%)	No Tinnitus (%)
Occupational noise exposure			
Yes	1870	24 (20–28)	76 (72–80)
No	3678	14 (12–16)	86 (84–88)
Missing	2	—	—
Self-reported hearing ability			
Excellent/good	4216	11 (9–13)	89 (87–91)
Little trouble	825	35 (29–41)	65 (59–71)
Moderate trouble	315	45 (36–55)	55 (45–64)
Severe trouble/deaf	192	49 (43–59)	51 (43–59)
Missing	2	—	—
General health status			
Excellent/very good	1836	14 (12–16)	86 (84–88)
Good	1951	19 (16–22)	81 (78–84)
Fair	903	27 (21–32)	73 (68–79)
Poor	179	29 (22–36)	71 (64–78)
Missing	681	—	—
Smoking			
Never	3137	15 (13–17)	85 (83–87)
Former	1331	19 (16–23)	81 (77–84)
Current	1076	23 (18–28)	77 (72–82)
Missing	6	—	—
Hypertension			
Yes	2079	25 (21–28)	75 (72–79)
No	3464	14 (12–16)	86 (84–88)
Missing	7	—	—
Hyperlipidemia			
Yes	1861	23 (18–29)	77 (71–82)
No	3550	14 (12–17)	86 (83–88)
Missing	139	—	—
Diabetes			
Yes	700	26 (19–32)	74 (68–81)
No	4723	16 (15–18)	84 (82–85)
Borderline	123	23 (7–38)	77 (62–93)
Missing	4	—	—
Cardiovascular disease			
Yes	608	27 (21–34)	73 (66–79)
No	4942	17 (15–19)	83 (81–85)
Missing	0	—	—
Cancer history			
Yes	545	21 (15–27)	79 (73–85)

(*continued on next page*)

Table 1
(*continued*)

Characteristic	Sample Size (n = 5550)	Tinnitus (%)	No Tinnitus (%)
No	5000	17 (15–19)	83 (81–85)
Missing	5	—	—

Data are shown as percentages (95% CI). All results are weighted using NHANES 2009 to 2012 examination weights. Row percentages are shown. From Prevalence of Self-Reported Depression Symptoms and Perceived Anxiety among Community-Dwelling US Adults Reporting Tinnitus," by Reavis K., 2020, Perspectives of the ASHA Special Interest Groups.11 https://perspectives.pubs.asha.org/.

roaring, or buzzing in your ears or head?" Response options for tinnitus duration were less than 3 months, 3 months to 1 year, 1 year to 4 years, 5 years to 9 years, greater than or equal to 10 years, and unknown. For the NHANES data presented in this article, tinnitus was defined as lasting greater than or equal to 3 months, a notably shorter time frame than the greater than or equal to 6 months suggested by the AAO-HNSF guidelines.[1]

NHANES 2009 to 2012 data (see **Table 1**) suggest that 15% (95% CI, 13%–17%) of US adults were "bothered by" tinnitus lasting 3 months or longer. A majority of adults with tinnitus were white, widowed or divorced, less academically accomplished, and at or slightly above the federal poverty line. Compared with adults without tinnitus, those with tinnitus tended to be older. Of the health behaviors and comorbidities examined, adults with tinnitus were more likely to be former or current smokers, to self-report poorer hearing, and to report having cardiovascular disease, hypertension, hyperlipidemia, diabetes, and cancer. Additionally, those who were military veterans were more likely to report tinnitus (26%; 95% CI, 19%–32%) than those without a history of military service (14%; 95% CI, 12%–16%).[11]

TINNITUS DATA FROM THE NOISE OUTCOMES IN SERVICE MEMBERS EPIDEMIOLOGY STUDY

Since 2007, tinnitus has been the most prevalent service-connected disability for US military veterans (Veterans Benefits Administration annual reports, 2007–2018, https://www.benefits.va.gov/REPORTS/abr/). Similar to the NHANES 2009 to 2012 data discussed previously, an analysis of NHANES data from 1999 to 2006 showed that veterans have twice the prevalence of tinnitus as nonveterans.[22] These results are not surprising, given that military service often involves exposure to hazardous noise, chemicals, and head injury. As of fiscal year 2018, more than 1.9 million veterans had a service-connected disability claim approved (awarded) for tinnitus (**Fig. 1**). From 2017 to 2018, this number increased by 184,221 in just 1 year.

