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Hearing Screening in the Community

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Abstract

Background: Adults typically wait 7–10 yr after noticing hearing problems before seeking help, possibly because they are unaware of the extent of their impairment. Hearing screenings, frequently conducted at health fairs, community events, and retirement centers can increase this awareness. To our knowledge, there are no published studies in which testing conditions and outcomes have been examined for multiple "typical screening events."

Purpose: The purpose of this article is to report hearing screening outcomes for pure tones and self-report screening tests and to examine their relationship with ambient noise levels in various screening environments.

Study Sample: One thousand nine hundred fifty-four individuals who completed a hearing screening at one of 191 community-based screening events that took place in the Portland, OR, and Tampa, FL, metro areas.

Data Collection and Analysis: The data were collected during the recruitment phase of a large multisite study. All participants received a hearing screening that consisted of otoscopy, pure-tone screening, and completion of the Hearing Handicap Inventory–Screening Version (HHI-S). In addition, ambient sound pressure levels were measured just before pure-tone testing.

Results: Many more individuals failed the pure-tone screening ($n = 1,238$) and then failed the HHI-S ($n = 796$). The percentage of individuals who failed the pure-tone screening increased linearly with age from $<$20% for ages $<$45 yr to almost 100% for individuals aged $\geq$85 yr. On the other hand, the percentage of individuals who failed the HHI-S remained unchanged at approximately 40% for individuals aged $\geq$55 yr. Ambient noise levels varied considerably across the hearing screening locations. They impacted the pure-tone screen failure rate but not the HHI-S failure rate.

Conclusions: It is important to select screening locations with a quiet space for pure-tone screening, use headphones with good passive attenuation, measure sound levels regularly during hearing screening events, halt testing if ambient noise levels are high, and/or alert individuals to the possibility of a false-positive screening failure. The data substantiate prior findings that the relationship between pure-tone sensitivity and reported hearing loss changes with age. Although it might be possible to develop age-specific HHI-S failure criteria to adjust for this, such an endeavor is not recommended because perceived difficulties are the best predictor of

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hearing health behaviors. Instead, it is proposed that a public health focus on education about hearing and hearing loss would be more effective.

Key Words: age-related hearing loss, hearing screening, self-report

Abbreviations: ASHA = American Speech-Language-Hearing Association; HHI-S = Hearing Handicap Inventory–Screening Version

INTRODUCTION

It is proposed that outcomes for individuals with age-related hearing loss may be better if auditory rehabilitation begins soon after the individual notices difficulty hearing (Pronk et al, 2011). However, data suggest that people wait on average 7–10 yr after noticing hearing problems before seeking help (Davis et al, 2007). One potential reason for the delay in uptake of hearing health care is that the onset of age-related hearing loss is very gradual, and thus individuals may be unaware of the extent of their impairment. As a result, they do not perceive a need for help (Fischer et al, 2011; Smith et al, 2011; Contrera et al, 2016). As noted by Smith et al (2011), population screening can give individuals who are unaware of a health problem an earlier awareness of that problem. Because of issues with accessibility and affordability of hearing health care, the US Preventive Services Task Force concluded that there was insufficient evidence to recommend guidelines for or against routine screening for asymptomatic adults >50 yr (Moyer, 2012). However, the American Speech-Language-Hearing Association (ASHA) statement regarding Scope of Practice in Audiology considers conduct of audiological screening to be a mechanism through which audiologists facilitate prevention of hearing loss (ASHA, 2004). It is thus not uncommon for hearing screenings to be conducted at health fairs, community events, and retirement centers.

ASHA published guidelines for adult hearing screenings (ASHA, n.d.) in which specific recommendations about testing personnel, hearing loss risk factors, screening settings and situations, pass/fail criteria, referrals and recommendations, equipment calibration, screening environment, universal precautions, etc., are detailed. However, to our knowledge, there are no published studies in which testing conditions and outcomes are examined for multiple "typical screening events." This information would provide insight on the extent to which setting specifications are typically met and what the implications are for screening outcomes when they are not. Of relevance to this study are ASHA's adult hearing screening guidelines regarding ambient noise which state "*Ambient noise levels may exceed ANSI standards for pure-tone threshold testing in audiometric test rooms (ANSI, 2013) but must be sufficiently low to allow accurate screening*." Ambient noise levels are rarely, if ever, measured and reported during hearing screening events. High levels of ambient noise can potentially result in false-positive pure-tone screen failures.

