The Efficacy of Routine Screening for High-Frequency Hearing Loss in Adults and Children

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Purpose: This study was conducted to investigate the efficacy of routine screening for high-frequency hearing loss (HFHL) including 3000, 6000, and 8000 Hz frequencies with conventional test frequencies (1000, 2000, and 4000 Hz) in adults and children in a university outreach program.

Method: Screening outcomes were examined in 2 cohorts of adults (Cohort 1, N = 315, M = 66.2 years; Cohort 2, N = 67, M = 68.3 years) and children (Cohort 1, N = 177, M = 6.5 years; Cohort 2, N = 57, M = 6.9 years) with a high-frequency screen protocol (1000–8000 Hz at 25 dB HL for adults and 20 dB HL for children) using supra-aural headphones. A rescreen was conducted in Cohort 2 with a modified protocol using insert earphones and monitored ambient noise levels.

Results: Average total test time significantly increased (p < .0001) and nearly doubled with inclusion of 3000-, 6000-, and 8000-Hz frequencies, adding approximately 1 min. Rescreen referral rates decreased by approximately 2%–16% at 1000–8000 Hz (approximately 13%–16% at 6000 and 8000 Hz) using the modified protocol in adults and children, supporting false-positive responses using supra-aural headphones.

Conclusion: Screening for HFHL should include insert earphones in order to prevent potential errors, particularly at 6000 and 8000 Hz.

Research in past years indicates an increased prevalence of hearing loss in children and adults, particularly in high-frequency (HF) regions above 2000 Hz. The third U.S. National Health and Nutrition Examination Survey (NHANES) from 1988 to 1994 reports an occurrence of high-frequency hearing loss (HFHL) in 12.2% of children 6 to 11 years old and 13% of children 12 to 19 years old (Niskar et al., 1998). According to the NHANES from 2005 to 2006, one in five adolescents 12 to 19 years of age presents with hearing loss, most commonly in the HFs, representing an increase in prevalence of hearing loss in this age group within the decade (Shargorodsky, Curhan, & Eavey, 2010). The NHANES from 2003 to 2004 revealed that 31% of adults 20 to 69 years old present with HFHL, with an increased prevalence noted in younger adults 20 to 39 years old (Agrawal, Platz, & Niparko, 2008).

HFHL may be attributed to several factors, but a typical cause—aside from maturation in adults (presbycusis)—is exposure to excessive levels of sound (e.g., noise, music). Hearing loss associated with noise exposure (i.e., noise-induced hearing loss [NIHL]) typically affects the 3000- to 6000-Hz hearing frequency range (Melnick, 1994). Numerous environmental, occupational, and recreational sources of excessive sound exposure are associated with NIHL; however, the use of personal listening devices at excessive volume under earphones has been identified recently as a risk factor among adults and children (Peng, Tao, & Huang, 2007; Vogel, Verschuure, van der Ploeg, Brug, & Raat, 2009).

Gradual NIHL characteristically presents as a notch pattern in audiometric testing, wherein hearing is affected at one or more frequencies of 3000, 4000, or 6000 Hz, though most typically at 4000 Hz, with recovery at 8000 Hz. With greater duration and intensity of noise exposure or interaction with other disorders such as presbycusis, surrounding HFs may also be affected (Feuerstein & Chasin, 2009).

HFHL may affect speech perception in individuals, particularly in background noise, and may compromise academic performance and social-emotional relationships in children (Davis, Elfenbein, Schum, & Bentler, 1986). Because HFHL due to initial NIHL is gradual and typically restricted to HFs, individuals are often unaware of the loss until speech perception is affected or until the loss is
identified with audiometric testing (Royster, 1996). Inclusion of HFs from 3000 to 6000 Hz (particularly 6000 Hz) in screening audiometric protocols to identify children at risk for NIHL has been suggested (e.g., Holmes et al., 1997; Holmes, Niskar, Kieszak, Rubin, & Brody, 2004; Serpanos & Berg, 2012). Diagnostic guidelines on pure-tone threshold testing were revised by the American Speech-Language-Hearing Association (ASHA) in 2005 to include routine testing of 3000 and 6000 Hz, in addition to the octave frequencies of 250, 500, 1000, 2000, 4000, and 8000 Hz (ASHA, 2005). Protocols for monitoring occupational NIHL in noise-exposed adults include testing HFs at 3000, 4000, 6000, and 8000 Hz (American Academy of Audiology [AAA], 2003).