Department of Veterans Affairs (VA) audiologists routinely conduct compensation and pension examinations for veterans claiming to have tinnitus linked to military service. These claims often are made many years after separating from the military, raising the question whether the onset of tinnitus might be delayed by years after noise and chemical exposures. In response to veterans' concerns about tinnitus and hearing loss, Congress mandated that the Institute of Medicine (now known as the Heath and Medicine Division of the National Academy of Sciences) produce a report including recommendations for research "to fill the void for prospective, longitudinal,

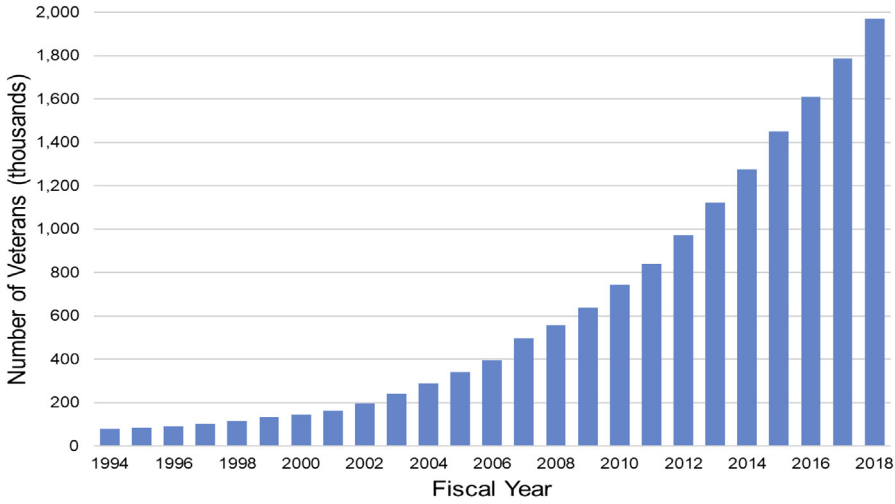

Fig. 1. Numbers of Veterans with a service-connected tinnitus disability in each of fiscal years, 1994 to 2018.

epidemiologic data on noise-induced hearing loss and tinnitus in military personnel."[23(p208)] Among the report's findings was the recommendation to

> *Establish cohorts of military veterans with various documented noise exposures, immediately upon discharge, and survey them periodically for ototoxic exposures, subsequent nonmilitary noise exposures, and hearing function, as well as presence and severity of tinnitus, in order to determine whether there is a delay in the effects of military noise exposure. These cohorts will need to be followed through the remainder of members' lifetimes, but this longitudinal study will reveal elements of the natural history of noise-induced hearing loss and tinnitus that otherwise will not be determined.*[23(p208)]

Heeding the Institute of Medicine recommendations, the authors' research group initiated a longitudinal epidemiologic study to address the etiology, prevalence, and effects of tinnitus and hearing loss among active-duty service members and veterans recently separated from military service (within approximately 2.5 years). The NOISE study, which began in early 2014, is building a longitudinal cohort that will enable long-term assessments of changes in tinnitus and hearing relative to military experiences and occupational and recreational exposures experienced since military separation. To date, more than 900 participants have enrolled as members of this study cohort. Data from the NOISE study that are specific to tinnitus are discussed later. The authors are careful in this study to use precise tinnitus, measurement, and reporting definitions that apply measurement best practices even when this sometimes has required the development of new instruments.

Method

Study sites

The NOISE study is being performed at 2 sites. The main study site is the National Center for Rehabilitative Auditory Research (NCRAR), which is part of the VA Portland Health Care System in Portland, Oregon. NOISE data also are collected at the Department of Defense Hearing Center of Excellence at Joint Base San Antonio–Lackland,

Texas. The study has been approved by the institutional review board at each site. Details of the full NOISE study's methodology have been published elsewhere[24]; the focus here is on procedures specifically relevant to tinnitus data collection.

Telephone screening

Study candidates are screened by telephone, answering questions designed to determine if tinnitus is present or absent. The authors developed an instrument, the Tinnitus Screener, to determine if any reported tinnitus is occasional (occurring less than weekly), intermittent (experienced at least weekly), or constant.[5] The Tinnitus Screener also allows ascertaining if a respondent has experienced only temporary tinnitus, for example, due to noise exposure or ototoxic medication. If tinnitus is instead constant or intermittent, 2 additional tinnitus questionnaires (Tinnitus History[25] and Tinnitus Functional Index [TFI][26]) are sent as part of a packet of questionnaires mailed to candidates prior to their in-laboratory baseline appointments.