ASHA's guidelines for adults specify that a hearing screening should consist of screening for an ear disorder; a hearing impairment and a hearing disability via a case history; a visual inspection of the ear; a pure-tone screen at 25-dB HL at the frequencies of 1000, 2000, and 4000 Hz in each ear; and completion of a valid and reliable hearing disability screening instrument such as the Hearing Handicap Inventory for the Elderly–Screening Version (Ventry and Weinstein, 1983) or the Self-Assessment of Communication (Schow and Nerbonne, 1982). If an individual shows signs of an ear disorder, he/she should be referred for medical evaluation or cerumen management. If an individual fails to respond to one of the pure tones in either ear and/or their score on the disability measure indicates a failure, he/she should be referred for a full audiological assessment.

The inclusion of both a pure-tone and self-report screening measure enables an examination of the sensitivity and specificity of the self-report measure used and can provide an understanding of the relationship between pure-tone screening outcome and self-reported screening outcome. This is of particular interest because underreporting of hearing loss is common, especially among older individuals (Merluzzi and Hinchcliffe, 1973; Nondahl et al, 1998; Wiley et al, 2000; Sindhusake et al, 2001; Uchida et al, 2003; Kamil et al, 2015).

The purpose of this article is to report on the comparison between hearing screening outcomes for pure tones and self-report screening tests and to examine their relationship to ambient noise levels in various screening environments.

MATERIALS AND METHODS

Study Synopsis

The data reported here were collected during the recruitment phase of a large multisite study designed to examine the role of health beliefs in hearing health care decision-making (NIH NIDCD R01 DC013761). No identifiable data were collected during the hearing screening thus, the Institutional Review Board did not require potential participants for the multisite to be consented. A full set of data were obtained from 1,954 individuals who completed a hearing screening at one of 191 community-based screening events that took place in the metro areas around Portland, OR (n = 1,219 screenings), and Tampa, FL (n = 735 screenings). The screening consisted of an otoscopic examination, a pure-tone screening, and completion of the Hearing Handicap Inventory–Screening Version (HHI-S; Newman et al, 1991). In addition, ambient sound pressure levels were measured just before each pure-tone testing.

Participants

Data were collected at community hearing screening events that took place between June 2015 and November 2016. Two thousand one hundred ninety-four individuals received a pure-tone hearing screening. However, because of time and/or language constraints, some did not complete the HHI-S (n = 113), some reported that they wore hearing aids (n = 102), and some chose not to provide their age (n = 25); thus, a full dataset were available from 1,954 individuals. The mean age of these individuals was 64.1 yr (standard deviation = 13.7, range = 20 to 89+). No other descriptive participant data were collected.

Test Measures

Hearing Screening

Hearing screenings were conducted in accordance with ASHA adult hearing screening guidelines (ASHA, n.d.). To this end, the following were completed:

- **Otoscopy.** Otoscopy was completed to check for wax and other abnormalities using an MD Scope portable video otoscope from JEDMED, St. Louis, MO.
- **Pure-tone hearing screening.** Pure-tone hearing screening was conducted using a Grason Stradler Inc. 18 audiometer (Eden Prairie, MN) and calibrated Sennheiser HDA 200 headphones (Hannover, Germany). Testing was completed for frequencies of 1000, 2000, and 4000 Hz. The left and right ears were tested separately. First, a familiarization tone was presented at 40-dB HL. If the participant indicated they heard a tone, the signal was presented at 25-dB HL. As per ASHA guidelines, a pass is indicated if responses are obtained in both ears to pure-tone stimuli at 25-dB HL at 1000, 2000, and 4000 Hz. A fail is indicated if there is no response at 25-dB HL at any screening test frequency in either ear. Note: During three initial screening events, the Tampa test site used calibrated TDH-39 supra-aural earphones (Farmingdale, NY) in lieu of the Sennheiser HDA 200 headphones because the Sennheiser phones were not yet available at their site.
- **HHI-S.** The HHI-S is a 10-item hearing screening questionnaire that assesses perceived participation restrictions associated with hearing loss. As per protocol, responses were "Yes," "Sometimes," or "No" with points assigned for scoring as follows: Yes = 4 points, Sometimes = 2 points, and No = 0 points. Points were added to yield a total score. Total scores range from 0 to 40, with higher scores indicating greater self-perceived handicap. As per ASHA screening guidelines, a score of 10 or greater was used as the recommended cutoff for referral for full audiometric testing (ASHA, n.d.). The HHI-S was administered in a pencil-paper format.

