

Auditory test result characteristics of subjects with and without tinnitus

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Abstract—Tinnitus is the perception of sound that does not have an acoustic source in the environment. Ascertaining the presence of tinnitus in individuals who claim tinnitus for compensation purposes is very difficult and increasingly becoming a problem. This study examined the potential to observe differences in loudness and pitch matches between individuals who experience tinnitus versus those who do not. This study follows a previous pilot study we completed that included 12 subjects with and 12 subjects without tinnitus. The current study included 36 subjects with and 36 without tinnitus. Results of this study revealed no significant differences between groups with regard to decibel sensation level (SL) loudness matches and within-session loudness-match reliability. Between-group differences revealed that the tinnitus subjects had (1) greater decibel sound pressure level loudness matches, (2) better between-session loudness-match reliability, (3) better pitch-match reliability, and (4) higher frequency pitch matches. These findings support the data from our pilot study with the exception that decibel SL loudness matches were greater for the tinnitus subjects in the pilot study. Tinnitus loudness and pitch matching may have some value in an overall battery of tests for evaluating tinnitus claims.

Key words: compensation, hearing disorders, loudness matching, loudness perception, malingering, pitch matching, pitch perception, rehabilitation, reliability of results, tinnitus, tinnitus diagnosis.

INTRODUCTION

Chronic tinnitus is the persistent sensation of hearing a sound that exists only inside the head. It is the result of abnormal neural activity within the auditory system and has been referred to as a “phantom auditory sensation” [1]. Epidemiology studies reveal that between 10 and 15 percent of all adults experience chronic tinnitus [2–7].

The Veterans Health Administration (VHA) regards tinnitus as a disabling condition. U.S. military veterans with service-connected disabilities may receive a monetary benefit as compensation. The basis for awarding a tinnitus disability is that the tinnitus is (1) at least recurrent (intermittent) and (2) related to military service [8–9]. The number of tinnitus disability claims has increased dramatically during this decade (**Figure 1**). As of October

Abbreviations: ANOVA = analysis of variance, HL = hearing level, LM = loudness match, PM = pitch match, PVAMC = Portland VA Medical Center, SD = standard deviation, SL = sensation level, SPL = sound pressure level, TES = Tinnitus Evaluation System, VA = Department of Veterans Affairs, VHA = Veterans Health Administration.

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DOI:10.1682/JRRD.2008.11.0157

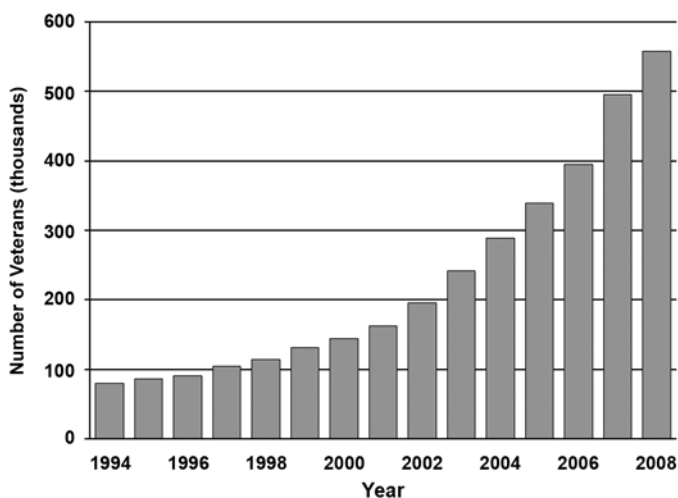


Figure 1.

Total numbers of veterans with service-connected tinnitus during fiscal years 1994–2008.

2008, 558,232 veterans had been awarded tinnitus service-connection disability.* Among veterans returning from the Iraq and Afghanistan wars, tinnitus is the most common service-connected disability (67,689 veterans in 2008). These concerns have prompted our overall effort to develop tests that can help ensure that a tinnitus disability is accurately rated and that allow for reexamination whenever a need exists to verify the continued existence of tinnitus. The current study is part of that overall effort.

Special audiological tests are effective in detecting deliberate exaggeration of hearing loss [10–11], but no documented test exists that is capable of detecting the presence or absence of tinnitus. Vernon developed the “two dB rule,” which involves matching the loudness of tinnitus to tones five or six times during a test session [12]. According to Vernon’s rule, the presence of tinnitus is indicated if the repeated results within a session agree to within 2 dB (provided the loudness matches [LMs] are obtained with 1 dB resolution). Jacobson et al., however, reported results from an experiment that showed test-retest reliability of LMs to be similar between individuals with and those without tinnitus [13]. The only difference

was that individuals without tinnitus generally provided LMs at higher levels.

Any type of audiometric test for tinnitus diagnosis may rely at least partly upon the demonstration of response reliability. That is, the validity of any response depends upon its reproducibility; thus, response reliability is expected to be an important component of any test developed to assess the presence of tinnitus for claims purposes. Because so many parameters of tinnitus are capable of being measured, any of those parameters could potentially be used for repeated testing to evaluate a tinnitus claim. The key is to determine which test, or combination of tests, will be most effective in accomplishing this purpose. Tinnitus loudness matching has been shown to be very reliable with tinnitus patients, but the Jacobson et al. study suggests that loudness matching alone may be of very limited value in distinguishing individuals with versus those without tinnitus [13].

Tinnitus loudness matching can be expanded to obtain LM functions, i.e., LMs at a series of audiometric frequencies. When tested in this manner, patients reveal characteristic patterns of responses [14]. Individuals with tinnitus, regardless of the perceived pitch of their tinnitus, have been shown to produce high agreement of tinnitus LMs across multiple presentations at 1/3-octave intervals between 1 and 16 kHz [15]. Thus, an entire LM function is generally reliable when tinnitus is present.

We completed a pilot study to investigate the potential for LM functions to detect differences between 12 subjects with tinnitus versus 12 subjects without tinnitus [16]. Testing was done using a computer-automated program that had recently been modified to allow more patient control of test stimuli (through the use of a handheld control pad device). Procedures that were performed in that study involved self-selected hearing thresholds and tinnitus LMs at frequencies between 1 and 16 kHz (in 1/3-octave intervals). Results of that study revealed that LMs for the tinnitus group were made at overall greater levels (in decibel sensation level [SL], i.e., the decibel level relative to the hearing threshold for a given acoustic signal) than for the nontinnitus group. Reliability of the LMs was at least as good for the nontinnitus group as for the tinnitus group, both within and across sessions. In addition, pitch matches (PMs) were obtained from each subject, which involved subject selection of the frequency that most closely matched the pitch of the tinnitus from the different test frequencies. These PMs were performed multiple times after loudness matching and the multiple PMs were

*Veterans Benefits Administration (VBA) Annual Benefits Report. Washington (DC): VBA; 2008. Available from: <http://www.vba.va.gov/REPORTS/abr/index.asp/>.

averaged. The result of pitch matching was that the mean PMs for the tinnitus group were significantly higher in frequency than for the nontinnitus group. The nontinnitus group revealed greater PM variability than did the tinnitus group.

