Guidelines for Manual Pure-Tone Threshold Audiometry

Working Group on Manual Pure-Tone Threshold Audiometry

These guidelines were developed by the Working Group on Manual Pure-Tone Threshold Audiometry, under the office of the Vice President for Professional Practices in Audiology of the American Speech-Language-Hearing Association (ASHA) and were approved by the ASHA Legislative Council in November 2005. Members of the Working Group were John Campbell, Jeffrey Graley, Deanna Meinke, Linda Vaughan (ex officio), Roberta Aungst (monitoring vice president), and Ted Madison (chair). This set of guidelines is the fourth of a series. The first was the Guidelines for Audiometric Symbols (1990a), adopted by ASHA in December 1973. The second was the Guidelines for Identification Audiometry (1975), adopted by ASHA in November 1974. The third was the Manual Pure-Tone Threshold Audiometry Guidelines (1976), adopted by ASHA in November 1977. ASHA encourages the professional community to use these guidelines.

These guidelines present a recommended set of procedures based on existing practice and research findings. Their intention is not to mandate a single way of accomplishing a clinical process, but to suggest standard procedures that in the final analysis should benefit the persons we serve. The purpose is to improve interclinician and interclinic comparison of data, thereby allowing for a more effective transfer of information.

The American Speech-Hearing-Language Association (ASHA) Guidelines for Manual Pure-Tone Threshold Audiometry contain procedures for accomplishing hearing threshold measurement with pure tones that are applicable in a wide variety of settings. Diagnostic standard pure-tone threshold audiometry, used most often in clinical settings, includes manual air-conduction measurements at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz (125 Hz under some circumstances) plus bone-conduction measurements at octave intervals from 250 Hz to 4000 Hz and at 3000 Hz as needed. Also, when required, appropriate masking is used. For special purposes, extended high-frequency audiometry may be used for frequencies of 9000 to 16000 Hz. Pure-tone threshold audiometry is used for both diagnostic and monitoring purposes.

Scope

Pure-tone threshold audiometry is the measurement of an individual’s hearing sensitivity for calibrated pure tones. Three general methods are used: (a) manual audiometry, also referred to as conventional audiometry; (b) automatic audiometry, also known as Békésy audiometry; and (c) computerized audiometry. The guidelines presented in this document are limited to manual pure-tone audiometry. Sound field audiometry using loudspeakers is not addressed in this document. Detailed information on auditory measurements in the sound field can be found in Sound Field Measurement Tutorial 11-371 (ASHA, 1990b).

The historical antecedents of pure-tone audiometry were the classical tuning fork tests. The development of the audiometer made it possible to control signal intensity and duration in ways that were not
possible with tuning forks. One cannot assume, however, that calibrated equipment ensures that valid measurements are always obtained. Differences among measurement methods may affect validity and reliability in significant ways, as pointed out by a number of authors (Carhart & Jerger, 1959; Harris, 1979; Hirsh, 1952; Hughson & Westlake, 1944; Newby, 1972; Price, 1971; Reger, 1950; Tyler & Wood, 1980; Watson & Tolan, 1949).

Because pure-tone audiometric results have significant influence on the medical, legal, educational, occupational, social, and psychological outcomes, it is critical that procedures be standardized and consistent among test providers. These guidelines present a standard set of procedures intended to minimize intertest differences. These guidelines represent a consensus of recommendations found in standards, such as Methods for Manual Pure-Tone Threshold Audiometry (ANSI S3.21-2004; American National Standards Institute, 2004a), and in the literature, with particular emphasis on the suggestions of Carhart and Jerger (1959) and Reger (1950). ASHA does not intend to imply that only one method is correct. Variations in procedure may be demanded by special clinical problems or regulatory demands. For example, special populations—such as very young children, those who are uncooperative, and persons with severe developmental delays, severe hearing impairment, or neurological disorders—may require modifications of the guideline procedures if the audiologist is to develop sufficient information for case management. Additionally, occupational, forensic, and financial compensation determinations, (e.g., disability, worker’s compensation), may also require modifications to standard procedures to obtain true and accurate results. When variations in procedure are necessary, they should be noted in a manner that allows other testers to understand how thresholds were obtained and to replicate the findings if necessary. The pure-tone guidelines are presented in five sections: (a) equipment and test environment, (b) determination of manual thresholds, (c) standard procedures for air-conduction measures, (d) standard procedures for bone-conduction measures, and (e) record keeping.