Ambient Sound Pressure Levels

At the start of each pure-tone screening, ambient sound levels were measured using an Extech 407732 type II sound level meter set to a slow setting and dBA weighting. These data were collected for 1,576 of the 1,954 participants who completed all elements of the hearing screening protocol.

Community Screening Events

At each screening event, the study team arranged for a table in a public area, a quiet private room for conducting pure-tone screening, and a private space for participant consenting (for individuals in the large multisite study, NIH NIDCD R01 DC013761). The screening events were not announced in advance because the multisite study aimed to recruit individuals who were not expecting to encounter the opportunity to have their hearing screened. In total, 191 screening events took place over an 18-mo period. Table 1 shows the event location type and the number of individuals screened at each.

Procedures

At each event, the study team offered passersby the option to have their hearing screened. They also answered the questions and handed out brochures about hearing,

Table 1. Number of Screening Events and Individuals Screened by Screening Event Type

Screening Event Type	No. of Screening Events, n (%)	Individuals Screened, n (% Total)
Senior center	29 (15.2)	290 (14.8)
Community center	40 (20.9)	448 (22.9)
Retirement community	18 (9.4)	151 (7.7)
Library	13 (6.8)	195 (10.0)
Grocery store	15 (7.9)	48 (2.5)
Health fair	9 (4.7)	285 (14.6)
Place of worship	10 (5.2)	176 (9.0)
Medical clinic	27 (14.1)	99 (5.1)
Golf course	5 (2.6)	25 (1.3)
Other*	25 (13.1)	237 (12.1)

*Includes: unknown, farmers market, book store, luau, health expo, farm, and science fair.

ear plugs, a list of local audiologists, and information for veterans about VA audiology services. Anyone who wanted their hearing screened was asked to complete the HHI-S and an information sheet requesting the individual's age, whether he/she had hearing aids, and whether he/she was interested in learning more about the multisite study. Once completed, the individual was accompanied to the quiet private space in which the screening audiometer was set up. A research audiologist computed the total HHI-S score, obtained a brief medical history, and conducted otoscopy. If there were any concerns, the individual was encouraged to make an appointment with a primary care provider or an ear, nose, and throat physician. The ambient sound level was then recorded and the pure-tone screening completed. Noise levels were monitored during testing and when feasible, testing was briefly suspended if the levels were determined to be too high. If the noise was not transitory, testing continued at the discretion of the audiologist. Once testing was completed, individuals received feedback about their results as follows: If their score on the HHI-S was <10 and they responded to tones of 25-dB HL at all frequencies in both ears, they were informed that they had passed the screening. If their HHI-S score was ≥10 and/or they missed one or more 25-dB HL tones at any frequency in either ear, it was recommended that they seek a full hearing evaluation from an audiologist. To facilitate this, they were provided with a list of local audiologists. The research audiologist remained available to answer any questions that arose.

RESULTS

Analyses

Descriptive statistics were used to examine the distribution of pass–fail responses for each testing method and analyses of variance were used to compare ambient noise levels for those who passed versus failed the screenings.

Screening Results

Table 2 shows the number and percentage of participants who passed and failed the pure-tone and HHI screenings. The failure rate is high, but this is to be expected because the screening events and locations were selected specifically to recruit older individuals with untreated hearing loss. In other words, these figures are not an estimate of the prevalence of untreated hearing loss in the community. From Table 2, it is noticeable that many more individuals failed the pure-tone screening (n = 1,238) than failed the HHI-S (n = 796). To further examine this, we explored the relationship between screening results and age, and screening results and ambient noise during testing.