Assessment questionnaires

The Tinnitus and Hearing Survey (THS) is completed by all participants, regardless of their tinnitus status. The THS contains 10 items, including 4 questions specific to tinnitus, 4 specific to hearing, and 2 specific to sound tolerance.[27] For nontinnitus participants, the 4 tinnitus items are ignored for reporting purposes. The tinnitus data, discussed later, were derived from the Tinnitus Screener, TFI, THS, and Tinnitus History. These data were obtained from NOISE study participants who were deemed to have intermittent or constant tinnitus according to the results of the initial Tinnitus Screener.

The accuracy of the initial phone screening is verified when participants present for audiologic testing. The research audiologist asks if they hear tinnitus. If they answer yes, then the audiologist works to determine the location of their tinnitus and whether it is "typical today." If a participant who screened negative for tinnitus over the phone is found to test positive for tinnitus during the in-person examination, that participant then completes the additional tinnitus questionnaires as part of the baseline appointment.

The 25-item TFI[26,28] has been tested extensively to support the classification of TFI scores (on a scale of 0–100) below a value of 25 as indicating relatively mild tinnitus, typically requiring little or no intervention. TFI scores from 25 to 50 suggest more significant problems with tinnitus, indicating possible or borderline need for professional attention. Scores above 50 indicate tinnitus that is severe enough to qualify for more aggressive clinical intervention, possibly involving referral to specialty tinnitus care.

The THS was designed primarily to distinguish tinnitus-specific from hearing-specific complaints.[27] The THS contains 3 sections: section A contains 4 items that assess self-reported functional effects of tinnitus that are not confounded by hearing difficulties; section B contains 4 items that query hearing difficulties that are not confounded by tinnitus problems; and section C contains 2 items that screen for a sound tolerance problem (hyperacusis, misophonia, or noise sensitivity).[29]

The Tinnitus History[25] establishes factors associated with tinnitus history (duration, onset rapidity, onset associations, changes since onset in intermittency, localization, and loudness), tinnitus attributes (present intermittency, localization, number and type of sounds heard, and loudness rating), and tinnitus impact/severity (relating to sleep disturbance, concentration difficulties, emotional reactions, and intrusiveness).

Data analysis

To ensure completeness of tinnitus-related data, all questionnaires were reviewed by a member of the study team during the participants' visits. If missing items were

Table 2
Demographics of Noise Outcomes in Servicemembers Epidemiology study participants (n = 690)

	Service Members With No Tinnitus (n = 176)	Service Members With Tinnitus (n = 111)	Veterans No Tinnitus (n = 151)	Veterans Tinnitus (n = 252)
Age (y), mean (SD), range	33.6 (8.6), 19–59	36.5 (8.8), 22–60	33.2 (8.2), 21–55	34.8 (9.6), 21–61
Gender: male (%)	56	85	82	89
Race/ethnicity: non-Hispanic, white (%)	62	65	79	80
Military branch, n (%)				
Army	48 (47)	54 (53)	53 (28)	138 (72)
Marines	3 (60)	2 (40)	27 (42)	38 (58)
Navy	8 (53)	7 (47)	40 (50)	40 (50)
Air Force	117 (71)	48 (29)	31 (46)	67 (54)
Tinnitus screener status, n (%)				
No tinnitus	152 (86)	0	126 (83)	0
Occasional/temporary tinnitus	24 (14)	0	25 (17)	0
Intermittent tinnitus	0	25 (22)	0	71 (28)
Constant tinnitus	0	86 (78)	0	181 (72)
Hearing loss (average >20 dB), n (%)				
Low frequency (0.25–2 kHz)	9 (5)	22 (20)	13 (9)	50 (20)
High frequency (3–8 kHz)	24 (14)	39 (35)	29 (19)	86 (34)
Extended high frequency (9–16 kHz)	45 (26)	62 (56)	49 (33)	115 (46)
Screened positive for depression), n (%)[a]	11 (6)	20 (18)	23 (15)	78 (31)
Screened positive for anxiety), n (%)[a]	35 (20)	51 (46)	59 (39)	143 (57)
Screened positive for sleepiness), n (%)[b]	67 (38)	58 (53)	58 (39)	153 (44)

[a] Hospital Anxiety and Depression Scale.
[b] Epworth Sleepiness Scale.

detected prior to data entry and verification, attempts were made to contact the participant by phone to complete and verify the data. To minimize data entry errors, all questionnaires were scanned twice into a study database using TeleForm (Hewlett Packard, Palo Alto, California). Any discrepancies noted between the 2 scans were resolved by the NOISE study data manager using an established protocol. The audiometric data were entered manually, with 1 audiologist reading the data from the source document and another entering the data and orally reporting the entry being made.