The current ASHA (1997) professional hearing screening guidelines for adults or children do not include routine screening at 3000, 6000, or 8000 Hz, which may miss the identification of some forms of HFHL, particularly NIHL. In a national review of protocols, Meinke and Dice (2007) determined that school-based hearing screening programs were inadequate for early identification of NIHL in adolescents. These authors suggested that further investigation was necessary to determine the sensitivity and specificity of the frequencies that should be included for the identification of NIHL.

The purpose of this study was to assess the efficacy, in terms of test time and screening referral outcomes, of including specific test frequencies targeted for detecting NIHL (i.e., 3000, 6000, or 8000 Hz) with conventional screening frequencies (i.e., 1000, 2000, and 4000 Hz; ASHA, 1997), using a HF screen protocol (screening at octave and interoctave frequencies inclusively from 1000 to 8000 Hz), in a hearing screening outreach program. The outcomes of this study will contribute information on the efficacy of routine screening for HFHL in adults and children, which may be useful to practitioners.

Part 1: HF Screen in Cohort 1
Methods

The hearing screening outcomes of Cohort 1 (N = 492 individuals: n = 315 adults, M = 66.2 years old, range = 19–93 years; n = 177 children, M = 6.5 years old, range = 5–11 years), evaluated at the Hearing Screening Outreach Program of the Adelphi University Hy Weinberg Center for Communication Disorders in Garden City, New York, were examined over a 1-year period (2012–2013). For the past 25 years, the program has provided free screening services to approximately 500 individuals annually, including services to self-referred adults in the local community at public libraries or community centers and to children (with signed parental consent maintained by the test site) in private or public school settings.

Over the period of study, the program protocol was modified to routinely screen for HFHL in adults (≥18 years) and children (≥5 years). The HF screen protocol included screening each ear at octave and interoctave frequencies inclusively from 1000 to 8000 Hz at 25 dB HL for adults and 20 dB HL for children. In addition, test times were recorded. Testing was conducted by a doctor of audiology and graduate-level speech-language pathology students, trained and supervised by a New York State–licensed, ASHA-certified audiologist. This study was approved by the Adelphi University Institutional Review Board.

The test environment varied by test site, but, in all cases, researchers chose a quiet test room free of visual and auditory distractions. Psychoacoustic listening checks were performed by the supervisor and at least one examiner prior to testing and as needed throughout the screening session to ensure that appropriate ambient noise levels were met. The acoustic room environment was considered appropriate when the examiner detected each test signal at the lowest hearing screening level criterion (i.e., 25 dB HL for adults, 20 dB HL for children; ASHA, 1997; Barrett, 1994).

Several portable audiometer screeners (two from Maico MA39 [Maico Diagnostics, Eden Prairie, MN] and three Earscan ES3Ms from Micro Audiometrics Corp.) were used during the duration of this study. Transducers were supra-aural headphones (Maico MA39: TDH 39, MX51 cushions; Earscan ES3M: TDH 39, MX41 cushions). Annual and onsite biologic equipment calibrations were conducted to ensure proper functioning (American National Standards Institute [ANSI], 2010; ASHA, 1997). Depending on the room dimensions, one to four test stations were configured and maximally distanced apart as room size allowed. Each test station consisted of one portable audiometer mounted on a table surrounded by two chairs, one for the examiner and one for the individual to be tested.

The hearing screening was conducted by two students (one as examiner, the other as assistant) under supervision of the audiologist. A hand-raising response task was used for most participants; conditioned play audiometry was used for children when the hand-raising response was deemed unreliable. Following instruction of the procedure and placement of the headphones, suprathreshold task conditioning was conducted at 50 dB HL at 1000 Hz to ensure ability to perform the task. Children who were unable to condition to the screening task were referred for further diagnostic testing and were not counted in the outcomes of this study.