**Equipment and Test Environment**

It is essential that audiometric equipment be calibrated, be functioning properly, and be used in an acceptable test environment to assure accurate test results.

*Audiometer and calibration.* Air- and bone-conduction audiometry shall be accomplished with an audiometer and transducers that meet the applicable specifications of ANSI S3.6-2004 (American National Standards Institute, 2004b) and are appropriate to the test technique being used. Exhaustive electroacoustic calibrations should be performed annually using instrumentation traceable to the National Institute of Standards and Technology (previously known as the National Bureau of Standards prior to 1988). Functional inspection, performance checks, and bio-acoustic measurements should be conducted daily to verify the equipment performance before use.

**Transducers.** The various transducers used for pure-tone audiometry, earphones (supra-aural, circumaural, and insert), and bone vibrators shall be appropriate to the test technique used. Transducers are matched to the audiometer and should not be interchanged without recalibration. Supra-aural and insert earphones are appropriate for air-conduction threshold measurements from 125 Hz through 8000 Hz, while circumaural earphones are used for extended high-frequency measurements within their respected frequency and intensity response ranges. Bone vibrators are used for bone-conducted threshold measurements for frequencies within their respected frequency response range and must meet the specification of Mechanical Coupler for Measurement of Bone Vibrators (ANSI S3.13-1987; American National Standards Institute, 2002). The use of specific transducers may be dictated by a particular regulatory standard, such as the use of insert earphones for audiometric monitoring under the Occupational Safety and Health Administration (OSHA) hearing conservation amendment (1983). The applicable regulation should be consulted before testing to assure compliance. The audiologist should control placement of the transducers on the listener.

**Test environment.** The test environment shall meet at all times the specifications detailed in Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms (ANSI S3.1-1999; American National Standards Institute, 2003). Confirmation of an acceptable test environment shall be documented at least annually. The use of passive noise-reducing earphone enclosures is discouraged owing to calibration and threshold measurement issues (Billings, 1978; Cozad & Goetzinger, 1970; Frank, Greer, & Magistro, 1997; Roeser & Glorig, 1975).

The use of sound-isolated rooms or booths is viewed as a standard practice. In the interest of comfort, the test room and audiologist work area should provide for proper control of temperature, air exchange, and humidity. In the interest of safety, sound-isolated areas must be provided with either or both visual and auditory warning systems. These warning systems should be connected to the building warning system (fire, civil defense). It is also advisable to
equip the sound-isolated areas with an emergency telephone or a panic button to signal for emergency assistance. To avoid disruption of the test, mobile phones, pagers, radios and other communication devices should be silenced or turned off during the audiometric evaluation.

**Infection control.** Adherence to universal precautions and appropriate infection control procedures should be in place. Instrumentation coming into physical contact with the patient must be cleaned and disinfected after each use. The use of disposable acoustically transparent earphone covers or disposable insert earphone tips is recommended. Hand washing should be routine for the audiologist between patients.

### Determination of Manual Thresholds

Before conducting threshold testing, a complete case history should be obtained and otoscopy completed. The audiologist should be able to monitor the listener’s alertness and physical condition at all times.

**Ear examination.** Visual inspection of the pinna and ear canal, including otoscopy, should precede audiometric testing to rule out active pathological conditions and the potential for ear canal collapse caused by audiometric earphones. The ear canal should be free of excessive cerumen before testing. Testing should begin with the better ear when identifiable, otherwise it is arbitrary. Hearing aids should be removed after the audiologist has instructed the participant on how to respond during the test.