Table 2. Pure-Tone and HHI-S Pass/Fail Matrix Showing Number of Cases with Percentage of Total Cases in Parentheses

		Pure-Tone Screen		
		Pass	Fail	Total
HHI screen	Pass	520 (26.6%)	638 (32.7%)	1,158 (59.3%)
	Fail	196 (10.0%)	600 (30.7%)	796 (40.7%)
	Total	716 (36.6%)	1,238 (63.4%)	

Screening Results and Age

Figure 1 shows the percentage of individuals by decade who failed the pure-tone (dark bars) and the HHI-S (light bars) screenings. The percentage of individuals who failed the pure-tone screening increased linearly with age, from <20% for those aged <45 yr to almost 100% for individuals aged ≥85 yr. In contrast, the percentage of individuals who failed the HHI-S increased between the youngest and second youngest decade, but remained unchanged at approximately 40% thereafter. The difference in pure-tone and HHI-S failure rates increased dramatically with age, such that by age 75–84 yr, twice as many individuals failed the pure-tone screen as failed the HHI screen. In contrast, in the age group of <45 yr, more individuals failed the HHI-S than the pure tones, whereas in the 45–54-yr age group, an equal percentage of individuals failed the pure-tone screening and HHI-S.

Screening Results and Ambient Noise

Figure 2 shows the relationship between screening results and ambient noise levels. As might be expected, the percentage of individuals who failed the pure-tone screening increased as ambient noise level increased for noise levels >30 dBA. Chi-squared testing showed the change across levels to be statistically significant

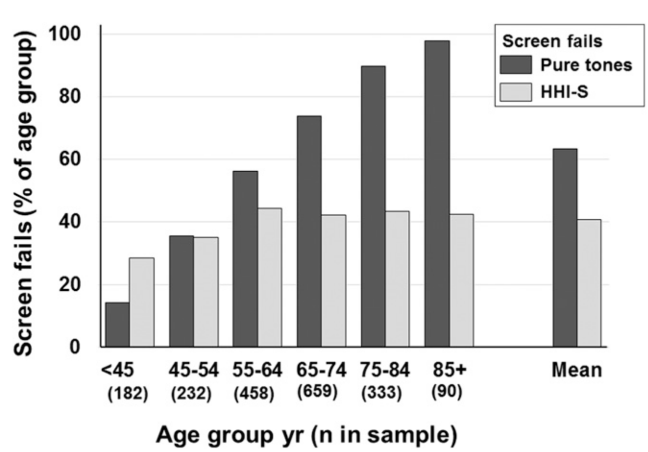

Figure 1. Percentage of individuals by age decade who failed the pure-tone (dark bars) and the HHI-S (light bars) screenings. The number of individuals screened within each age decade is shown in parentheses.

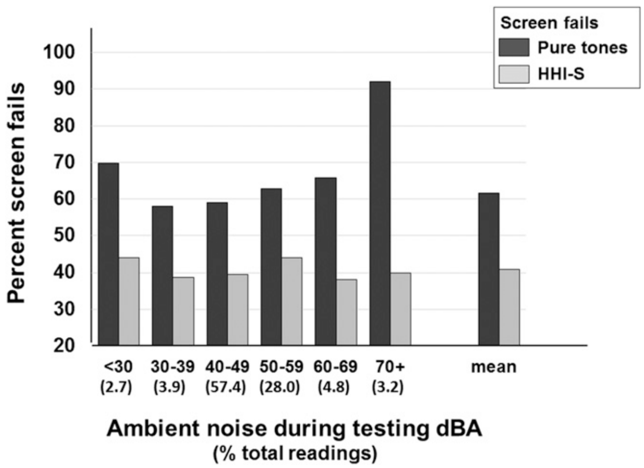

Figure 2. Percentage of pure-tone (dark bars) and the HHI-S (light bars) screen fails by ambient noise level. The percentage of individuals screened at each ambient noise level range is shown in parentheses.