The screening was conducted first at conventional test frequencies of 1000, 2000, and 4000 Hz at 25 dB HL (adults) or 20 dB HL (children) in each ear. The test began in one ear with a single air-conducted pure tone presented at 1000 Hz and progressed to the next frequencies upon indication of a response or no response. The time taken (in seconds) to conduct the screening test (exclusive of instruction, conditioning, and set-up time) at frequencies of 1000, 2000, and 4000 Hz in each ear was recorded. The same procedure was used to screen the additional HFs of 3000, 6000, and 8000 Hz in each ear. When an individual failed to respond at the criterion level at any frequency in either ear, a rescreen was conducted at those specific frequencies within the same screening session. Individuals who did not pass one or more test frequencies at the criterion level in either ear upon rescreening or who could not be tested reliably were referred for further diagnostic evaluation (ASHA, 1997).
The efficacy of screening additional HFs (3000, 6000, and 8000 Hz) with conventional test frequencies (1000, 2000, and 4000 Hz) in routine hearing screening was evaluated by test time and referral outcomes. The time taken (in seconds) to conduct the screening was recorded separately for the conventional screen (1000, 2000, and 4000 Hz) and additional HFs (3000, 6000, and 8000 Hz) bilaterally, then was calculated for the HF screen protocol (1000–8000 Hz) bilaterally. A comparison was made of referral outcomes for the conventional screen, for additional HFs (3000, 6000, 8000 Hz), and for the HF screen protocol.

**Results**

The average total test time using the HF screen protocol (1000–8000 Hz) was 1.85 min (110.9 s) for adults and 2.28 min (136.5 s) for children (see Table 1). Test time nearly doubled with the inclusion of additional HFs (3000, 6000, and 8000 Hz) to the conventional screen frequencies (1000, 2000, and 4000 Hz), representing a significant increase in test time and adding approximately 1 min per individual to the test protocol: adults = 0.9 min (54.2 s), \( F(1, 628) = 3.86, p < .0001; \) children =1.1 min (66.9 s), \( F(1, 352) = 3.87, p < .0001. \)

Table 1 presents the referral rates and unilateral/bilateral outcomes at each frequency and by protocols (for conventional screen, 1000, 2000, and 4000 Hz; for additional HFs, 3000, 6000, and 8000 Hz; and for HF screen, 1000–8000 Hz). The large majority of adults (85.7%; \( n = 270 \)) and nearly half (48%; \( n = 53 \)) of the children did not pass the HF screen at one or more frequencies in either ear. Of those who did not pass, most were bilateral in adults (84.1%; \( n = 227 \)) and unilateral in children (56.5%; \( n = 48 \)).

Almost two-thirds of adults (67.3%; \( n = 212 \)) and less than one-third of children (29.9%; \( n = 53 \)) did not pass the conventional screen. Referral rates increased by 18% in both adults (18.4%; \( n = 58 \)) and children (18.1%; \( n = 32 \)) with inclusion of the additional HFs 3000, 6000, and 8000 Hz to the conventional screen (i.e., outcomes from HF screen protocol compared to those of the conventional screen). The highest referral rate at an individual frequency was obtained at 6000 Hz in both groups (see Table 1): 78.1% (\( n = 246 \)) in adults and 33.3% (\( n = 59 \)) in children. In adults, the referral rate of 76.1% (\( n = 241 \)) at 8000 Hz was close to the referral rate at 6000 Hz (see Table 1).

**Discussion**

This study examined the efficacy of including additional HFs (3000, 6000, and 8000 Hz) with conventional hearing screening frequencies (1000, 2000, and 4000 Hz) using supra-aural headphones to routinely screen for HFHL in adults and children in a hearing screening outreach program. The HF screen protocol (1000–8000 Hz) was compared to the conventional screen protocol (1000, 2000, and 4000 Hz) for test time and referral outcomes.

Test time increased by approximately 1 min on average in adults (0.9 min) and children (1.1 min) with inclusion of additional HFs of 3000, 6000, and 8000 Hz to the conventional screen. The total test time using the HF screen protocol was nearly 2 min: 1.9 min for adults and 2.3 min for children. The increased test time using the HF screen was statistically significant (\( p < .0001 \)) and nearly doubled from that of the conventional screen. Time considerations are of importance in screening outreach programs, which are geared to screen large numbers of individuals in a designated period. Fractions of additional test time may adversely affect the efficiency of the screening program by increasing the overall time needed to conduct the screening, which may result in an inability to complete testing or increased costs.