**Participant seating.** The participant should be seated in a manner to promote safety and comfort as well as valid testing. Such seating considerations may include the following:

- Avoid giving inadvertent visual cues to the participant.
- Enable easy observation of participant responses to stimuli.
- Allow for the monitoring and reinforcement of responses.
- Permit observation of participant comfort, safety, and health.

Some of the factors that influence the manual assessment of pure-tone thresholds are (a) the instructions to the participant, (b) the response task, and (c) the audiologist’s interpretation of the participant’s response behavior during the test.

**Instructions.** The test instructions should be presented in a language or manner appropriate for the participant. Interpreters (oral or manual) should be used when necessary. Supplemental instructions may be provided to enhance understanding, such as written directives, gestures, and demonstrations. Test instructions shall accomplish the following:

- Indicate the purpose of the test, that is, to find the faintest tone that can be heard.
- Emphasize that it is necessary to sit quietly, without talking, during the test.
- Indicate that the participant is to respond whenever the tone is heard, no matter how faint it may be.
- Describe the need to respond overtly as soon as the tone comes on and to respond overtly immediately when the tone goes off.
- Indicate that each ear is to be tested separately with tones of different pitches.
- Describe inappropriate behaviors such as drinking, eating, smoking, chewing, or any additional behavior that may interfere with the test.
- Provide an opportunity for any questions the listener may have.

**Response task.** Overt responses are required from the participant to indicate when he or she hears the tone going on and off. Any response task meeting this criterion is acceptable. Examples of commonly used responses are (a) raising and lowering the finger, hand, or arm, (b) pressing and releasing a signal switch, and (c) verbalizing “yes”.

**Interpretation of response behavior.** The primary parameters used by the audiologist in determining threshold are the presence of “on” and “off” responses, latency of responses, and number of false responses:

- Each suprathreshold presentation should elicit two responses: an “on” response at the start of the test tone and an “off” response at the end of the tone. Participants who are unable to correctly signal the termination of the tone, after proper instruction and reinstruction, may be demonstrating auditory problems and may need more detailed testing.
- The latency of the “on” responses varies usually with the level of presentation. If the first response to a tone in an ascending series is slow, present a 5-dB-higher tone until the response is without hesitation.
- False responses may be of two types: (a) false positive, a response when no tone is present, or (b) false negative, no response to a tone that the audiologist believes to be audible to the participant. Either type complicates the measurement procedure. Reinstruction may
reduce the occurrence rate of either type. The rate of false responses may also be reduced by such techniques as varying the time between audible tones, pulsing or warbling of the signal, or using pulse-counting procedures.

Threshold Measurement Procedure

The basic procedure for threshold determination consists of (a) familiarization with the test signal and (b) threshold measurement. The procedure is the same regardless of frequency, output transducer, or ear under test. Audiologists are encouraged to establish standard procedures and best practices appropriate to their clinical population to ensure consistency of approach to each participant and minimize the risk of omissions.

**Familiarization.** The purpose of familiarization is to assure the audiologist that the participant understands and can perform the response task. Familiarization is a recommended practice for general populations and should be used whenever warranted by the mental or physical status of the patient. The participant should be familiarized with the task before threshold determination by presenting a signal of sufficient intensity to evoke a clear response. The following two methods of familiarization are commonly used:

1. **Beginning with a 1000-Hz tone, continuously on but completely attenuated, gradually increase the sound-pressure level of the tone until a response occurs.**
2. **Present a 1000-Hz tone at a 30 dB hearing level (HL). If a clear response occurs, begin threshold measurement. If no response occurs, present the tone at 50 dB HL and at successive additional increments of 10 dB until a response is obtained.**

The decision as to which method to use, or whether to familiarize the participant at all, may be influenced by the purpose of the test and the clinical history. For example, familiarization is not typically done in compensation or forensic cases. Likewise, when the clinical history indicates a profound hearing loss, the audiologist may begin the familiarization process at a much higher presentation level or at a lower, more audible frequency.