The current study followed our pilot study to obtain data from a larger subject sample. Essentially the same protocol was used, except this study used a computer-automated testing system that was completely redesigned for improved functionality.

METHODS

Research Subjects

Study inclusion criteria were intended to identify two groups of individuals: those who experienced chronic tinnitus (tinnitus subjects) and those who did not experience tinnitus (nontinnitus subjects). Subjects were recruited by a local newspaper advertisement, by flyers posted around the Portland Department of Veterans Affairs (VA) Medical Center (PVAMC), and from other auditory investigations that were being conducted at the National Center for Rehabilitative Auditory Research.

Telephone screening was conducted by the research coordinator, who asked “How often do you have humming, ringing, buzzing, or other noises in your ears or head—never, rarely, sometimes, almost always, or always?” Callers who responded “never” or “rarely” were identified as not having tinnitus. Those who responded “almost always” or “always” were identified as having tinnitus. Those who responded “sometimes” were not considered study candidates because of the likelihood that their tinnitus perception was intermittent. No other screening criteria were applied because the intent was to simulate real-life individuals who might be attempting to claim the presence of tinnitus. Any screening criteria other than the presence or absence of tinnitus might have introduced bias to the samples.

Candidates who passed telephone screening were invited to make an appointment to determine whether they met the audiometric criteria for study entry. As part of the informed consent process at the start of the appointment, all candidates were told that the study was being conducted to determine the effectiveness of a new technique for measuring various aspects of tinnitus. Candidates with tinnitus were told that they had been invited to participate in the study because they had tinnitus that

was constant and therefore could be measured. Candidates who did not have tinnitus were told that they could represent individuals who might want to claim tinnitus when they do not actually experience it.

After signing informed consent, subjects had their hearing evaluated manually by an audiologist (conventional hearing threshold evaluation that obtained results in decibel hearing level [HL]). Subjects were excluded from further participation if they showed visible signs of outer or middle ear problems (impacted wax, effusion, perforated eardrum, etc.) or if audiometric testing revealed air-bone gaps of 15 dB at two or more frequencies in one ear or an air-bone gap greater than 15 dB at any one frequency between 0.5 and 4 kHz.

Following the conventional hearing threshold evaluation, subjects completed a baseline questionnaire that asked their age, sex, veteran status, and tinnitus status. Subjects with tinnitus completed a written tinnitus questionnaire in which they reported the length of time they had had tinnitus, whether their tinnitus was tonal or nontonal, and whether their tinnitus was binaural or unilateral.

To ensure that the tinnitus and nontinnitus groups exhibited approximately the same degree of hearing loss, we matched subjects by hearing loss with respect to both their low (0.5, 1, 2 kHz) and high (3, 4, 6 kHz) frequency average hearing thresholds (in decibel HL). Collection of data from human subjects was approved by the PVAMC institutional review board committee. Subjects received \$20 at the end of each test session.

Testing Equipment

Audiometric testing was conducted in a double-walled sound-attenuated suite (Acoustic Systems Model RE-245S, ETS Lindgren; Cedar Park, Texas). We used the latest version of our computer-automated testing system that has undergone several revisions over a period of 10 years [16–19]. The system enabled direct patient control of certain stimulus parameters during testing to make testing more efficient. The present fifth-generation system is referred to as the Tinnitus Evaluation System (TES).

For testing with the TES, the patient sits facing a laptop computer. All instructions for testing are displayed on the computer screen. For most of the tests, the computer presents a starting sound and the patient turns a dial on a peripheral hardware device (TES Module) to control output level, frequency, or bandwidth of the sound. Subjects depress buttons on the TES Module to make response

choices. All of the testing sequences are completely automated.

Hardware

For the present project, the system required ground-up development to transform it from a “liquid research platform” into a stable, clinically viable instrument. The TES has been entirely redesigned and reconstructed from its previous iteration [16]. The peripheral hardware device (TES Module) was developed to enable specialized auditory tests. The TES Module brings various capabilities together in one small device that connects to a personal computer. These capabilities include signal generation (pure tones and noise bands) and signal processing (mixing, switching, muting, attenuation, and headphone buffering). The pure tone quality, output linearity, frequency accuracy, pulse characteristics, and signal cross talk of the TES Module conform to the American National Standards Institute specification for audiometers across the standard frequency range from 125 to 8,000 Hz [20].

The TES Module also serves as a control device (user interface), enabling patients to easily control stimulus parameters and respond to tests. This was accomplished by constructing the TES Module enclosure to also serve as a handheld control pad for patients to control the auditory stimuli. The TES control pad includes a continuous rotating encoder dial that provides a single-point adjustment of a parameter of interest (programmable and determined according to the particular test or test phase). In addition, four push buttons are included on the TES control pad to facilitate patient responses.

Software

All-new programming was required to support the new platform and to create new testing capabilities. The system can be configured to test at any or all of the 19 available test frequencies at 1/3-octave steps between 250 and 16,000 Hz (with future capability to test in 1/6-octave steps). Many parameters of each test are individually configurable.

All testing data are stored via connectivity to a Microsoft Access database (Microsoft Corp; Redmond, Washington). Testing is done according to the test session templates, with parameters preconfigured with the “management interface” and read from the database with the “testing interface,” which controls the testing process and interacts with a patient. Patients are presented a series of dialog screens that guide them through the tests. Patient

responses made with the TES Module encoder dial and response buttons are recorded to the same database from which the test session parameters are read. The test session status/outcome is reported back to the management interface through the database.

The management interface is used to manage patient information, create and configure test session templates (preconfigured test scenarios), launch test sessions, and report on test results. It includes a dialog window for adding, searching, and modifying patient records. Information about test parameters is stored in an Access database, which also determines which tests to run for each session and provides parameters to control the hardware behavior. The management interface presents configuration options through the test session configuration dialogs, in which tests and their parameters can be preset into session templates to allow an operator to easily run many patients through the same battery of tests. Testing sessions can then be launched by selecting a patient record and preconfigured template. The operator can override the template tests’ default values of some parameters on a per-session basis. The user interface dialogs are heavily dynamic and use the parameter information from the database as much as possible in rendering test/template configuration options. The reporting module of the management interface uses preformatted reports for presenting test results from the response database.