Referral outcomes were high (85.7% in adults; 48% in children) using the HF screen and were 18% more than referral rates from the conventional screen in both groups. Though this screening protocol did not include case history information or validate screening outcomes with diagnostic audiometry, the equal increase (18%) in referral outcomes using the HF screen protocol over the conventional protocol in adults and children is suspect. An increase in referral outcomes using the HF screen protocol could be expected in this adult population, given the high prevalence of HFHL from presbycusis and noise exposure among this age group (\( M = 66.2 \) years old). It is estimated that one in three adults over the age of 65 years and approximately

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<th>Table 1. Referral outcomes and mean test times in Cohort 1 using the high-frequency (HF) screen protocol.</th>
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<td><strong>Frequency (kHz)</strong></td>
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<td><strong>Cohort 1 Adults (n = 315)</strong></td>
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Serpanos et al.: Routine Screening for HFHL

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one-half of those 75 years and older have hearing loss due primarily to the effects of aging and noise (Hearing Loss Association of America, 2014; National Institute on Deafness and Other Communication Disorders, 2014). Moreover, because adult populations are often self-referred in screening outreach programs due to suspected loss, a high referral rate is probable. A smaller prevalence (approximately 12%) of HFHL has been reported in this age group of children (M = 6.5 years; Niskar et al., 1998), which may be attributed to many possible congenital or acquired factors such as hereditary loss, infection, ototoxicity, NIHL, acoustic trauma, or other reasons (Cunningham & Cox, 2003; Niskar et al., 1998).

The HF screen protocol yielded the highest referral rate, at 6000 Hz (78.1% in adults, 33.3% in children), which may be a frequency affected by NIHL. Though hearing loss at 6000 Hz may be a characteristic of NIHL, loss at 4000 Hz is a more typical occurrence following exposure to excessive noise. NIHL is less likely a contributor to the high referral rate at 6000 Hz in this young age group of children. In a study on noise exposure and audiometric thresholds, McBride and Williams (2001) concluded that although a hearing loss notch at 4000 Hz is an established indicator of NIHL, a notch at 6000 Hz is a variable outcome and of less clinical significance. Fligor and Meinke (2009) indicate that because NIHL occurs gradually over long durations of exposure, it may take years to develop in a small percentage (approximately 5%–10%) of those exposed to excessive levels using personal listening devices. In a similar age group of children 6 to 11 years old, Niskar et al. (2001) estimated a prevalence of noise-induced threshold shifts of 8.5% in one or both ears. In this study of children, it was further noted that of the number of referrals at 3000, 4000, 6000, and 8000 Hz (n = 21–59), the large majority were unilateral (62%–79%; n = 13–39) and were likely not related to NIHL, which occurs primarily bilaterally (Royester, 1996).

The high referral rate at 6000 Hz and the increase in referral outcomes using the HF screen protocol may be a result of false-positive outcomes due to measurement errors associated with the use of supra-aural headphones in this screening. Although insert earphones offer distinct advantages in clinical testing, supra-aural earphones are less costly and more appropriate for use with specific abnormalities of the pinna or ear canal (Hall, 2014)—factors advantageous for use in mass hearing screening such as the screening conducted in this program. Background noise levels, though monitored with periodic biologic calibration throughout test sessions in this screening, may have contributed to referral rates at higher frequencies. Background noise levels in screening outreach programs are typically less than ideal and may change throughout the test session. Use of insert earphones that provide greater sound attenuation than supra-aural headphones (Martin & Clark, 2012) may be the transducer of choice when screening HF’s. Measures of background noise levels using a sound-level meter should also be considered to ensure that allowable ambient noise levels (ANSI, 1999) are met at the specific HF’s to be tested. Ear canal collapse arising from the pressure of the headband and supra-aural earphone cushions is a possible occurrence in young children and older adults due to decreased elasticity of the external ear cartilage, and it may lead to false conductive hearing loss primarily in the HF’s (DeBonis & Donohue, 2008). Supra-aural earphones may create greater response variability at 6000 and 8000 Hz than insert earphones. False responses may also be attributed to calibration errors related to the supra-aural TDH-style headphones (Schlauch & Carney, 2007, 2011; Schlauch & Nelson, 2009). Schlauch and Carney (2011) recommended improving the precision of pure-tone testing at HF’s by repeated measures, by correction of earphone calibration errors, and/or by use of earphones that reduce errors in measurements specifically at 6000 and 8000 Hz.

Due to the nature of this screening outreach program, it was not possible to conduct follow-up testing on the individuals that did not pass the HF screen in Cohort 1. Therefore, the HF screen protocol was repeated in an additional cohort of adults and children (Cohort 2). Individuals in Cohort 2 who did not pass the HF screen were retested using a modified protocol in order to address the possibility of false-positive outcomes using supra-aural headphones.