**Threshold determination.** The method described, an ascending technique beginning with an inaudible signal, is recommended as a standard procedure for manual pure-tone threshold audiometry.

1. **Tone duration.** Pure-tone stimuli of 1 to 2 seconds’ duration.
2. **Interval between tones.** The interval between successive tone presentations shall be varied but not shorter than the test tone.
3. **Level of first presentation.** The level of the first presentation of the test tone shall be well below the expected threshold.
4. **Levels of succeeding presentations.** The level of each succeeding presentation is determined by the preceding response. After each failure to respond to a signal, the level is increased in 5-dB steps until the first response occurs. After the response, the intensity is decreased 10 dB, and another ascending series is begun. (An exception is as explained previously under Interpretation of response behavior—Latency.)
5. **Threshold of hearing.** Threshold is defined as the lowest decibel hearing level at which responses occur in at least one half of a series of ascending trials. The minimum number of responses needed to determine the threshold of hearing is two responses out of three presentations at a single level (American National Standards Institute, 2004a).

**Variability of threshold measures.** The audiologist should establish limits on acceptable test–retest variability for a given participant. A general discussion of this subject may be found in Annex B of Methods for Manual Pure-Tone Threshold Audiometry (ANSI S3.21-2004; American National Standards Institute, 2004a).

**Standard Procedures for Air-Conduction Measures**

Supra-aural or circumaural earphones shall be held in place by a headband with the earphone grid directly over the entrance to the ear canal.

**Earphone placement.** The audiologist should instruct participants to remove hats, headbands, eyeglasses, earrings, or anything that may interfere with proper positioning of the earphone cushions on the ears. After visual inspection of the outer ear (see previous Ear examination section), the audiologist should place the earphones on the participant and adjust them to fit her or his head properly. Insert earphones shall be placed comfortably deep in the ear canal and in accordance with manufacturer recommendations.

**Stimuli.** Continuous or pulsed pure-tone signals should be used. Pulsed tones have been shown to increase a test participant’s awareness of the stimuli (Burk & Wiley, 2004).

**Frequency.** The frequencies tested differ, depending on the technique used. In a departure from pre-
vious guidelines, routine testing of air-conduction thresholds at 3000 Hz and 6000 Hz is recommended. Inclusion of these two additional frequencies in audiometric evaluations may provide the audiologist with a more complete profile of the participant’s hearing status for prevention and diagnostic purposes (Fausti et al., 1999; Holmes, Niskar, Kieszak, Rubin, & Brody, 2004; Humes, Joellenbeck, & Durch, 2005). Additionally, audiometric threshold data obtained at 3000 Hz and 6000 Hz are often essential in cases where the audiometric test results are used for determination of compensation and/or the identification of work-related (occupational) hearing loss.

1. Monitoring technique. Threshold assessment should be made at 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz when monitoring as part of hearing loss prevention programs. When monitoring for other purposes (e.g., ototoxicity, medical management), thresholds may be measured at other test frequencies as appropriate.

2. Diagnostic technique. Threshold assessment should be made at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz, except when a low-frequency hearing loss exists, in which case the hearing threshold at 125 Hz should also be measured. When a difference of 20 dB or more exists between the threshold values at any two adjacent octave frequencies from 500 to 2000 Hz, interoctave measurements should be made.

Order. When appropriate information is available, the better ear should be tested first. The initial test frequency should be 1000 Hz. Following the initial test frequency, the audiologist should test, in order, 2000, 3000, 4000, 6000, and 8000 Hz, followed by a retest of 1000 Hz before testing 500, 250, and 125 Hz. A retest at 1000 Hz is not necessary when testing the second ear. Although the order of frequencies is not likely to significantly influence test results, presentation of frequencies in the order described may help ensure consistency of approach to each test participant and minimize the risk of omissions (American National Standards Institute, 2004b).