Calibration

As a single integrated device with earphones (ER-4B, Etymotic Research, Inc; Elk Grove Village, Illinois) permanently attached, the TES Module is calibrated independently in the laboratory and then sent out to a testing site. Calibration data are stored in the TES Module’s nonvolatile memory. When connected to a computer for testing, the device is thus precalibrated. A testing interface program checks the device’s calibration time stamp and compares it with the one already stored in the database. If newer calibration data are available, they are downloaded from the TES Module, saved in the database, and used in testing to provide calibrated stimulus levels. Old calibrations are permanently stored in the database for traceability. A special test template was devised to enable the device to be calibration-checked on-site at regular intervals. A sound level meter (Brüel & Kjær Type 2231; Norcross, Georgia) and ear simulator (Brüel & Kjær Type 4157) are presently used for calibration and calibration checking. All calibration procedures are

conducted in a double-walled sound-attenuated suite (Acoustic Systems Model RE-245S).

Subject Testing

Instructions to Nontinnitus Subjects

Prior to conducting the tinnitus matching tests, we carefully instructed the nontinnitus subjects to ensure that they responded to all testing as if they were attempting to prove that they did in fact experience chronic tinnitus. They were instructed to “Imagine a sound in your head or ears and try to match that sound consistently to the sounds that you will hear through earphones. Your job is to try to convince the examiner that you have tinnitus by providing consistent responses to all of the tests.” Note that subjects were not instructed to use any particular method to provide consistent responses. Subjects determined on their own how they would respond in a consistent manner in spite of their nonexistent tinnitus.

Tinnitus Ear and Stimulus Ear

Tinnitus matching requires patients to make a clear distinction between the tinnitus perception and the matching tones. This is done most easily if the stimulus in one ear is compared to the tinnitus in the contralateral ear [21–22]. Tinnitus subjects were queried as to the location of their more predominant tinnitus. If one side of the head was more predominant, then the ear on that side was designated the “tinnitus ear.” The “stimulus ear” was always contralateral to the tinnitus ear, and subjects were instructed to match the tone in the stimulus ear with the tinnitus in the tinnitus ear. If the tinnitus was perceived to be symmetrical, then the stimulus ear was determined randomly.

For the nontinnitus subjects, if one ear had better hearing sensitivity, then that ear was selected as the stimulus ear. If hearing sensitivity was symmetrical, then the stimulus ear was selected randomly. The nontinnitus subjects received the same instructions for performing tinnitus matching. They were queried to ensure that they understood that they would be matching tones in one ear to an imagined tinnitus in the contralateral ear.

On-Screen Instructions

Throughout testing, instruction screens appeared as necessary to guide the subjects. Before testing began, the program presented a series of screens describing the gen-

eral testing procedures, followed by specific instructions for hearing threshold testing.

Hearing Thresholds and Tinnitus Loudness Matches with TES

Hearing thresholds and tinnitus LMs were obtained with the TES. All subjects were capable of providing valid hearing thresholds. For tinnitus loudness matching, the tinnitus subjects’ task was to match the loudness of the tones to the loudness of their tinnitus while the nontinnitus subjects’ task was to match the loudness of the tones to the imagined loudness of imagined tinnitus.

The hearing thresholds differed from the conventional hearing thresholds that were obtained with a clinical audiometer in the following ways: (1) the purpose of obtaining thresholds with the TES was to enable the calculation of tinnitus LMs in decibel SL (i.e., decibel level above threshold), whereas the purpose of obtaining conventional hearing thresholds was to determine auditory hearing sensitivity in decibel HL (i.e., decibel level that corresponds to population norms); (2) testing with the TES involved subject control via the TES Module (explained previously), while conventional hearing thresholds were obtained by the research audiologist controlling all stimuli with a conventional audiometer and observing the subject’s responses; and (3) TES thresholds were obtained between 1 and 16 kHz at test frequencies separated by 1/3 octave, while conventional thresholds were obtained at standard audiometric frequencies (0.25–8 kHz in 1 kHz intervals plus interoctave frequencies of 3 and 6 kHz).

Following the general instructions, we provided specific instructions for obtaining hearing thresholds (in decibel sound pressure level [SPL]) with the TES. (Note: all thresholds and LMs obtained by the TES were recorded in decibel SPL, i.e., decibel referenced to an SPL of 0.0002 μ bar. The TES uses decibel SPL because normative hearing threshold levels have not been established for frequencies above 8 kHz and because the earphones used with the TES have not been documented for conventional audiometric testing of hearing sensitivity.) Testing started when a hearing threshold was obtained at 1 kHz. Subjects were instructed to rotate the encoder dial to the point that the test tone could “just barely be heard.” When subjects indicated that the instructions were understood, the computer presented the tone at an output level selected at random from within a designated range. Subjects rotated the encoder dial to find the point of minimum

audibility for the tone and then selected the threshold level by pressing the response button. A second response was obtained in the same manner. The two responses were averaged to specify the hearing threshold at that frequency.

After a threshold was obtained at 1 kHz, we then obtained an LM (in decibel SPL) at the same frequency. Patients often confuse the concepts of pitch and loudness. It is critical for them to clearly understand the difference between these two psychological attributes of sound for us to obtain well-informed, and therefore accurate, matching measurements [21,23]. To ensure that the subjects understood pitch and loudness, we included a series of instruction screens that explained the concepts prior to performing tinnitus loudness matching. Instructions were then shown that explained the procedure for obtaining an LM. Following the instructions, we presented the tone at a randomized output level above the level of the hearing threshold that had just been established. The subject rotated the encoder dial to select the level of the tone that matched the "loudness of the tinnitus." The tone was again presented at a randomized output level, and the subject provided a second LM. The two LMs were averaged to specify the LM at that frequency.

This sequence of testing (average hearing threshold followed by average LM) was then repeated at the next higher test frequency (1,260 Hz) followed by the remainder of the test frequencies in ascending order. Hearing thresholds and tinnitus LMs at all 13 test frequencies were obtained (1–16 kHz in 1/3-octave steps) in this manner.

Tinnitus Pitch Matching with TES

When hearing thresholds and tinnitus LMs had been obtained at all 13 test frequencies, on-screen instructions were shown to explain the PM task. Both tinnitus and nontinnitus subjects performed pitch matching. For pitch matching, the tinnitus subjects' task was to match the pitch of the tones to the pitch of their tinnitus, while the nontinnitus subjects' task was to match the pitch of the tones to the imagined pitch of imagined tinnitus.

Subjects were instructed to rotate the encoder dial to sweep through the test frequencies. Each test frequency was presented at the output level previously selected as a tinnitus LM during the threshold and LM testing. (Note: if the subject did not provide an LM at a test frequency, then that test frequency was not included in pitch matching.) For pitch matching, subjects rotated the encoder dial

to identify the tone that provided the "closest match" to the pitch of their tinnitus. They then pressed a response button to indicate that a PM had been obtained.

Subjects were then presented with the PM tone and instructed to indicate if the tone was a "good match" with the tinnitus. Response options were "yes" or "no." Following the response, another PM was obtained, and the subject was again presented with the PM tone and asked to indicate if it was a "good match." This sequence of testing was repeated five times, and the computer calculated the average of the five PMs.