($\chi^2 = 24.51$, $p < 0.001$), with z-test paired comparisons using Bonferroni corrections showing that the proportion of pure screen failures at 70 dBA was significantly greater ($p < 0.05$) than at all ambient noise levels, except <30 dBA. The high failure rate at ambient noise levels <30 dBA is likely a random finding due to a small sample size. The percentage of individuals who failed the HHI-S, however, was independent of ambient noise level ($\chi^2 = 2.98$, $p < 0.702$), with z-test paired comparisons using Bonferroni corrections showing failure rates at all levels to be the same ($p > 0.05$). These findings are also conveyed by the data in Table 3, which shows the ambient noise levels during screening as a function of the pass–fail status for both the pure-tone screenings and HHI-S. The mean ambient noise level was significantly higher for individuals who failed the pure-tone screening than who passed the screening, but did not differ (in fact they were identical) for those who passed versus failed the HHI-S.

Ambient Noise Levels and Screening Location

Figure 3 is a histogram showing that ambient noise levels were normally distributed with a mean of 48.0 dBA and a range of <20 to almost 90 dBA. It seems probable that the outlying values were errors made when the research audiologist read and/or transcribed the sound level; nonetheless, they are presented here because we cannot be certain of this. Figure 4 is a box plot of the ambient noise levels at each type of screening event. The median ambient noise level is shown by the solid horizontal line, with the lower and upper ends of the box showing the 25th and 75th percentiles, respectively, and the upper and lower ends of the whisker indicating the range of values within 1.5× the interquartile range. Circles depict outliers that are >2 whisker lengths above or below the 75th or 25th percentile, respectively, and asterisks depict outliers that are >3 whisker lengths above the 75th percentile. The figure illustrates the variability of the ambient noise levels both within and across location types. For example, sound levels at the library events were low, showed little variability, and there were few outliers, whereas levels at the grocery store and health fair events were considerably higher and more variable.

DISCUSSION

These data were collected during 191 community hearing screening events. The screening procedures were not adapted for research; thus, the data provide valuable insight into typical hearing screening events. As noted in the "Results" section, the number of individuals who failed one or both screening measures is high because the locations at which the screenings took place were selected specifically to have large populations of older individuals with age-related hearing loss. In other words, the data are not an estimate of the prevalence of untreated hearing loss in the community. Somewhat related is the fact that there was no rationale for noting the gender of individuals screened; thus, male–female comparisons could not be made.

Ambient noise levels varied greatly both within and between screening event types. At some event types, such as the library, the levels were consistently low with little variability. At other event types, such as at medical clinics, senior centers, and retirement communities, the median levels were low, but there was a fair amount of variability. Finally, at yet other event types, such as grocery stores

Table 3. Ambient Noise Levels during Pure-Tone Screening for Individuals Who Passed and Failed the Pure-Tone Screening and HHI-S

	Ambient Noise Level (dBA) Mean (Standard Deviation) n		
	Pass	Fail	Results of Analysis of Variance
Pure-tone screen	47.0 (7.1) 604	48.6 (9.7) 972	$F = 12.1$ $p = 0.001$
HHI-S	47.9 (8.8) 932	48.0 (8.8) 644	$F = 0.104$ $p = 0.747$

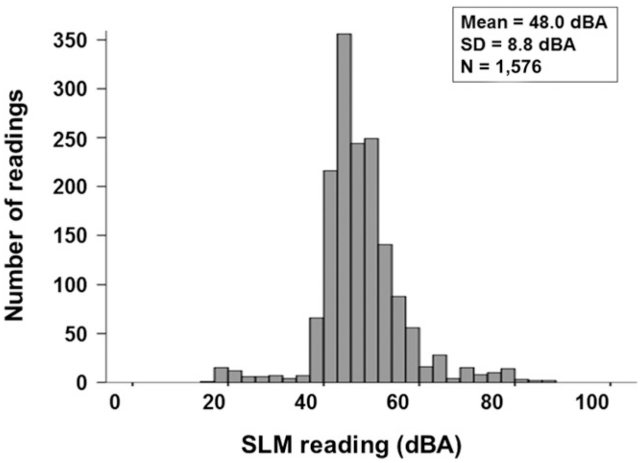

Figure 3. Histogram showing the distribution of ambient noise levels during pure-tone screening.