Masking for diagnostic audiometry. Appropriate masking should be applied to the nontest ear when the air-conduction threshold obtained in the test ear exceeds the interaural attenuation to the nontest ear. Because the procedures for masking are not confined to pure-tone measures, these procedures are not discussed in this set of guidelines.

Special Considerations
1. Frequencies other than 1000 Hz may be used as the initial frequency depending on the circumstances, such as mental or physical status of the participant, and the availability of previous hearing tests.
   The audiologist may choose to test 500 Hz immediately after the initial 1000-Hz threshold measurement if there is a question of reliability or discrepancy with other measures such as speech audiometry thresholds or to minimize retesting time if a discrepancy for the 1000-Hz retest is evident.

2. If the retest threshold at 1000 Hz differs by more than 5 dB from the first test, the lower of the two thresholds may be accepted, and at least one other test frequency should be retested.

Standard Procedures for Bone-Conduction Measures

Standard bone-conduction vibrator placement should allow mastoid or forehead placement with proper force applied (American National Standards Institute, 2004b; Dirks, 1964). The test ear should never be covered for standard bone-conduction measurements. The contralateral ear will be covered when masking is being used. The audiologist shall place the transducer(s), not the participant. It may be necessary to clip the transducer wire to the participant to avoid unintentional movement.

It may be necessary to include the following instructions during bone-conduction testing:
- Advise the participant to sit quietly and avoid movement that will dislodge the bone vibrator from the proper position.
- Request that the participant notify the audiologist when the bone vibrator slips or moves in any way from the original placement.

Frequency. Thresholds should be obtained at octave intervals from 250 to 4000 Hz and at 3000 Hz. Testing at frequencies below 500 Hz demands excellent sound isolation for cases with normal or near normal sensitivity but may be accomplished when such an environment is available. Higher frequencies may be tested if the transducer has sufficient frequency-response characteristics.

Order. The initial frequency tested should be 1000 Hz. After the initial test frequency, the audiologist should test, in order, 2000, 3000, 4000, 6000, and 4000 Hz followed by a retest of 1000 Hz before testing 500 and 250 Hz.

Masking. If the unmasked bone-conduction threshold is 10 dB better than the air-conduction threshold at that frequency in either ear, masking must be used. Because the threshold values on which the calibration of bone vibrators is based were mea-
sured with masking noise in the contralateral ear, the audiologist may prefer always to use masking in the testing procedure.

**Responses.** Vibrotactile responses to bone-conducted signals are possible, especially at low frequencies (Boothroyd & Cawkwell, 1970). Suspected vibrotactile responses should be noted on the audiogram form.

**Record Keeping**

**Recording of results.** Results may be recorded in graphic or tabular form or both. Separate forms to represent each ear may be used. Results must be legible and should be of sufficient quality to allow copying and electronic storage and communication. The privacy and confidentiality of audiometric records must be maintained and protected in accordance with all applicable state and federal regulations, such as the Health Insurance Portability and Accountability Act of 1996 (Final Regulations for Health Coverage Portability for Group and Medicaid Services, 2004).

**Audiogram form.** When the graphic form is used, the test frequencies shall be recorded on the abscissa, indicating frequency on a logarithmic scale, and hearing levels shall be recorded on the ordinate, using a linear scale to include the units of decibels. The aspect ratio of the audiogram is important for standardization. The correct aspect ratio is realized when a square is formed between any given octave pair on the abscissa and any 20 dB increment on the ordinate. For conventional audiometry, the vertical scale is to be designated hearing level in decibels; the horizontal scale is to be labeled frequency in hertz. By convention, frequency is recorded in ascending order from left to right, and hearing level is recorded in ascending order from top to bottom, ranging from a minimum value of –10 dB to the maximum output limits of the audiometer (usually 110 or 120 dB HL). It is advisable when reporting extended high-frequency audiometric results to use a separate graph that incorporates the appropriate decibel scale (HL vs. SPL) and frequency range measured.

**Audiogram symbols.** When the graphic form is used, the symbols presented in the Guidelines for Audiometric Symbols (American Speech-Language-Hearing Association, 1990a) should be used.