Test Runs/Sessions

The previously described testing was conducted during two sessions that were at least 3 days apart. Two test runs (thresholds, loudness matching, and pitch matching) were conducted within each session.

Statistical Analysis

Each subject was tested twice at each of two sessions for a total of four tests. A repeated measures analysis of variance (ANOVA) was used to assess the difference in LMs (dB SPL and dB SL) between the tinnitus and nontinnitus subjects across the four tests.

Within- and between-session correlations were computed for the dB SPL LMs and compared between the tinnitus and nontinnitus subjects. This analysis was motivated by the expectation that the correlations between the two tests within a session and the correlations between sessions would be greater for the tinnitus subjects than for the nontinnitus subjects and would represent more consistent responses for the tinnitus subjects.

Within-subject PM variability (five observations for each of the two tests within the two test sessions) was pooled within and across subjects and compared between the tinnitus and nontinnitus subjects on the premise that subjects with tinnitus would exhibit less variability in pitch matching.

RESULTS

Description of Subjects

A total of 83 subjects were recruited into the study. Of these, 72 subjects were matched for hearing loss. Of the 36 subjects with tinnitus, 32 had binaural tinnitus, 2 had predominantly left-ear tinnitus, and 2 had predominantly right-ear tinnitus; 26 reported "tonal" tinnitus.

Tinnitus and nontinnitus subjects were similar in age, sex, veteran status, and mean hearing thresholds (**Table 1**).

Tinnitus Loudness Matches

Tables 2 and **3** show the LM means (and standard errors) in decibel SPL and decibel SL, respectively, for the sessions and runs in the tinnitus and nontinnitus subjects for 1 to 16 kHz. With one exception (10,080 Hz), mean SPL LMs were consistently greater for nontinnitus than for tinnitus subjects. These differences were significant at frequencies of 2 kHz and below and diminished in the higher frequencies. SL LMs were essentially equal between the tinnitus and nontinnitus subjects across the frequencies.

Loudness Match Correlations

Table 4 shows the within-session LM correlations (between two test runs on the same day) for the tinnitus and nontinnitus subjects for 1,000 to 12,700 Hz. For session 1, the tinnitus subjects had correlations that ranged from 0.79 to 0.99, with all except one frequency (1,000 Hz) greater than 0.90 (considered to be an excellent correlation). The nontinnitus group had a similar distribution of correlations, except that half the frequencies had correlations that were below 0.90. Examination of correlations by frequencies for session 1 indicated that in 5 of the 12 frequencies, the tinnitus subjects showed significantly greater correlations ($p < 0.05$) than the nontinnitus subjects.

Table 1.

Demographic and audiometric characteristics of tinnitus subjects ($n = 36$) and nontinnitus subjects ($n = 36$). Data presented as mean \pm standard deviation unless otherwise noted.

Group	Age (yr)	Age Range (yr)	M/F (n)	Veterans/ Nonveterans (n)	Right PTA 0.5, 1, 2 kHz (dB HL)	Left PTA 0.5, 1, 2 kHz (dB HL)	Right PTA 3, 4, 6 kHz (dB HL)	Left PTA 3, 4, 6 kHz (dB HL)
Tinnitus	62.2 \pm 8.7	45–81	32/4	28/8	24.3 \pm 14.9	23.1 \pm 12.1	48.4 \pm 19.9	47.3 \pm 20.1
Nontinnitus	63.6 \pm 9.5	46–84	28/8	26/10	23.8 \pm 12.7	24.6 \pm 12.6	43.0 \pm 21.4	44.6 \pm 21.8

F = female, HL = hearing level, M = male, PTA = pure tone average.

Table 2.

Across-subject mean loudness matches (dB sound pressure level) for tinnitus subjects ($n = 36$) and nontinnitus subjects ($n = 36$).

Frequency (Hz)	Tinnitus			Nontinnitus			<i>p</i> -Value [‡]
	Total <i>n</i>	Mean [*]	SE [†]	Total <i>n</i>	Mean [*]	SE [†]	
1,000	140	42.8	2.4	144	51.1	2.4	0.02
1,260	136	44.7	2.7	144	53.5	2.6	0.02
1,580	132	47.6	2.6	132	51.2	2.6	0.011
2,000	136	47.4	2.6	128	60.2	2.7	0.008
2,520	136	59.3	2.9	116	65.4	3.1	0.15
3,180	132	62.4	3.0	116	67.9	3.2	0.22
4,000	132	66.6	3.1	116	70.8	3.3	0.35
5,040	132	67.9	3.0	112	72.7	3.3	0.29
6,340	132	68.8	3.2	104	73.8	3.6	0.31
8,000	112	70.8	3.4	76	73.3	4.2	0.65
10,080	96	80.6	3.6	72	79.0	4.2	0.78
12,700	52	87.3	2.8	48	89.8	2.9	0.55
16,000	16	88.7	2.7	12	93.0	3.2	0.38

^{*}Least square means of four loudness match presentations from repeated measures analysis of variance across subjects in both tinnitus and nontinnitus groups.

[†]Standard errors (SEs) estimated from between-subjects (tinnitus vs nontinnitus) error mean square.

[‡]*p*-value for comparisons of tinnitus versus nontinnitus subject means in repeated measures analyses of variance. Total *n* for higher frequencies differs because of missing data.

Table 3.Across-subject mean loudness matches (decibel sensation level) for tinnitus subjects ($n = 36$) and nontinnitus subjects ($n = 36$).

Frequency (Hz)	Tinnitus			Nontinnitus			<i>p</i> -Value [‡]
	Total <i>n</i>	Mean*	SE [†]	Total <i>n</i>	Mean*	SE [†]	
1,000	140	11.0	1.8	144	10.2	1.7	0.77
1,260	136	10.9	1.8	144	10.1	1.7	0.74
1,580	132	10.6	1.9	132	10.6	1.9	0.98
2,000	136	10.2	1.8	128	10.0	1.8	0.94
2,520	136	9.6	1.6	116	9.3	1.8	0.89
3,180	132	9.1	1.5	116	8.7	1.6	0.86
4,000	132	8.4	1.4	116	8.2	1.5	0.90
5,040	132	7.8	1.3	112	8.4	1.4	0.76
6,340	132	7.8	1.1	104	7.8	1.3	0.99
8,000	112	7.3	1.3	76	9.1	1.5	0.39
10,080	96	6.5	1.0	72	7.3	1.2	0.63
12,700	52	9.2	1.8	48	7.7	1.9	0.57
16,000	16	6.2	3.8	12	8.4	4.4	0.72

*Least square means of four loudness match presentations from repeated measures analysis of variance across subjects in both tinnitus and nontinnitus groups.

†Standard errors (SEs) estimated from between-subjects (tinnitus vs nontinnitus) error mean square.