Part 2: HF Screen and Modified Protocol in Cohort 2

In the second part of this study, the HF screen protocol was used and restested with modifications in a second cohort of individuals to address potential false-positive outcomes, as discussed above. The screening outcomes in Cohort 2 (N = 124 individuals; n = 67 adults, M = 68.3 years old, range = 22–94 years; n = 57 children, M = 6.9 years, range = 5–16 years) were obtained 1 year after those of Cohort 1 (i.e., in 2014). Individuals were tested using the HF protocol in similar settings as those in Cohort 1 (i.e., in libraries and a school setting). The same methods for the HF screen protocol described above were used, except that a rescreen was conducted with modifications. Those who did not pass were rescreened at the specific frequencies that met referral criteria (i.e., no response at 25 dB HL [adults] or 20 dB HL [children] in either ear). The rescreen included the following modifications to the HF screen protocol: (a) 10-ohm insert earphones (Maico MA39 audiometer; E.A.RTONE 3A [3M Auditory Systems, Indianapolis, IN]) were used instead of supra-aural headphones and (b) a check of background ambient noise levels using a calibrated sound-level meter (SLM; B&K Type 2203/Octave Filler Set Type 1613; B&K, Pistonphone Type 4220 [Brüel & Kjær, Nærum, Denmark]; ANSI, 2014) was conducted prior to the rescreen to ensure that ANSI S3.1-1999 (R2013) permissible noise levels using insert earphones were not exceeded at each test frequency (1000–8000 Hz).

Results

Table 2 presents the initial and rescreen referral rates and unilateral/bilateral outcomes at each frequency and by protocols (conventional screen, 1000, 2000, and 4000 Hz; additional HFs, 3000, 6000, and 8000 Hz; and HF screen, 1000–8000 Hz) for Cohort 2. Most adults (92.5%; n = 62)
and less than one-third of children (29.8%; n = 17) did not pass the initial HF screen using supra-aural headphones at one or more frequencies in either ear. Of those who did not pass, most were unilateral in adults (83.9%; n = 52), whereas most were unilateral in children (82.4%; n = 14).

More than three-quarters of adults (77.6%; n = 52) and 5.3% of children (n = 3) did not pass the initial conventional screen using supra-aural headphones. Referral rates increased by 14.9% in adults (n = 10) and 24.6% in children (n = 14) with the inclusion of 3000, 6000, and 8000 Hz to the conventional screen (i.e., outcomes from HF screen protocol compared to those of the conventional screen). The highest referral rates at individual frequencies in the initial screen using supra-aural headphones occurred at 6000 Hz (adults: 88.1%, n = 59; children: 14% n = 8) and 8000 Hz (adults: 82.1%, n = 55; children: 17.5% n = 10) in both groups (see Table 2).

Rescreen outcomes were obtained with modifications to the HF protocol (i.e., use of insert earphones and monitoring of background ambient noise levels with a SLM) for 62 adults and 17 children at each frequency that did not meet pass criteria in the initial screen. The rescreen results using the modified HF screen protocol (1000–8000 Hz) revealed a decreased referral rate in adults by 9% (n = 6) and by 28.1% (n = 16) in children (see Table 2) when compared to the initial screen. Rescreen referral rates using the modified HF screen protocol (1000–8000 Hz) decreased to 83.6% (n = 56) in adults, and to 1.8% (n = 1) in children.

Rescreen referral rates were also lower than the initial screen at all individual frequencies (1000–8000 Hz) in adults (by 4.5%–13.4%; n = 3–9) and at most frequencies in children (by 1.8%–15.8%; n = 1–9), except at 3000 and 4000 Hz (0% referral on the initial screen). The greatest decrease in rescreen referral rates occurred at 6000 Hz in adults (by 13.4%; n = 9) and at 6000 Hz (by 14%; n = 8) and 8000 Hz (by 15.8%; n = 9) in children. The rescreen referral rate using the modified HF protocol in adults dropped to 74.6% (n = 50) at 6000 Hz. In children, rescreen referral rates decreased to 0% at 6000 Hz and 1.8% (n = 1) at 8000 Hz (see Table 2; Figure 1).

**Discussion**

Outcomes from a second cohort of 124 adults and children using the HF screen protocol (1000–8000 Hz) with supra-aural headphones revealed an increase in referral rates by approximately 15% (adults) to 25% (children) with the inclusion of 3000, 6000, and 8000 Hz to the conventional screen (1000, 2000, and 4000 Hz). Findings were similar to those obtained in the first part of this study, wherein referral rates using the HF screen protocol with supra-aural headphones increased by approximately 18% over the conventional screen in Cohort 1 (N = 492 adults and children).