Tinnitus data were obtained from the first 690 NOISE study participants (287 service members and 403 veterans). Data analyses were conducted using SPSS, version 22, with the goal of describing characteristics of service members and veterans with and without tinnitus on factors related to demographics, tinnitus and hearing status, mental health screening, and tinnitus characteristics. Observations of similarities and differences between groups are discussed later.

Results

Table 2 shows baseline demographic data for 690 NOISE study participants, broken down for service members and veterans with and without tinnitus. The average age for these 4 cohorts was between 33.2 years and 36.5 years. In each category, most participants were men. Among service members, most were in the Air Force. Among veterans, most had served in the Army. More than one-third (39%) of service members and approximately two-thirds (63%) of veterans reported intermittent or constant tinnitus. The prevalence of tinnitus was highest for participants who serve/served in the Army. Among all participants, the percent of hearing loss (mean hearing thresholds >20-dB HL [hearing level]) across all 3 frequency ranges (low-frequency, 0.25–2 kHz; high-frequency, 3–8 kHz; and extended high-frequency, 9–16 kHz) was higher for those who reported tinnitus. Hearing loss was most prevalent in the extended high-frequency range (56% of service members and 46% of veterans with tinnitus). The prevalence of depression, anxiety, and sleepiness also was higher for those who reported tinnitus (depression: an additional 12% of service members and 16% of veterans; anxiety: an additional 26% of service members and 18% of veterans; and sleepiness: an additional 15% of service members and 5% of veterans).

Table 3 shows data from the Tinnitus History that describe characteristics of tinnitus for 360 NOISE study participants with constant or intermittent tinnitus. Most service members and veterans reported having experienced tinnitus for 3 years to 5 years. Tinnitus was reported most often as linked with noise exposure; however, most participants were uncertain what caused their tinnitus. Most service members and veterans reported their tinnitus location in “both ears.” When asked, “How much of a problem is your tinnitus?” 43% of service members and 56% of veterans rated their tinnitus as at least “a moderate problem.” Slightly more than half of service members (54%) and almost half of veterans described their tinnitus as “one sound.” Service members and veterans both reported that their tinnitus caused difficulties performing work or other activities (22% of service members and 29% of veterans).

Table 3 also shows results of the Tinnitus Functional Index (TFI) and Tinnitus and Hearing Survey (THS). The mean score for the TFI (range of possible scores: 0–100) was 30.5 for service members and 36.6 for veterans, whereas the mean score for the THS section A (tinnitus section; range of possible scores: 0–16) was 2.9 for service members and 3.6 for veterans.

Discussion of Noise Outcomes in Service Members Epidemiology Study Results

The authors have been reporting tinnitus data from the NOISE study since they evaluated the first 100 veteran participants, 67% of whom met the definition for chronic

tinnitus.[5] Since then, the authors have refined methods of identifying the presence of tinnitus by administering the Tinnitus Screener over the telephone as well as verifying results during in-laboratory testing by an audiologist. The "occasional" category was also added, to differentiate tinnitus that occurs irregularly (occasional = less than weekly) versus regularly (intermittent = at least weekly). Current results reveal a tinnitus prevalence estimate of 63% in the veteran cohort. Although this is reduced from the previous estimate of 67%, current data are consistent in showing that approximately two-thirds of the 403 veteran participants experienced chronic tinnitus. This high prevalence is remarkable considering that these veterans are young (average 34.8 years of age) and have been separated from the military for less than 3 years.