and health fairs, median levels were high and levels were highly variable. This finding in particular is troublesome because health fairs are traditionally viewed as an ideal opportunity for conducting hearing screenings. These data, coupled with the finding that pure-tone screen failure rates increased as ambient noise level increased, emphasize the importance of (a) arranging for a quiet space when planning screening events, (b) using headphones with good passive attenuation or even, as suggested by Lo and McPherson (2013), using noise-cancelling headphones, (c) closely monitoring sound levels during screening, and (d) suspending testing if levels are too high. As noted previously, ASHA's adult hearing screening guidelines regarding ambient noise state that "*Ambient noise levels may exceed ANSI standards for pure-tone threshold testing in audiometric test rooms (ANSI, 2013) but must be sufficiently low to allow accurate screening*." This somewhat vague statement is presumably because the type of headphones being employed and the frequency spectrum of the ambient noise both impact the extent to which ambient noise will mask pure-tone signals. Although the ASHA guidelines also state that based on the data of Frank and Williams (1993) for supra-aural earphones, the maximum permissible ambient noise levels are 51.5-, 53.0-, and 59.5-dB SPL at 1000, 2000, and 4000 Hz, respectively, we were not able to easily assess frequency-specific noise levels. By choosing to use the dBA weighting, which seemed a reasonable approach, we found that levels here were <50 dBA during 64% of screenings, and <60 dBA during 92% of screenings. Levels were between 60 and 69 dBA during 4.8% of screening and were greater than 70 dBA in 3.2% of screenings. This, in combination with the data in Figure 3 illustrating that pure-tone screen failures increased gradually up to 70 dBA and then dramatically at ambient noise levels >70 dBA, lends support to the ASHA guidelines.

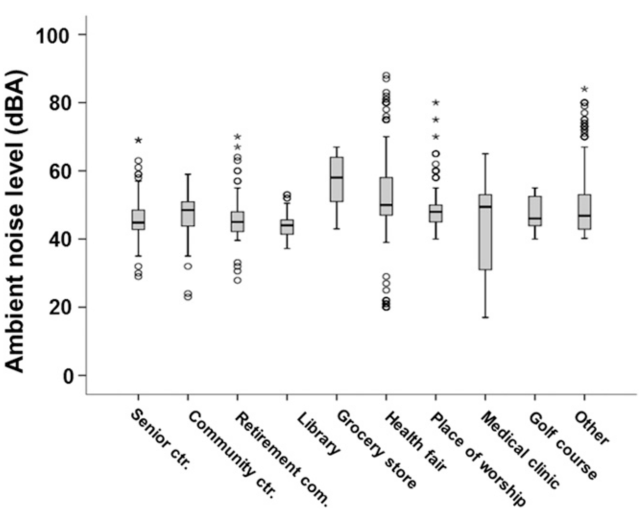

Figure 4. Box plot of the ambient noise levels at each type of screening event. Median ambient noise level is shown by the solid horizontal line, with the lower and upper ends of the box showing the 25th and 75th percentiles, respectively. The upper and lower ends of the whiskers indicate the range of values within 1.5× the interquartile range. Circles depict outliers that are >2 whisker lengths above or below the 75th or 25th percentile, respectively. Asterisks depict outliers that are >3 whisker lengths above the 75th percentile.

This ambient noise levels measured here probably reflect average levels at "typical" screening events. The fact that some events were on average noisier and levels were more variable suggests that caution is necessary when selecting venues for hearing screening events and as noted previously, it underscores the importance of using sound-attenuating headphones, monitoring ambient noise throughout the event, and educating staff that they should be willing to halt testing if levels are too high. If these suggestions are not followed then at the minimum, testers should inform individuals of the potential of a false-positive result.