‡*p*-Value for comparisons of tinnitus versus nontinnitus subject means in repeated measures analyses of variance. Total *n* for higher frequencies differs because of missing data.**Table 4.**Within-session loudness-match correlations (decibel sound pressure level) for tinnitus subjects ($n = 36$) and nontinnitus subjects ($n = 36$).

Frequency (Hz)	Session 1			Session 2		
	Tinnitus	Nontinnitus	Tinnitus vs Nontinnitus	Tinnitus	Nontinnitus	Tinnitus vs Nontinnitus
1,000	0.79	0.74	—	0.89	0.73	—
1,260	0.90	0.86	—	0.87	0.87	—
1,580	0.91	0.92	—	0.83	0.92	—
2,000	0.94	0.92	—	0.97	0.92	—
2,520	0.97	0.93	—	0.98	0.98	—
3,180	0.97	0.90	—	0.99	0.95	—
4,000	0.97	0.94	—	0.97	0.98	—
5,040	0.99	0.88	—	0.98	0.97	—
6,340	0.99	0.88	—	0.99	0.93	—
8,000	0.97	0.95	—	0.98	0.95	—
10,080	0.98	0.89	—	0.98	0.98	—
12,700	0.96	0.60	—	0.87	0.82	—
Mean ± SD	0.94 ± 0.06	0.87 ± 0.10	—	0.94 ± 0.06	0.92 ± 0.08	—
Difference	—	—	0.07	—	—	0.02
<i>p</i> -Value*	—	—	0.004	—	—	0.22

*Kruskal-Wallis nonparametric rank test.

SD = standard deviation.

In session 2, the tinnitus subjects showed significantly greater correlations in 4 of the 12 frequencies.

Table 5 shows the between-session LM correlations for tinnitus and nontinnitus subjects for 1,000 Hz to 10,080 Hz (the sample size for 12,700 and 16,000 Hz were too small to provide meaningful data) based on the

mean LMs for the two test runs within each session. Time between sessions ranged from 3 to 64 days. The majority (72%) of the subjects was tested no more than 15 days apart; 23 percent were tested 15 to 28 days apart; and the remaining subjects (5%) were tested 43 to 64 days apart. Correlations for the nontinnitus subjects (range 0.57–0.83)

Table 5.

Between-session loudness-match correlations (dB sound pressure level) for tinnitus subjects ($n = 36$) and nontinnitus subjects ($n = 36$).

Frequency (Hz)	Tinnitus	Nontinnitus	Tinnitus vs Nontinnitus
1,000	0.81	0.57	—
1,260	0.87	0.67	—
1,585	0.90	0.69	—
2,000	0.91	0.71	—
2,520	0.92	0.72	—
3,175	0.92	0.82	—
4,000	0.93	0.81	—
5,040	0.91	0.82	—
6,350	0.95	0.77	—
8,000	0.89	0.83	—
10,080	0.95	0.78	—
Mean \pm SD	0.91 \pm 0.04	0.75 \pm 0.08	—
Difference	—	—	0.16
<i>p</i> -Value*	—	—	<0.001

*Kruskal-Wallis nonparametric rank test.

SD = standard deviation.

were consistently lower than for the tinnitus subjects (range 0.81–0.95). Tinnitus subjects showed significantly greater between-session correlations than the nontinnitus subjects for 8 of the 11 frequencies, indicating better between-session consistency in identifying LMs.

Tinnitus Pitch Matches

Five PMs were presented to each of the 36 tinnitus and 36 nontinnitus subjects for each of the four test rounds. A sample (selected at random) of these data for nontinnitus subjects is presented in **Table 6**. Variability across the five PMs was examined by pooling the variability of the five PMs across the 36 subjects in each of the tinnitus and nontinnitus groups (**Table 7**). Standard deviations (SDs) for the tinnitus subjects ranged from 1,643 to 2,501 and for the nontinnitus subjects from 2,237 to 2,549; variability for the nontinnitus subjects was consistently greater than for tinnitus subjects. The

p-values for the *F*-ratios comparing nontinnitus variability to tinnitus variability ranged from <0.001 to 0.58. When pooled across the four test rounds (which were not independent for each subject), the SDs for the tinnitus and nontinnitus subjects averaged 1,954 and 2,425, respectively ($p = 0.007$). Thus, the variability of the PMs for the nontinnitus subjects was significantly greater than for the tinnitus subjects.

Table 8 compares the mean PMs (mean over 20 presentations) for the tinnitus versus nontinnitus subjects. Subjects with tinnitus consistently chose pitches that were higher in frequency than those chosen by the subjects without tinnitus (p -values <0.001–0.03). The variability across patients was similar in the tinnitus and nontinnitus groups. A repeated measures ANOVA showed that the overall mean for the tinnitus subjects was not significantly greater than the overall mean for the nontinnitus subjects ($p = 0.11$), but the time \times tinnitus group interaction was highly significant ($p = 0.001$); i.e., the PM means increased significantly more rapidly over time for the tinnitus subjects than for the nontinnitus subjects (**Figure 2**).

DISCUSSION

The primary purpose of this study was to compare a group of individuals with tinnitus to a group without tinnitus with regard to tinnitus LMs and PMs obtained using a computerized testing protocol. All subjects completed the exact same testing and were asked to attempt to provide repeatable tinnitus matches to the best of their ability.

This study's findings suggest that tinnitus loudness and pitch matching will not be sufficient to develop a defined test for detecting the presence or absence of tinnitus with a high degree of confidence. Results from a number of tinnitus psychoacoustic tests, including loudness and pitch matching, should be evaluated in the aggregate to optimize the accuracy of diagnosing the presence of

Table 6.

Example of pitch-match data for nontinnitus subject.

Test Round	Pitch Matches					Mean \pm SD
Session 1, Run 1	10,080	8,000	10,080	10,080	10,080	9,964 \pm 930
Session 1, Run 2	8,000	10,080	10,080	10,080	10,080	9,964 \pm 930
Session 2, Run 1	8,000	10,080	8,000	10,080	8,000	8,832 \pm 1139
Session 2, Run 2	10,080	10,080	10,080	10,080	10,080	10,080 \pm 0

SD = standard deviation.

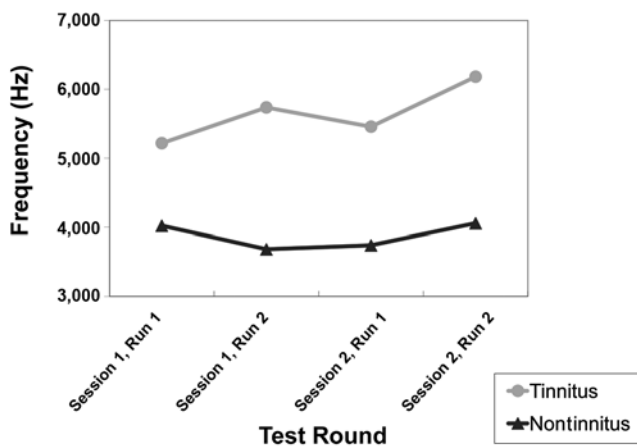
Table 7.Comparison of within-subject pitch-match variability between tinnitus subjects ($n = 36$) and nontinnitus subjects ($n = 36$).