Among adults who experience tinnitus, only approximately 20% are bothered enough by it to seek clinical intervention.[1,8] Those who seek help report effects ranging from mild to severe.[3] The NOISE study participants (service members and veterans) with tinnitus responded to the question, "How much of a problem is tinnitus?" Service members' and veterans' responses to this question were similar with respect to tinnitus being "not a problem" (13% of service members and 12% of veterans) or a "big" or "very big problem" (combined: 9% of service members and 11% of veterans) (see **Table 3**). Where the service member and veteran cohorts were less comparable was in their descriptions of tinnitus as a "small problem" (44% of service members and 32% of veterans) or "moderate problem" (34% of service members and 45% of veterans). It is reasonable to assume that individuals with at least a "big problem" would be most likely to seek clinical services and that those with a "moderate problem" would be less likely to seek intervention (though some might). The findings to date comport generally with overall estimates that approximately 20% of adults with tinnitus are likely to seek clinical services.[1,8] It is further noted that the mean index score for the TFI was 30.5 (SD 20.7; range 0–90.8) for service members and 36.6 (SD 21.9; range 0–96.8) for veterans, indicating that for both cohorts, tinnitus is a relatively mild problem overall, with large variability appearing as a range of scores spanning almost the entire range of possible scores on the TFI (0–100).

DISCUSSION

This article includes a relatively cursory review of epidemiologic studies that have included data on tinnitus. Most of these studies addressed general health, including tinnitus as 1 of many specific health conditions. Definitions of tinnitus have varied widely between studies, although most studies attempt to distinguish acute versus chronic and nonbothersome versus bothersome tinnitus. Although it may seem straightforward to ask individuals whether or not they experience tinnitus, this was not always the case in the NOISE study. Participants occasionally were confused as to what actually constitutes tinnitus, and some were unreliable with their responses. It was evident that precise definitions were needed, and this is what motivated development of the Tinnitus Screener.[5] As described previously, the Tinnitus Screener categorizes tinnitus as temporary, occasional, intermittent, or constant. It also can categorize the absence of tinnitus (which indicates the person has experienced only transient ear noise, also known as spontaneous tinnitus).

Any epidemiologic study reporting tinnitus prevalence data must at least differentiate between subjects who do and do not have tinnitus. A common definition is needed to develop findings that can be compared between studies. Adhering to the suggestion that tinnitus must exceed 5 minutes in duration[30–32] rules out spontaneous tinnitus (transient ear noise). Tinnitus of 5 minutes duration that occurs irregularly (eg, every few weeks) does not constitute pathologic tinnitus.

Table 3
Tinnitus characteristics of Noise Outcomes in Servicemembers Epidemiology study participants with constant or intermittent tinnitus (n = 360)

Tinnitus Characteristic	Service Members (n = 110)	Veterans (n = 250)
Tinnitus duration (%)		
<1 y	11	4
1–2 y	23	18
3–5 y	26	41
6–10 y	22	21
11+ y	18	16
Tinnitus onset associations (%)[a]		
Accident	2	7
Illness	0	2
Loud noise	30	44
Other	10	7
Not sure	63	54
Tinnitus localization (%)[a]		
Left ear only	15	7
Right ear only	8	6
Both ears	66	78
In head, right	6	5
In head, left	4	3
Fills head	21	23
Other location	0	1
Number of tinnitus sounds (%)		
1 sound	54	49
2 sounds	17	17
3+ sounds	28	34
How much of a problem is tinnitus? (%)		
Not a problem	13	12
Small problem	44	32
Moderate problem	34	45
Big problem	8	7
Very big problem	1	4
Because of tinnitus, over the past 6 mo have you found that you (%)		
Had to take frequent rests when doing work or other activities?	3	11
Cut down the amount of time you spend on work or other activities?	7	15
Accomplished less than you would like?	12	20
Did not do work or other activities as carefully as usual?	11	17
Were limited in the kind of work you do or other activities?	8	15
Had difficulty performing work or other activities?	22	29
Needed special assistance?	6	11
TFI, mean (SD), range	30.5 (20.7), 0–90.8	36.6 (21.9), 0–96.8
THS section A—tinnitus, mean (SD), range	2.9 (2.9) 0–14	3.6 (3.3) 0–16

[a] Participants may report more than 1 response.