Similar to screening findings obtained in Cohort 1, outcomes in Cohort 2 using supra-aural headphones also revealed that the greatest referral rates occurred at 6000 and 8000 Hz. The HF screen protocol was modified in
order to determine whether the increased referral rates were false-positive responses due to measurement errors associated with the use of supra-aural headphones (see Part I Discussion above). Individuals who did not pass the initial HF screen using supra-aural headphones at 1000–8000 Hz (i.e., n = 62 adults and 17 children) were rescreened at the specific frequencies in which referral criteria were met using a modified HF screen protocol with insert earphones and monitoring of background noise levels with a SLM.

Following the modifications to the HF screen protocol, rescreen outcomes revealed a decrease in referral rates by 4.5%–13.4% at 1000–8000 Hz in adults, and by 1.8%–15.8% at 1000, 2000, 6000, and 8000 Hz in children. The greatest decrease in referral rates occurred at 6000 Hz in both adults and children (by 13.4% and 14%, respectively) and at 8000 Hz in children (by 15.8%). These outcomes support that the initial HF screen protocol using supra-aural headphones produced false-positive outcomes at most frequencies from 1000 to 8000 Hz, but particularly at 6000 and 8000 Hz in adults and children. The false-positive errors are probable measurement errors associated with the use of supra-aural headphones (see Part I Discussion above).

Because the greatest percentage of false-positive responses with supra-aural headphones occurred at 6000 and 8000 Hz in both adults and children, the likeliest causes of error are related to the variability of testing and calibration errors associated with the use of headphone transducers. Greater variability has been reported in threshold testing at 6000 and 8000 Hz using supra-aural headphones as compared to insert earphones (Schlauch & Carney, 2007, 2011; Schlauch & Nelson, 2009). In addition, calibration errors at 6000 Hz have been noted with TDH-style supra-aural headphones, which are likely the result of the typical coupler used for calibration (Schlauch & Carney, 2011). Collapsed ear canals, another source of potential error resulting from supra-aural headphones in these age groups, typically cause the greatest artifacts at 4000 Hz (Gelfand, 2009). Background ambient noise levels may have contributed to the false responses using supra-aural headphones. Insert earphones provide greater attenuation across frequencies (125–8000 Hz) in adults and children than do supra-aural headphones (Wright & Frank, 1992). Greater maximum permissible ambient noise levels (approximately 15–29 dB SPL) are therefore allowed from 250 to 8000 Hz using insert earphones versus supra-aural headphones (ANSI, 1999). The outcomes of this study suggest that insert earphones should be the transducer of choice when screening for HFHL at 3000, 6000, and 8000 Hz. Future study in this area may be considered in order to investigate the sensitivity and specificity of the conventional screening protocol versus a HF protocol that includes 3000, 6000, and 8000 Hz.

**Conclusions**

The outcomes of this study do not support the efficacy of routine screening for HFHL using supra-aural headphones at HFs of 3000, 6000, and 8000 Hz with conventional screening at 1000, 2000, 4000 Hz in adults and children. Results from this screening outreach program revealed that adding 3000, 6000, and 8000 Hz to the conventional screening protocol using supra-aural headphones resulted in a significantly longer test time (p < .0001) and false-positive outcomes, particularly at 6000 and 8000 Hz. Retest outcomes with a modified HF screen protocol using insert earphones and monitoring of ambient noise levels with a SLM decreased referral rates by approximately 2%–16% at 1000–8000 Hz in adults and children. The greatest decrease in referral rates occurred at 6000 Hz in adults and at 6000 and 8000 Hz in children (approximately 13%–16%). The false-positive results obtained with supra-aural headphones at 6000 and 8000 Hz are most likely due to response variability and calibration errors associated with the headphone-style transducer at these frequencies. Other contributions of error associated with headphones may include the effects of potential ear canal collapse in these age groups of young children and older adults as well as background noise. These outcomes should caution practitioners to consider using insert earphones and conduct periodic measures of ambient noise levels when testing 3000, 6000, and 8000 Hz in a hearing screening program. Individuals at risk for HFHL including NIHL should be screened using corrective steps to account for potential errors at 6000 and 8000 Hz.

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**References**