Test Round	Tinnitus		Nontinnitus		F-Ratio	p-Value
	Variance	SD	Variance	SD		
Session 1, Fixed Run 1	2,697,983	1,643	6,496,486	2,549	2.408	<0.001
Session 1, Fixed Run 2	6,252,538	2,501	6,477,832	2,545	1.036	0.58
Session 2, Fixed Run 1	2,779,301	1,667	5,002,236	2,237	1.800	<0.001
Session 2, Fixed Run 2	3,546,219	1,883	5,537,334	2,353	1.561	0.004
Pooled Across Test Rounds	3,819,010	1,954	5,878,472	2,425	1.516	0.007

SD = standard deviation.

Table 8.Comparison of mean (\pm standard deviation) pitch frequencies between tinnitus subjects ($n = 36$) and nontinnitus subjects ($n = 36$).

Test Round	Tinnitus	Nontinnitus	p-Value
Session 1, Fixed Run 1	5,217 \pm 2,222	4,020 \pm 2,232	0.03
Session 1, Fixed Run 2	5,735 \pm 2,148	3,684 \pm 2,364	<0.001
Session 2, Fixed Run 1	5,457 \pm 2,703	3,741 \pm 2,509	0.007
Session 2, Fixed Run 2	6,182 \pm 2,689	4,056 \pm 2,974	0.002

**Figure 2.**

Pitch-match means by trial for tinnitus and nontinnitus subjects.

tinnitus. Test results should be considered along with factors that would be relevant in supporting a tinnitus claim, including patient credibility, plausible and consistent history, early documentation, unsolicited complaint, and hearing loss that is not exaggerated [24]. Our laboratory is currently funded to develop a fully documented test

that can help to ensure that a tinnitus disability is accurately rated and that will allow for reexaminations whenever a need exists to verify the continued existence of tinnitus. The test will include a series of tinnitus psychoacoustic tests along with a special questionnaire that has been developed and is being evaluated for its ability to differentiate between people who have chronic tinnitus and those who do not.

Some comments need to be made concerning the “severity” of tinnitus. Evaluating a patient for the presence of chronic tinnitus (i.e., providing a diagnosis that the patient experiences tinnitus) is one thing, but determining the degree to which the tinnitus affects the patient’s life is quite another. Tinnitus questionnaires have been developed for this latter purpose, and a number of them have been validated for clinical use [25]. However, tinnitus questionnaires have shortcomings, even when the patient answers each question as honestly as possible. Many domains of human functionality can be affected by tinnitus, and different questionnaires weigh these domains differently [26]. In addition, patients often confuse the effects of tinnitus with the effects of hearing loss [27]. That is, if they experience both (which they often do), then they often blame the hearing difficulties on the tinnitus. Thus, any responses on a tinnitus questionnaire may be confounded by this misconception. Finally, we should note that tinnitus “loudness” as measured by loudness matching has been shown to have little if any correlation with tinnitus severity [28]. Because of these issues, when evaluating a claim for tinnitus, clinicians must separately evaluate (1) the perception of tinnitus, i.e., its existence as an auditory percept and the different parameters that can be used to describe it, and (2) the severity of tinnitus, which pertains to any functional impairments caused by the tinnitus.

As described previously, subjects were identified on the basis of whether or not they experienced chronic tinnitus,

resulting in tinnitus and nontinnitus groups. No other screening criteria were applied to ensure that subjects were selected at random with respect to all other potential confounding factors. It is conceivable, but not likely, that some of the subjects were in the process of submitting an actual claim for tinnitus—either to the VA or to some other entity. If a subject was involved in pending tinnitus litigation, it should not have had any effect on their performance in this study. We made it clear to all subjects that this was a research study and that all testing was for experimental purposes. The data obtained could not be used to bolster a tinnitus claim. We should note that none of the subjects in this study requested a copy of their tinnitus test results.

This study provided data to assist in developing testing techniques that could be used to evaluate tinnitus claims for disability awards. The basis for testing was obtaining tinnitus LMs at a series of test frequencies. Pitch matching was included in the testing protocols to determine whether any differences in PMs existed between the tinnitus and nontinnitus subjects. All testing was done using a new iteration of our computerized TES. The rights to produce and market the TES have been purchased by a company that plans on making the TES commercially available in the near future. It would be necessary to use the TES to reproduce the testing that is described in this study. Once the testing procedures have been fully developed and documented, developing a testing version that does not rely on use of the TES, i.e., one that could be done with standard audiometric equipment, will be important.

For the purpose of assessing the presence or absence of tinnitus, completing all testing within a single session would be optimal. However, providing repeatable responses during two testing sessions separated by a day or more may present more of a challenge to an individual who is claiming tinnitus. Therefore, determining the reliability of the measures both within and between sessions is important.

This study primarily included subjects who had binaural hearing loss, although a smaller subgroup of individuals with normal hearing sensitivity was also tested. Matching subjects with respect to hearing loss was important because of the potential confounding effects of loudness recruitment (abnormally rapid growth of loudness that is caused by sensorineural hearing loss) on the size of the tinnitus LMs. Since the 1970s, researchers

have attributed the small size of tinnitus LMs to loudness recruitment [29].

The findings of this study can be summarized as follows: (1) decibel SPL LMs were greater for nontinnitus subjects than for tinnitus subjects, (2) LMs converted to decibel SL showed no differences between groups, (3) within-session LM reliability was essentially the same between tinnitus and nontinnitus subjects, (4) between-session LM reliability was significantly better for the tinnitus subjects than the nontinnitus subjects, (5) the nontinnitus subjects showed consistently greater PM variability than the tinnitus subjects, and (6) subjects with tinnitus consistently chose pitches that were higher in frequency than those chosen by the nontinnitus subjects. These findings support the data from our pilot study with one exception: the decibel SL LMs were greater for the tinnitus subjects than for the nontinnitus subjects in the pilot study, while subjects in the present study showed no differences in decibel SL LMs [16].

Testing for each subject with the TES first involved the evaluation of hearing thresholds. Although the purpose of obtaining hearing thresholds with the TES is not to assess hearing sensitivity, it has been of interest to compare hearing thresholds obtained with the TES with those obtained with a standard audiometer. These results have been published for previous iterations of the TES and showed close correspondence between measures obtained using the two techniques [30–31]. A similar evaluation has been done for the present version of the TES, which revealed comparable results (unpublished data). These results are not included in the present article because of length considerations.