Every audiogram, whether graphic or tabular, should include, as a minimum, the following information:

- date and location of test
- names of participant, audiologist, and, if applicable, referral source
- professional credentials, license, or registration held by the audiologist, as required
- description of test equipment used, including audiometer and transducers, and the audiometric test room
- calibration information for equipment used
- threshold values for each of the frequencies tested for each ear by air conduction and bone conduction
- explanation of all symbols used
- observations of physical conditions of the outer ear or other conditions that may have influenced the results and any steps taken to mitigate these conditions
- observations of participant behavior, symptoms, or difficulties
- assessment of test reliability
- reason for the evaluation
- description of alternate test methods or non-standard test stimuli used, for example,
  - “threshold determined by descending presentations method”
  - “pulsed tone substituted”
  - “warbled tone substituted”

**Testing Issues**

Table 1 contains issues that may be encountered during pure-tone audiometry. The test considerations are offered as a resource for potential test modifications. These modifications are not intended to be comprehensive in scope or ideal for all situations; sound clinical judgment is always paramount.

**Conclusion**

These guidelines present a standard set of procedures intended to minimize intertest and intersite differences among audiologists and audiometric technicians who conduct manual pure-tone threshold audiometry. When variations in procedure are necessary, they should be noted in a manner that allows other test providers to understand how the thresholds were obtained and to replicate the findings if necessary.
### Table 1. Considerations for Pure-Tone Audiometry.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Test considerations</th>
</tr>
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<tbody>
<tr>
<td>1 Regulatory compliance (e.g., OSHA, MSHA)</td>
<td>Consult applicable regulatory requirements for specifics and required documentation.</td>
</tr>
<tr>
<td>2 Developmental or chronological age of the participant</td>
<td>Use age-appropriate test modifications, such as visual reinforcement audiometry, conditioned play, conditioned orientation response, or computerized audiometry. When testing pediatric patients, it may be advisable to test at 500 Hz and then 2000 Hz in each ear before testing additional frequencies in both ears.</td>
</tr>
<tr>
<td>3 Claustrophobia</td>
<td>Instruct the patient how to exit the booth or test with the booth door ajar. If door is left open, consider use of insert earphones to minimize effects of ambient noise.</td>
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<tr>
<td>4 Exaggerated or non-organic hearing loss</td>
<td>Reinstruction, counseling, and reexamination are valid strategies. In compensation cases, use ascending threshold technique.</td>
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<tr>
<td>5 Collapsed ear canal</td>
<td>Use insert earphones, support the pinna from behind to prevent the collapse or test with the participant’s mouth open (Reiter &amp; Silman, 1993).</td>
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<tr>
<td>6 Tinnitus</td>
<td>Use a pulsed signal or a warble tone to help distinguish the test signal from the tinnitus.</td>
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<td>7 Physical limitations for motor response</td>
<td>Modify motor response task or use verbal response task.</td>
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<tr>
<td>8 Compensation or forensic</td>
<td>Familiarization to the test tone before threshold measurement is not recommended. Consult applicable regulatory requirements.</td>
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<tr>
<td>9 Severe/profound hearing loss</td>
<td>Begin testing with low-frequency pure tones.</td>
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<tr>
<td>10 Difficult to test</td>
<td>Reinstruction, counseling, and reexamination are valid strategies. Use alternative objective measures. Modify behavioral procedures as appropriate to cognitive abilities. Repeat familiarization task at test frequencies other than 1000 Hz when responses are inconsistent.</td>
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<tr>
<td>11 Unilateral loss</td>
<td>Use appropriate masking, rule out testing errors, and verify proper function of audiometer and transducers.</td>
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<tr>
<td>12 Atypical threshold responses such as identical thresholds in both ears or unusual configurations</td>
<td>Consider reinstruction and/or retest to verify threshold response accuracy. Verify proper function of audiometer and transducers.</td>
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References