There was not a one-to-one relationship between pure-tone and HHI screen failures and the relationship between pure-tone and HHI screen failures changed with age. Specifically, considerably more individuals failed the pure-tone screening (n = 1,238) than the HHI-S (n = 796), and whereas there was a linear increase in the percentage of participants who failed the pure-tone screening with age (from 20% to 98%), the percentage of individuals who failed the HHI-S remained stable at about 40% after 55 yr of age. Other studies have also demonstrated that older individuals report less subjective handicap relative to measured hearing than younger individuals (Merluzzi and Hinchcliffe, 1973; Nondahl et al, 1998; Wiley et al, 2000; Sindhusake et al, 2001; Uchida et al, 2003; Kamil et al, 2015). As illustrative examples, Nondahl et al found that the "accuracy" or concurrence of HHI-S to measured hearing loss was 67% for all individuals in their sample (n = 3,471), with accuracy being greater for those aged 48–64 yr (79%) than for those aged 62–92 yr (55%). Similarly, Wiley et al (2000) reported that although the prevalence of individuals reporting hearing loss (defined as an HHI-S score >8) was greater for those with more measured hearing loss, there were significant effects of age such that the prevalence of reported handicap was lower for older individuals.

A number of explanations for the disconnect between measured hearing loss and self-reported hearing difficulties among older individuals have been proposed. These include older individuals having (a) less awareness of their hearing loss because the onset is typically very gradual, (b) lower expectations about their hearing because they expect it to decline with age, (c) lessened demands to communicate in difficult listening environments and thus the impact of hearing loss is less, and (d) less reliance on hearing due to lifestyle changes potentially associated with hearing loss (Hétu, 1996; Nondahl et al, 1998; Saunders et al, 2004; Wallhagen, 2010). Regardless of the reason(s) why, the inverse relationship between perceived difficulties and age might raise concerns about the suitability of using self-report alone as a screening tool because it could lead to many false-negative screening results in older individuals. One solution might be to develop age-specific pass–fail criteria for the HHI-S, adjusting for changes in perceived hearing handicap with age. However, it has been consistently shown that perceived hearing difficulty is the strongest predictor of hearing help seeking, hearing aid uptake, its use, and satisfaction (see Knudsen et al, 2010 for review, and Hickson et al, 2014; Meyer et al, 2014); therefore, a change in criteria without an associated change in perceived problems, would be unlikely to result in changes in hearing health care uptake. A more fruitful but longer term approach might be to focus on educating the public about the importance of hearing, the detrimental effects of hearing loss, and the benefits of hearing rehabilitation, so people obtain help at a younger age while they are sensitive to hearing problems.

It is important, however, to consider another explanation for our data that lies in the original HHI-S work of Ventry and Weinstein (1983). Ventry and Weinstein examined the relationship between differing definitions of pure-tone screen failure and the HHI-S screen failure cut point of 10. They concluded that HHI-S and pure-tone screen failure rates were closest when screening was conducted at 1000 and 2000 Hz with a 40-dB HL tone, with the inability to respond to any one frequency in each ear defining a screen fail. Using the ASHA-recommended definition of a pure-tone screen fail (no response at 25-dB HL at any screening test frequency [1000, 2000, and 4000 Hz] in either ear) pure-tone screen failures are being over-identified relative to HHI-S failures. With age, pure-tone sensitivity decreases, especially at 4 kHz, and thus the discrepancy between pure-tone and HHI-S failure increases. This is clearly reflected in the data here and likely in part explains our data and that of others as described previously.

As for the youngest group of individuals, who tended to fail the HHI-S but pass the pure-tone screening, they seem to fit the "not-severe" profile of an individual with obscure auditory dysfunction who underestimates their hearing ability (Saunders et al, 1992), perhaps because they lack auditory confidence. Individuals meeting this profile would have been more inclined to have their hearing screened when the opportunity arose than individuals who did not perceive hearing difficulties—hence our finding that the youngest individuals failed the HHI-S but passed the pure-tone screening.

Summary and Clinical Applications

This study demonstrated that ambient noise levels vary considerably across typical hearing screening locations and that consequently, it is important to measure levels routinely during hearing screening events. The data also substantiate prior findings that the relationship between measured and reported hearing loss changes with age. This was illustrated here by the linear increase in pure-tone screen failures with age but the absence of change in HHI-S fails among individuals aged >55 yr. From a clinical perspective, it seems unlikely that developing age-specific HHI-S failure criteria would be beneficial because perceived difficulties are the best predictor of hearing health behaviors. Instead, it is proposed that a public health focus on education about hearing and hearing loss would be more effective.

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