There is increasing recognition that tinnitus is a problem deserving of financial compensation [24,32]. In most workers' compensation cases that involve tinnitus, the standard of proof is that the tinnitus is "more likely than not" a result of events or exposures in the workplace. Currently, no objective standards exist for assessing injury and damages resulting from tinnitus [33]. Because of the large number of subjects in the present study, these data lend credibility to the idea that tinnitus psychoacoustic testing can be useful in evaluating tinnitus claims.

Like pain, tinnitus is a personal experience that can be indirectly observed only through a patient's behavior and verbal descriptions [24]. No objective test for subjective tinnitus has been discovered in spite of dozens of attempts to do so. Ultimately, the examiner must determine whether the patient's report of tinnitus is true "to a

reasonable medical certainty” based on the report’s plausibility, credibility, and consistency. The best evidence supporting a claim often comes from the results of audiological testing. While tests for detecting exaggerated hearing loss are well developed [10], we are aware of only two studies that have evaluated the differences between individuals with and those without tinnitus [16,34]. Thus, little evidence exists from research studies that support tests to confirm the presence of tinnitus. Testing procedures generally are recommended based on clinical data and experience [12,28,32,35–36].

In Jacobson and Henderson’s study, individuals without tinnitus provided LMs at a higher level than actual tinnitus patients, but the reliability of the LMs was not significantly different [34]. Our pilot study also showed that the reliability of tinnitus LMs was unaffected by whether or not a person had tinnitus [16]. Our present efforts have expanded on these studies, and it is becoming apparent that results from a number of tinnitus psychoacoustic tests should be evaluated in the aggregate to optimize the accuracy of determining whether or not a patient has tinnitus as claimed. These combined psychoacoustic results should then be considered along with other factors that would be relevant in supporting a tinnitus claim. These factors, summarized by Dobie, include plausible and consistent history, patient credibility, early documentation, unsolicited complaint, and hearing loss that is not exaggerated [24].

The development of testing procedures to evaluate tinnitus claims is of special importance to the VHA. Veterans with service-connected disabilities receive a monetary benefit as compensation. The amount of disability compensation corresponds to the degree of disability on a scale of 0 to 100 percent (in 10% increments), with payment amount proportionate to the degree of disability. The number of veterans applying for a service-connected tinnitus disability, as well as the associated costs to the VHA, has been increasing at an accelerated rate. Tinnitus was the most common disability among veterans who began receiving disability compensation in 2008.* The number of veterans service-connected for tinnitus and their annual compensation amount have doubled in the last 4 years, indicating the breadth and potential eco-

nomical consequences of the problem. Clearly, the need exists to develop psychoacoustic tests that would reliably predict the accuracy of tinnitus claims.

CONCLUSIONS

Currently, no objective method exists to validate the claimed presence of tinnitus. It is essential to have a test that can authenticate legitimate claims of tinnitus for medical, insurance, and litigation purposes. The current study represents a critical step in our efforts to develop clinical methodology that can be used by the medical community for this purpose. At this time, we cannot advocate a specific test protocol for evaluating the claimed presence of tinnitus. As described by Dobie, any protocol for assessing a tinnitus claim should evaluate the patient’s credibility, the plausibility and consistency of the reported tinnitus history, and documentation that would support the claim [24]. The tinnitus complaint should be unsolicited, and any hearing loss should not be exaggerated. The validity of such an evaluation depends largely on the clinician’s skill in interpreting the patient’s responses. Clinicians who conduct such examinations would ideally have considerable experience providing clinical services for tinnitus assessment and management. Psychoacoustic testing of tinnitus parameters adds another important component to the evaluation, and clinicians should perform the basic tests and use the data in the overall context of making an informed decision as to the validity of the claim.

In addition, the TES represents an innovative and useful technological advancement that has potential for contributing toward standardized methodology for the clinical assessment of psychoacoustic parameters of tinnitus.

ACKNOWLEDGMENTS

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*Veterans Benefits Administration (VBA) Annual Benefits Report. Washington (DC): VBA; 2008. Available from: <http://www.vba.va.gov/REPORTS/abr/index.asp/>.

Obtained funding: J. A. Henry.

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Administrative support: K. Owens.

Technical support: E. Porsov, G. Silaski.

Financial Disclosures: VA and Oregon Health & Science University own a technology used in this research. Sonitus Medical, Inc, has licensed the technology and may have an interest in the results of this study. Ms. Owens, Mr. Silaski, Mr. Porsov, VA, and Oregon Health & Science University have rights to royalties from the licensing agreement with Sonitus Medical, Inc.

Funding/Support: This material was based on work supported by the VHA and VA Rehabilitation Research and Development Service (grant C2300R).

Additional Contributions: Special thanks to Stephen Fausti, PhD; Sara Ruth Oliver, AuD; and Martin Schechter, PhD, for their significant contributions to our tinnitus research.

Participant Follow-Up: The authors do not plan to inform participants of the publication of this study.