Dauman and Tyler[33] proposed that tinnitus of at least 5 minutes duration, however, must occur at least twice per week to be considered pathologic. For the NOISE study, the authors required that in order to place participants in the tinnitus group, their tinnitus of at least 5 minutes duration must be experienced at least weekly. For future epidemiologic studies, the authors recommend that "tinnitus lasting at least 5 minutes and occurring at least weekly" be used to define the presence of tinnitus. It also should be determined if the tinnitus has been experienced for 6 months or more, to distinguish between tinnitus that is persistent/chronic versus recent-onset/acute.[1]

Once it is established that a person experiences pathologic tinnitus, chronic or otherwise, the next task is to determine if the tinnitus is bothersome and, if so, to what degree. A global question that has been used for this purpose is, "How much of a problem is tinnitus?"[25,26] Response options are "not a problem," "small problem," "moderate problem," "big problem," and "very big problem." The authors' concern with this question is that individuals who experience both tinnitus and hearing loss might be bothered primarily by the hearing loss, attributing their problem instead to the presence of tinnitus. Blaming tinnitus for a hearing problem is a common mistake.[34] For this reason, epidemiologic studies examining the association between problematic tinnitus and any outcome of interest may be confounded by hearing loss. To address this concern, the authors recommend using the THS,[27] which is ideal for epidemiologic research because of its brevity, validation, and demonstrated value in separating self-perceived hearing problems from tinnitus problems.[5,35–37]

Despite the many epidemiologic studies that have reported data on tinnitus, much remains to be learned. The science of epidemiology can help elucidate causes of tinnitus and point to promising methods of prevention, treatment, and/or cures. Because many epidemiologic studies are observational in nature (ie, they do not involve controlled conditions), however, care in their design and conduct is of the utmost importance. Heterogeneity in the findings of epidemiologic studies reported to date underscores the importance and the need for consistent definitions and precise measures.

Despite the inconsistent use of definitions and questions in epidemiologic studies, some findings have been consistent. The prevalence of tinnitus in adult populations tends consistently to be in the 10% to 15% range. It appears that military experience increases the prevalence of tinnitus, as seen by the NHANES analyses and the NOISE study. It appears, therefore, that veteran status represents a collection of military risk factors, along with predictable risk factors, such as poorer health status, hearing loss, gender, posttraumatic stress disorder, and traumatic brain injury.[38] As discussed previously, Hoffman and Reed[8] concluded that, once hearing loss is accounted for, age is not a risk factor for tinnitus. Other studies consistently have identified age as a risk factor.[4,20,38,39]

Although a majority of people with chronic tinnitus are not significantly bothered by the phantom sound, many experience tinnitus-related functional limitations and seek help from health care providers. A study of veterans using VA health care found that, among all veterans who had used VA health care in the prior 5 years, 11% had been diagnosed with and received clinical services for tinnitus at least once and 3% at least twice.[40] Comorbid hearing loss, traumatic brain injury, and mental health and substance use outcomes were highly prevalent among these patients. A random sample of these veterans (those diagnosed at least once with tinnitus) found that the majority had TFI scores in the severe or very severe range of tinnitus severity. Therefore, health care providers (otolaryngologists) should be prepared with tools to help these patients, including collaborative relationships with other key clinicians, including audiologists and mental health providers.

Although there currently is no cure for tinnitus,[41] that is, no method demonstrated by evidence to consistently reduce or eliminate the perception of the phantom sound, it is a common misconception that nothing can be done for those who suffer from this condition. Evidence-based practices for reducing tinnitus-related distress do exist, so patients should never be told that "nothing can be done" or they should "learn to live with it." Cognitive behavioral therapy has the strongest research evidentiary support for management of tinnitus-related distress.[1,42] Because of the common comorbidity of mental health conditions, cognitive behavioral therapy is a logical choice for intervention especially for those with the most problematic tinnitus. Other methods may be equally effective despite not being vetted by systematic reviews. These methods include Tinnitus Retraining Therapy,[43] Progressive Tinnitus Management,[37] and Tinnitus Activities Treatment.[44] There also is considerable evidence that hearing aids and combination instruments (hearing aids with a built-in sound generator) are effective tools for tinnitus management.[45–47]

SUMMARY

The study of tinnitus is, in many ways, still in its infancy, with much to be gained through ongoing and future research. Prevalence data are needed to understand the distribution of tinnitus in various populations. Longitudinal studies are needed to address gaps in the understanding of how tinnitus prevalence changes over time and how tinnitus characteristics change within individuals and to establish the determinants of new-onset tinnitus. Cross-sectional studies can estimate prevalence to speculate about tinnitus determinants, but incidence studies are needed to confirm theories of etiology. Prevalence over time can be estimated by examining a series of cross-sectional studies. For instance, NHANES data over the years can be used to determine how prevalence is changing. Epidemiology research is essential to answer these key questions and inform best practices.

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