REFERENCES

- Jastreboff PJ. Phantom auditory perception (tinnitus): Mechanisms of generation and perception. *Neurosci Res.* 1990;8(4):221–54. [PMID: 2175858] DOI:10.1016/0168-0102(90)90031-9
- Brown SC. Older Americans and tinnitus: A demographic study and chartbook. GRI Monograph Series A;2. Washington (DC): Gallaudet Research Institute, Gallaudet University; 1990.
- Hinchcliffe R. Prevalence of the commoner ear, nose, and throat conditions in the adult rural population of Great Britain. A study by direct examination of two random samples. *Br J Prev Soc Med.* 1961;15:128–40. [PMID: 13907508]
- Leske MC. Prevalence estimates of communicative disorders in the U.S.: Language, hearing and vestibular disorders. *ASHA.* 1981;23(3):229–37. [PMID: 6972221]
- Office of Population Census and Surveys (OPCS). General household survey: The prevalence of tinnitus 1981. OPCS Monitor, Reference GHS83/1. London (UK): Office for National Statistics; 1983.
- Davis AC. Hearing in adults. London (UK): Whurr Publishers; 1994.
- Sindhusake D, Mitchell P, Newall P, Golding M, Rochtchina E, Rubin G. Prevalence and characteristics of tinnitus in older adults: The Blue Mountains Hearing Study. *Int J Audiol.* 2003;42(5):289–94. [PMID: 12916702]
- Henry JA, Schechter MA, Loovis CL, Zaugg TL, Kaelin C, Montero M. Clinical management of tinnitus using a “progressive intervention” approach. *J Rehabil Res Dev.* 2005; 42(4 Suppl 2):95–116. [PMID: 16470467] DOI:10.1682/JRRD.2005.01.0005
- Henry JA, Schechter MA, Regelein RT, Dennis KC. Veterans and tinnitus. In: Snow JB, editor. *Tinnitus: Theory and management.* Lewiston (NY): BC Decker; 2004. p. 337–55.
- Martin FN. Pseudohypacusis. In: Katz J, Gabbay WL, editors. *Handbook of clinical audiology.* Baltimore (MD): Williams & Wilkins; 1994. p. 553–67.
- Martin FN, Champlin CA, McCreery TM. Strategies used in feigning hearing loss. *J Am Acad Audiol.* 2001;12(2): 59–63. [PMID: 11261459]
- Vernon JA. Is the claimed tinnitus real and is the claimed cause correct? In: Reich GE, Vernon JA, editors. *Proceedings of the Fifth International Tinnitus Seminar; 1995 Jul 12–15; Portland, OR.* Portland (OR): American Tinnitus Association; 1996. p. 395–96.
- Jacobson GP, Henderson JA, McCaslin DL. A re-evaluation of tinnitus reliability testing. *J Am Acad Audiol.* 2000; 11(3):156–61. [PMID: 10755811]
- Meikle MB, Henry JA, Mitchell CM. Methods for matching the loudness of tinnitus using external tones. In: Reich GE, Vernon JA, editors. *Proceedings of the Fifth International Tinnitus Seminar; 1995 Jul 12–15; Portland, OR.* Portland (OR): American Tinnitus Association; 1996. p. 178–79.
- Henry JA, Flick CL, Gilbert A, Ellingson RM, Fausti SA. Reliability of tinnitus loudness matches under procedural variation. *J Am Acad Audiol.* 1999;10(9):502–20. [PMID: 10522624]
- Henry JA, Rheinsburg B, Owens KK, Ellingson RM. New instrumentation for automated tinnitus psychoacoustic assessment. *Acta Otolaryngol Suppl.* 2006;(556):34–38. [PMID: 17114140] DOI:10.1080/03655230600895291
- Henry JA, Fausti SA, Mitchell CR, Flick CL, Helt WJ. An automated technique for tinnitus evaluation. In: Reich GE, Vernon JA, editors. *Proceedings of the Fifth International Tinnitus Seminar; 1995 Jul 12–15; Portland, OR.* Portland (OR): American Tinnitus Association; 1996. p. 325–26.
- Henry JA, Fausti SA, Flick CL, Helt WJ, Ellingson RM. Computer-automated clinical technique for tinnitus quantification. *Am J Audiol.* 2000;9(1):36–49. [PMID: 10943023] DOI:10.1044/1059-0889(2000/002)
- Henry JA, Flick CL, Gilbert AM, Ellingson RM, Silaski GC, Fausti SA. Fully-automated system for tinnitus loudness and pitch matching. In: Hazell J, editor. *Proceedings of the Sixth International Tinnitus Seminar; 1999 Sep 5–9; Cambridge, UK.* London (UK): The Tinnitus and Hyperacusis Centre; 1999. p. 520–21.
- American National Standards Institute (ANSI). *American national standard: Specification for audiometers.* Washington (DC): ANSI; 1996. ANSI S3.6-1996.
- Vernon J, Fenwick J. Identification of tinnitus: A plea for standardization. *J Laryngol Otol.* 1984;45(Suppl 9):45–53.

22. Vernon JA, Meikle MB. Tinnitus masking: Unresolved problems. In: Evered D, Lawrenson G, editors. CIBA Foundation Symposium 85: Tinnitus; 1981 Jan 13–15; London, UK. London (UK): Pitman Books; 1981. p. 239–56.
 23. Henry JA, Flick CL, Gilbert A, Ellingson RM, Fausti SA. Comparison of two computer-automated procedures for tinnitus pitch matching. *J Rehabil Res Dev.* 2001;38(5): 557–66. [[PMID: 11732833](#)]
 24. Dobie RA. Medico-legal aspects of tinnitus. In: Patuzzi R, editor. Proceedings of the Seventh International Tinnitus Seminar; 2002 Mar 5–9; Perth, Australia. Perth (Australia): Discipline of Physiology, School of Biomedical and Chemical Sciences, University of Western Australia; 2003. p. 25–28.
 25. Newman CW, Sandridge SA. Tinnitus questionnaires. In: Snow JB, editor. Tinnitus: Theory and management. Lewiston (NY): BC Decker; 2004. p. 237–54.
 26. Henry JA, Dennis KC, Schechter MA. General review of tinnitus: Prevalence, mechanisms, effects, and management. *J Speech Lang Hear Res.* 2005;48(5):1204–35. [[PMID: 16411806](#)] [[DOI:10.1044/1092-4388\(2005/084\)](#)]
 27. Zaugg TL, Schechter MA, Fausti SA, Henry JA. Difficulties caused by patients' misconceptions that hearing problems are due to tinnitus. In: Patuzzi R, editor. Proceedings of the Seventh International Tinnitus Seminar; 2002 Mar 5–9; Perth, Australia. Perth (Australia): Discipline of Physiology, School of Biomedical and Chemical Sciences, University of Western Australia; 2003. p. 226–28.
 28. Meikle M, Taylor-Walsh E. Characteristics of tinnitus and related observations in over 1800 tinnitus patients. Proceedings of the Second International Tinnitus Seminar; 1983 Jun 10–11; New York, NY. Ashford (UK): Headley Brothers; 1984. p. 17–21.
 29. Vernon JA. The loudness (?) of tinnitus. *Hear Speech Action.* 1976;44:17–19.
 30. Henry JA, Flick CL, Gilbert A, Ellingson RM, Fausti SA. Reliability of computer-automated hearing thresholds in cochlear-impaired listeners using ER-4B Canal Phone earphones. *J Rehabil Res Dev.* 2003;40(3):253–64. [[PMID: 14582529](#)]
 31. Henry JA, Flick CL, Gilbert A, Ellingson RM, Fausti SA. Reliability of hearing thresholds: Computer-automated testing with ER-4B Canal Phone earphones. *J Rehabil Res Dev.* 2001;38(5):567–81. [[PMID: 11732834](#)]
 32. Tyler RS. Considerations when evaluating a tinnitus patient for compensation. *Austral New Zeal J Audiol.* 2002;24(2): 85–91. [[DOI:10.1375/audi.24.2.85.31106](#)]
 33. Dobie RA. Medical-legal evaluation of hearing loss. 2nd ed. San Diego (CA): Singular; 2001.
 34. Jacobson GP, Henderson JA. Toward the development of a subjective measure of the presence of tinnitus: Preliminary observations. In: Popelka GR, editor. Association for Research in Otolaryngology Abstracts. Mt. Royal (NJ): Association for Research in Otolaryngology; 1999. p. 172.
 35. Coles RRA. Medicolegal issues. In: Tyler RS, editor. Tinnitus handbook. San Diego (CA): Singular; 2000. p. 399–417.
 36. Hinchcliffe R, King PF. Medicolegal aspects of tinnitus. III. Assessment of claimants with tinnitus. *J Audiol Med.* 1992;1:127–47.
- Submitted for publication November 25, 2008. Accepted in revised form March 16, 2009.